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ORIGINAL ARTICLE – Silviculture

Phenology of *Copernicia alba* in Flooded and Not Flooded Environments

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Abstract

The objective of this study is to describe the reproductive and vegetative phenological patterns of individuals of *Copernicia alba*, popularly known as "carandá," in two areas of the Pantanal of Mato Grosso and to test the relations between their phenophases and climatic seasonality. We obtained the phenological aspects of the carandá through a biweekly observation of 22 individuals from two areas of the Pantanal of Mato Grosso between August 2015 and August 2017. The carandá population presented a perennial behavior, flowering during the dry season and greater leaf intensity in the transition period to the rainy season. Budding, although continuous, was intense in the rainy season, and the leaf deciduous pattern had a direct interference from the absence of rainfalls in the dry period. The incidence of floral buds occurred in the dry period, and the flowering occurred between the dry and rainy periods. The fruiting period occurred in the rainy season, indicating a high synchronism of phenophases.

Keywords: carandá, flowering, fructification, phenophases.

1. INTRODUCTION AND OBJECTIVES

The Pantanal is composed by the intersection of four major phytoecological regions, which are regionally known as Deciduous Forest, Semi-deciduous Forest, Cerrado and Chaco. In addition to these four regions, in several portions of the Pantanal there are floristic contacts among the Phytoecological Regions (Abdon et al., 2007). Although this biome excels in the world conservation scenario because of its high species richness and high rate of endemism, the Pantanal can be considered a biome threatened by the intense and progressive de-characterization caused by anthropic actions (Belo et al., 2013).

An important endemic species in this biome is the *Copernicia alba* (Morong ex Morong & Britton), popularly known as "carandá," which belongs to the family Arecaceae (Pott & Pott, 1994). The estimated carandá area in the Pantanal vegetation is 2.3%, the second most representative monotypic formation. The carandá is also found in phytophysiognomies known as mixed forests, where semi-deciduous forest species are found associated with balloon vine (*Tabebuia aurea* (Manso) B. and H.) (Fava & Albuquerque, 2011).

Due to its representativeness, studies aiming to understand and produce knowledge on the behavior of this species can be a basis for strategies of conservation and restoration of this biome. In this case, the study of phenology represents a good tool for understanding the factors that influence the reproduction and survival of plant species, contributing to the understanding of the dynamics and structuring of plant communities (Morellato et al., 1992).

This is because plants present phenological strategies related to the environmental characteristics of their habitats, their habits, reproductive biology and modes of dispersion (Conceição et al., 2007). The interaction between the phenology of a particular plant species and the seasonal variation in climate is one of the most important determinants of its distribution (Chuine & Beaubien, 2001). Thus, it is expected that endemic species present phenological responses adapted to the peculiarities of the habitat in which they occur.

In addition, understanding the reproductive cycles of plants is of fundamental importance for the conservation and management of native and endangered species. However, phenological studies on plants of the Pantanal biome are scarce, especially in endemic species, such as the carandá (Coelho & Machado, 2009; Conceição et al., 2007; Dutra et al., 2009; Miola et al., 2011).

The objective of this work is to describe the reproductive and vegetative phenological patterns of individuals of *Copernicia alba* occurring in flooded and not flooded environments of the

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Pantanal of Mato Grosso, and to test the relationship between their phenophases and climatic seasonality.

2. MATERIALS AND METHODS

2.1. Study areas

This study was carried out in two municipalities of the state of Mato Grosso using 12 individuals located in the urban region of Cuiabá at the coordinates 15º36'29" S and 56º45'16" W, and 10 individuals located in the Jubran Private Reservation of Natural Heritage in Cáceres at the coordinates 16°53'23.3" S and 57°24'22.2" W, from August 2015 to August 2017.

The climate of the regions is Aw, according to the Köppen classification, that is, semi-humid tropical, with average temperatures of 24-26 °C, four to five dry months and two well defined seasons: a dry (autumn-winter) and a rainy (spring-summer) season, with an annual rainfall index of 1,250-1,500 mm.

The soils of these sites are typical Dystrophic Petric Plinthosol (Valentini et al., 2013). We collected samples of the soils from Cuiabá and Cáceres at a depth of 0-15 cm, presenting, respectively, the following characteristics: pH: 5.3 and 5.5; organic matter: 19% and 33%; sand: 60% and 68%; silt: 22% and 16%; and clay: 18% and 16%.

2.2. Phenological data

For the phenological monitoring of *Copernicia alba*, the selected individuals were marked and georeferenced. From September 2015 to June 2017, we conducted biweekly evaluations at the study site to monitor vegetative phenophases. In some cases, the sacking deposited under the projection of the canopy where we observed floral buds, new aborted fruits, green fruits, and ripe fruits were only examined for conformation of the current phenophases.

We recorded the percentage of occurrence of the following phenophases (Koptur et al., 1988): (i) budding: period of the occurrence of leaf buds up to the expansion of new leaves; (ii) leaf fall; (iii) flowering: divided into periods with buds and open flowers; and (iv) fruiting, divided in periods with unripe fruits and ripe fruits. We performed observations of the phenophases in the dry and rainy periods. In all data collections, we observed the reproductive and vegetative aspects of each species, noting all the data and obtaining the photographic records for possible comparisons of each phenophase.

2.3. Data analysis

We analyzed the data from both places separately and comparatively, according to the following indexes:

(1) Activity index is the percentage of individuals in a given phenophase. For a given moment, the presence (1) or absence (0) of individuals in a phenophase is quantified in relation to the total number (N) of individuals sampled. This index, therefore, allows to evaluate the synchrony of the individuals of a population. The greater the percentage of individuals in the phenophase, the more synchronized they are (Bencke & Morellato, 2002; Fournier, 1974; Souza et al., 2014).

(2) Fournier Intensity or Fournier Index (Fournier, 1974) provides the abundance data of the phenophase at an evaluated moment. This index is determined by individual evaluations in the sample, assigning a score (E) to each individual according to the following categorization: 0 – no phenomena observed; 1 – presence of the phenomenon observed with a magnitude from 1 to 25%; 2 – presence of the phenomenon observed with a magnitude from 26 to 50%; 3 – presence of the phenomenon observed with a magnitude from 51 to 75%; and 4 – presence of the phenomenon observed with a magnitude from 76 to 100% (Bencke & Morellato, 2002). The calculation was performed by Equation 1 (Marchioretto et al., 2007):

$$[\%Fournier = (\Sigma Fournier / 4N) \times 100] \quad (1)$$

Where Σ Fournier: sum of Fournier categories for each individual; N: number of sample individuals.

In order to analyze how much each phenophase was expressed in a period, that is to say, the amplitude of time in months of each vegetative or reproductive event, we used the methodology proposed by Newstrom et al. (1994). It recognizes three different classes: a short one, in which the event lasts up to one month; an intermediate one, in which the phenophase extends from two to five months; and a long one, in which the phenophase extends for six months or more.

We tested the relations between the occurrence of each phenophase and the climatic variables (air temperature, rainfall, relative humidity, wind speed and radiation) using Spearman correlation and the climatic data of the four fortnights prior to the phenological event (Rocha et al., 2015). Deviations from the normality of phenological data were confirmed by the Kolmogorov-Smirnov test for use of Spearman non-parametric correlation.

2.4. Weather data

We obtained climatic data of rainfall (mm) and average temperature (°C), provided by the Instituto Nacional de Meteorologia (INMET), from conventional stations located in the municipalities of Cuiabá and Cáceres (Figures 1 and 2).

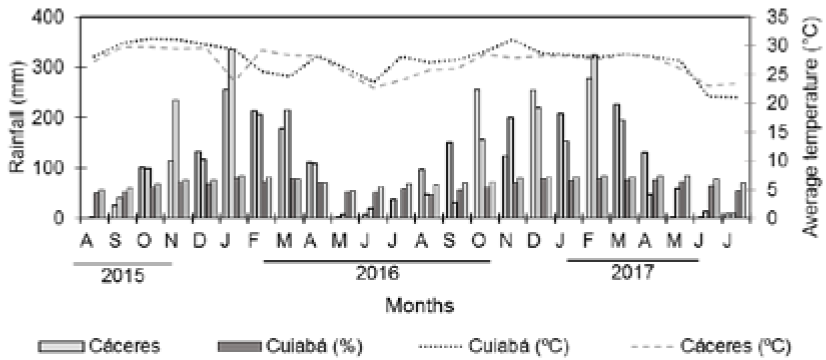

Figure 1. Meteorological data of rainfall (mm) and average temperature (°C) over the evaluation months for the cities of Cuiabá, MT, and Cáceres, MT.Source: INMET (2017).

3. RESULTS AND DISCUSSION

The rainfall distribution presented two distinct periods for the regions under study. A rainy period extended from October to April, concentrating the highest rainfall rates, which on average equals to 91% of the rains, followed by a period of drought from May to September, whose precipitation corresponds to only 9%, characterizing the dry period (Martins et al., 2011).

Leaf fall remained low throughout the observed period. In August and September of 2015 and 2016, there was a markedly vegetative growth of the species for both sites, and the lowest leaf fall percentage. This characterizes the vegetative development of the plant, and it can therefore be classified as perennial (Negrelle & Degen-Naumannn, 2012).

Other species that also have a perennial leaf behavior were the "cagaiteira" (*Eugenia dysenterica* Mart.), according to a study by Sano et al. (1995) in the Cerrado region of Planaltina, DF.

The dry period presented the greatest loss of leaves by the species studied, mainly in June and peaking in September. The events of senescence and leaf fall are probably related to the beginning of the dry season, when evapotranspiration increases. Thus, leaf loss in the dry season is a water saving factor for plants, and low moisture indexes stimulate leaf abscission (Vilela et al., 2008).

The proportion of individuals at the budding phenophase was high in the rainy season, between December and January, although it was significant in the other periods. This shows that the species under study maintained the growth and production of new leaves or shoots throughout the period (Figure 2).

The highest Fournier intensity indexes occurred during the period when activity indexes were higher, that is, when all the individuals of the population presented a determined phenophase with the greatest intensity. In this study, the maximum intensity reached by each individual of the population was 27% of the canopy at the phenophase.

During the rainy season, between December and March, only 5% of the individuals presented leaf loss, while 40% of the individuals presented leaf fall during the dry season, between April and August. That is, there was a considerable variation in the number of individuals at this phenophase as they occur mainly due to the availability of water during the observed periods.

The emission flux of new leaves occurred moderately throughout the year, with a higher intensity in October (Figure 2c and d), indicating that the individuals are synchronous with this phenophase and suggesting that the budding occurs at the beginning of the year.

By comparing both indexes, the peaks of activity and intensity of Fournier coincided for the population of *C. alba*, indicating growth of new buds and leaves throughout the whole period. The Fournier intensity index revealed a continuous pattern of intensity for the leaf fall phenophase, indicating loss of leaves during the observed period. However, it showed a high intensity in the dry period. The coincidence between activity peaks and intensity tends to be more evident in vegetative phenophases, because the cumulative increase in the magnitude of these phenophases is slower and more gradual than in the reproductive phenophase (Bencke & Morellato, 2002).

The results obtained in this study corroborate those obtained by Coelho & Machado (2009), who studied the phenology of *Heteropterys aphrodisiaca* in different regions of Mato Grosso, and observed that the leaf deciduousity appears to suffer a direct interference from the absence of rains during the dry season (between April and August). Fournier activity and intensity indexes were corresponding and proportional, indicating a high synchronization of phenophases.

During the period between July and August, when individuals presented 100% of flowers with fruits, the peak of intensity for the reproductive phase reached the highest value. At the flowering phenophase (Figure 3a) and at the fruiting phenophase (Figure 3b), the activity and intensity indexes were corresponding and proportional, indicating a high intraspecific synchronicity.

The flowering of *C. alba* began in March with about 15% of individuals with flowers and reached the maximum flowering in September, with 90% of individuals with flowers. On the other hand, the fruiting phenophase began at the peak of the flowering (September), extending until June, presenting an intense fruit production in February and an asynchronous behavior in the flowering period. Salgado (2006) associated flowering in the dry season with conditions conducing to the dispersion of pollen in anemophilous species.

Apparently, for some Pantanal species, including *C. alba*, flowering is associated with water availability and temperature, and this may be a characteristic of the species in the region.

The fruiting of *C. alba* followed the annual flowering pattern, that is, it occurred once a year. We observed that the period of greatest intensity of unripe fruits is between March and April for both regions (Figure 4a and b). The intensity of the formation of ripe fruits was high, showing a peak of production in May for Cuiabá and Cáceres plants (Figure 4c and d).

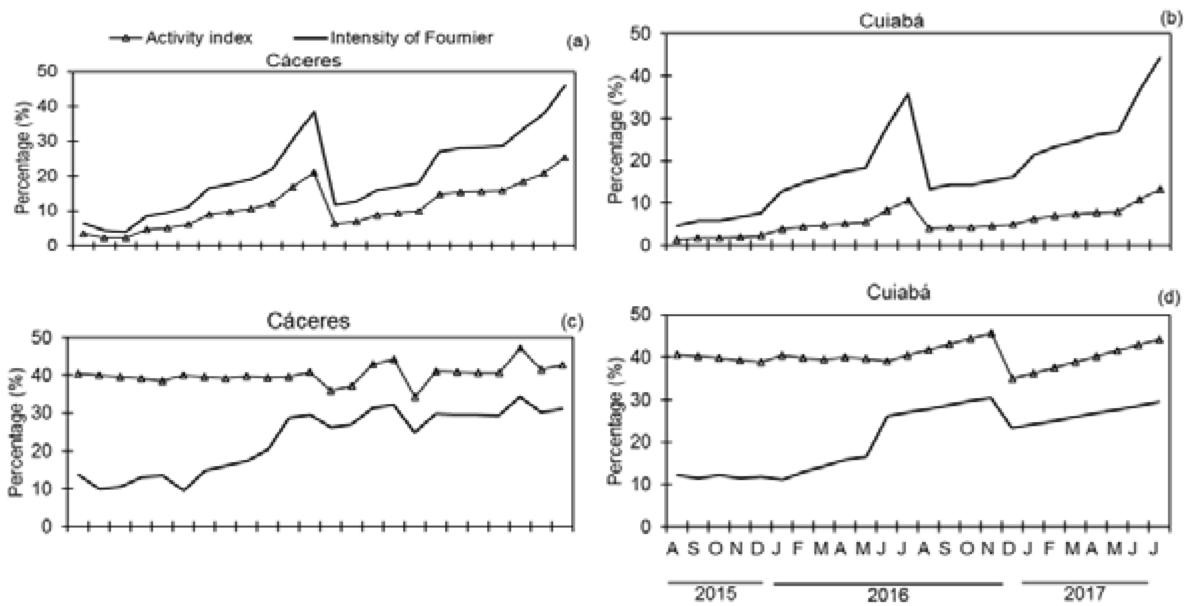

Figure 2. Activity index and intensity of Fournier for vegetative phenology of individuals of *Copernicia alba* in the municipalities of Cáceres and Cuiabá, MT.

(a) and (b) leaf fall; (c) and (d) budding.'

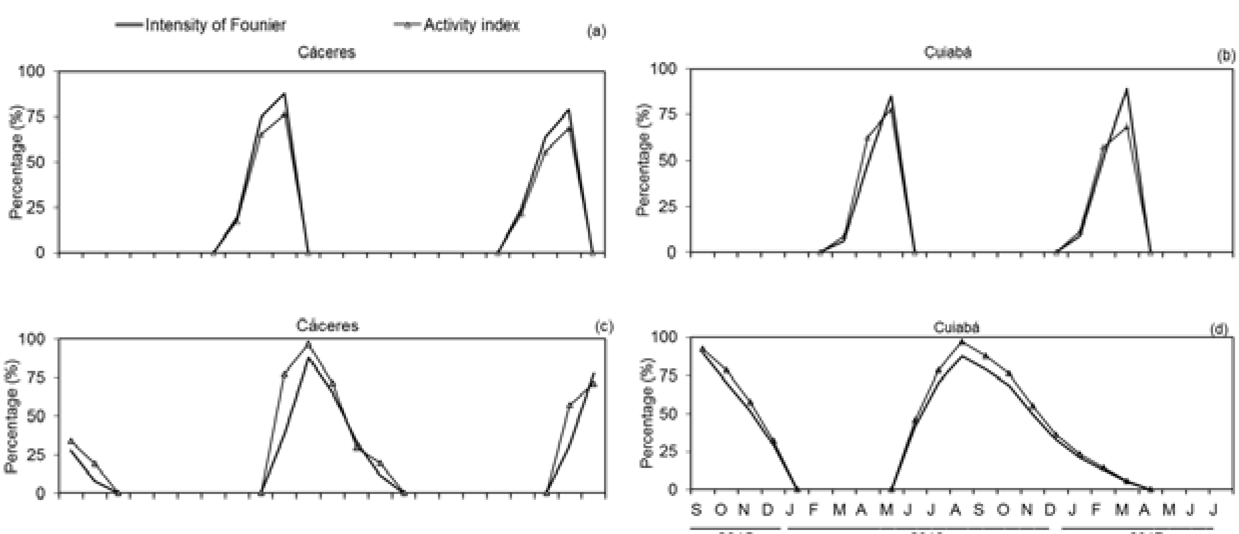

Figure 3. Reproductive phenology of individuals of *Copernicia alba* in the municipalities of Cáceres and Cuiabá, MT.

(a) and (b) flower buds; (c) and (d) open flowers.

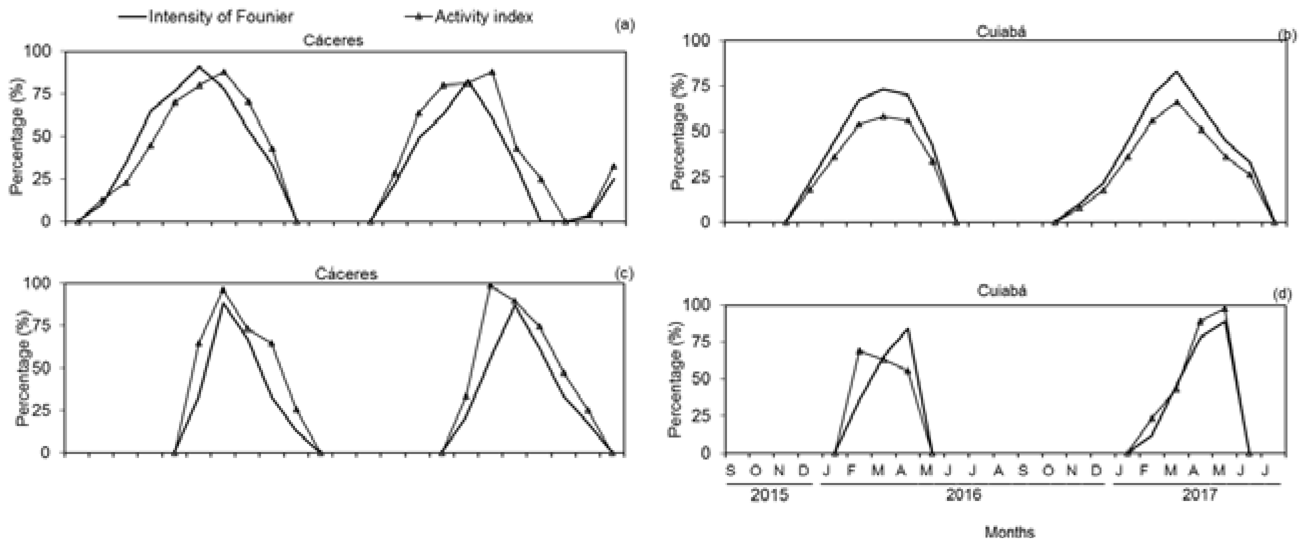

Figure 4. Reproductive phenology of individuals of *Copernicia alba* in the municipalities of Cuiabá and Cáceres, MT.

(a) and (b) unripe fruits; (c) and (d) ripe fruits.

According to the pattern described by Piña-Rodrigues & Aguiar (1993) in anemocorous species, fruit production and ripening occur in shorter periods (two to three months). In addition, fruit and seed production is abundant, usually concentrated in a particular time of the year, and fruit ripening is fast, with little variation within the same individual. The ripening, dispersal and ripening times of fruits and seeds may occur during the dry season for some species such as *Tabebuia avellanedae*, *Schizolobium parahyba*, *Copernicia cerifera*, *Cedrela fissilis*, *Cordia trichotoma*, among others.

Leaf loss correlated significantly with climatic variables, with the exception of wind speed, and Fournier intensity index during the four fortnights prior to the occurrence of the phenological event (Table 1).

Table 1. Spearman correlations (rS) between biweekly averages of climatic variables and vegetative phenological events of *Copernicia alba*.

Climate variables	Fortnight	Leaf loss		Budding	
		Activity	Fournier	Activity	Fournier
T °C	1°	ns	0.664	ns	Ns
	2°	ns	0.648	ns	Ns
	3°	ns	0.599	ns	– 0.256
	4°	ns	0.545	ns	– 0.283
Rainfall	1°	ns	– 0.404	ns	Ns
	2°	ns	– 0.435	ns	Ns
	3°	ns	– 0.361	ns	Ns
	4°	ns	– 0.400	ns	Ns
RH%	1°	ns	– 0.260	ns	Ns
	2°	ns	– 0.288	ns	Ns
	3°	ns	– 0.325	ns	Ns
	4°	ns	ns	ns	Ns
Wind speed	1°	ns	ns	ns	Ns
	2°	ns	ns	ns	Ns
	3°	ns	ns	ns	Ns
	4°	ns	ns	ns	Ns
Radiation	1°	ns	0.498	ns	Ns
	2°	ns	0.574	ns	Ns
	3°	ns	0.597	ns	Ns
	4°	ns	0.540	ns	Ns

ns: not significant correlation (α = 0.05); T °C: average temperature; RH%: relative humidity.

Plants may present a delayed phenological response to a given environmental stimulus (Marques et al., 2004; Rocha et al., 2015). Thus, leaf fall may be related to climatic factors before the events, that is, an increase in temperature and radiation and a decrease in rainfall and relative humidity may have determined the loss of leaves.

In a study of the phenology of *Copernicia prunifera* in a Caatinga area of Rio Grande do Norte, Rocha et al. (2015) showed a positive correlation between the leaf fall phenophase and climatic variables. The authors attributed to the water stress, imposed to the population of plants analyzed, a determining factor to leaf abscission. The decrease in the volume of water in the most superficial layers of the soil at the beginning of the dry season has been associated with leaf fall (Rebelatto et al., 2013). Thus, the decrease in water potential may have induced leaf fall in carandá.

The emergence of flower buds showed a significant correlation with all climatic variables analyzed. Thus, the increase in temperature, rainfall and relative air humidity results in a greater emission of flower buds. On the other hand, the increase in wind speed and radiation results in a lower emission of buds (Table 2).

Flower opening showed a positive correlation with average temperature in the last three fortnights that preceded the event and with the rainfall in the last fortnight evaluated. The last two fortnights showed a significant negative correlation with global radiation. Therefore, flower opening may be associated with later climatic conditions, indicating a high influence of temperature increase and rainfall and the decrease in global radiation in the third and/or fourth fortnight before this event.

Fruiting presented a low correlation with climatic variables. The relation between unripe fruits and the period of higher temperature in the fourth week preceding the event is indicated by the positive correlation (Table 2). The decrease in wind speed in the second and third weeks prior to fruiting significantly influences the production of unripe fruits.

Rocha et al. (2015) found that fruiting in *C. prunifera* is related to rainfall and that the influence of climate is complex, since each climatic variable seems to have a different weight in the phenology of the species. In fact, the occurrence and intensity of a particular phenophase are usually associated with one or several abiotic factors acting together, such as temperature, rainfall, moisture and nutrient availability, and biotic factors, such as pollinators, dispersants, seed predators and herbivores (Nazareno & Reis, 2012; Vilela et al., 2008). Therefore, for the evaluation of the interference of biotic and abiotic factors with phenological patterns, it is necessary to carry out a long-term phenological monitoring for several reproductive cycles.

Table 2. Spearman correlations (rS) between biweekly averages of climatic variables and reproductive phenological events of *Copernicia alba*.

Climate variables	Fortnight	Floral Buttons		Open flowers		Unripe fruits		Ripe fruits	
		Activ.	Fournier	Activ.	Fournier	Activ.	Fournier	Activ.	Fournier
T °C	1º	0.144	0.160	ns	ns	ns	ns	ns	0.611
	2º	0.156	0.172	0.444	0.468	ns	ns	ns	0.601
	3º	0.207	0.223	0.436	0.46	ns	ns	ns	0.566
	4º	0.256	0.272	0.488	0.512	0.388	0.499	ns	0.567
Rainfall	1º	0.488	0.504	ns	ns	ns	ns	ns	ns
	2º	0.482	0.498	ns	0.278	ns	ns	ns	ns
	3º	0.488	0.504	ns	ns	ns	ns	ns	ns
	4º	0.501	0.517	0.187	ns	ns	ns	ns	0.198
RH%	1º	0.417	0.433	ns	ns	ns	ns	ns	0.398
	2º	0.499	0.515	ns	ns	ns	ns	ns	0.301
	3º	ns	ns	ns	ns	ns	ns	ns	ns
	4º	ns	ns	ns	ns	ns	ns	ns	ns
Wind speed	1º	− 0.209	− 0.309	ns	ns	ns	ns	ns	ns
	2º	− 0.251	− 0.351	ns	ns	ns	0.201	ns	ns
	3º	ns	ns	ns	ns	0.477	0.469	ns	ns
	4º	ns	ns	ns	ns	ns	ns	ns	ns
Radiation	1º	− 0.502	− 0.414	ns	ns	ns	ns	ns	ns
	2º	− 0.477	− 0.389	ns	ns	ns	ns	ns	ns
	3º	ns	ns	− 0.333	− 0.354	ns	ns	ns	ns
	4º	ns	ns	− 0.387	− 0.837	ns	ns	ns	ns

Activ.: intensity of activity; ns: not significant correlation (α = 0.05); T °C: average temperature; RH%: relative humidity.

4. CONCLUSIONS

The carandá (*Copernicia alba*) is a perennial species with a great loss of leaves in the dry period, and a greater leaf intensity in the transition period between the rainy season and the dry season.

We observed sprouting throughout the year. However, peaks of activity and intensity of *Copernicia alba*, for both sites, also occurred at the end of the rainy season.

The incidence of floral buds occurred in the dry period and an intense flowering in the transition between the dry and rainy periods. The fruiting period occurred only in the rainy season.

Fournier activity and intensity indexes were corresponding and proportional, indicating a high intraspecific synchronization of phenophases.

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