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# Phenological patterns of zoochoric shrub and tree species in two areas of Ibura National Forest, Northeastern Brazil

## Padrões fenológicos de espécies zoocóricas arbustivo-arbóreas em duas áreas na Floresta Nacional do Ibura, Brasil

José Paulo Santana[1*]
psantanasanto@gmail.com

Patrício Adriano da Rocha[2]
parocha2@yahoo.com.br

Eduardo Vinícius da Silva Oliveira[3]
eduardovso@yahoo.com.br

Ana Paula do Nascimento Prata[4]
ana.prata@ceca.ufal.br

Adauto de Souza Ribeiro[2,3]
adautoead@gmail.com

## Abstract

The phenology of zoochoric species is fundamentally important for understanding fluctuations in the availability of food resources for the fauna. The objective of this study is to describe the phenological patterns of shrub and tree species in the National Forest of Ibura, Sergipe. In addition, we sought to analyze whether phenological cycles are influenced by climatic seasonality. Sampling was done by means of plots, ten plots in an area of more conserved forest and ten in a eucalypt plantation (*Corymbia citriodora*). All individuals satisfying the inclusion criteria had their phenological cycles monitored monthly (November 2013 to May 2016). Results showed that leaf fall was more typical between December and February, while budding was more common from February to May. Flowering occurred between the months of December and March and consequent fruiting between February and May. Phenological data describe reproductive rhythms highly synchronized with precipitation, resulting in the development of flowering at the end of the dry season and fruiting at the beginning of the rainy season. Most individuals had a well-defined reproductive pattern with cycles influenced by seasonal conditions.

**Keywords**: Atlantic Forest, climatic seasonality, Sergipe, eucalypt plantations.

## Resumo

A fenologia das espécies zoocóricas é de fundamental importância para o entendimento das flutuações na disponibilidade de recursos alimentares para a fauna. O objetivo deste estudo é descrever os padrões fenológicos de espécies arbustivas e arbóreas na Floresta Nacional do Ibura, Sergipe. Além disso, procuramos analisar se os ciclos fenológicos são influenciados pela sazonalidade climática. A amostragem foi feita por meio de parcelas, dez parcelas em uma área de floresta mais conservada e dez em uma plantação de eucalipto (*Corymbia citriodora*). Todos os indivíduos que satisfizeram os critérios de inclusão tiveram seus ciclos fenológicos monitorados mensalmente (novembro de 2013 a maio de 2016). Os resultados mostraram que a queda das folhas foi mais típica entre dezembro e fevereiro, enquanto a brotação foi mais comum entre fevereiro e maio. A floração ocorreu entre os meses de dezembro e março e a consequente frutificação entre fevereiro e maio. Dados fenológicos descrevem ritmos reprodutivos altamente sincronizados com a precipitação, resultando no desenvolvimento de floração no final da estação seca e frutificação no início da estação chuvosa. A maioria dos indivíduos apresentou um padrão reprodutivo bem definido, com ciclos influenciados por condições sazonais.

**Palavras-chave**: Floresta Atlântica, sazonalidade climática, Sergipe, plantação de eucalipto.

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[1] Universidade Federal de Sergipe. Departamento de Biologia. Av. Marechal Rondon, s/n, 49100-000, São Cristóvão, SE, Brazil.
[2] Universidade Federal de Sergipe. Departamento de Ecologia. Av. Marechal Rondon, s/n, 49100-000, São Cristóvão, SE, Brazil.
[3] Universidade Federal de Sergipe. Programa de Pós-Graduação em Ecologia e Conservação. Av. Marechal Rondon, s/n, 49100-000, São Cristóvão, SE, Brazil.
[4] Universidade Federal de Alagoas. Centro de Ciências Agrárias. BR 104, Norte Km 85, s/n, Mata do Rolo, 57100-000, Rio Largo, AL, Brazil.
* Corresponding author.

## Introduction

Studies in Brazilian rainforests monitor local climatic influences on the rhythms of reproduction (flowering and fruiting) and leaf development (budding and falling) to describe the periodic rhythms of plant development (Morellato and Leitão-Filho, 1990; Camilo *et al*., 2013; Ferreira and Consolaro, 2013). The periodicity of phenological cycles, associated with local climatic seasonality, observed in tropical rainforests is the main factor influencing peak flower and fruit production, budding and foliar abscission (Morellato, 1991; Talora and Morellato, 2000; Bencker and Morellato, 2002). In these forests, for most species, flowering development is stimulated by increased radiation and decreased precipitation while fruiting is associated with increased precipitation and humidity (Marques and Oliveira, 2004).

In rainy tropical regions the variables precipitation and photoperiod, which are directly related to primary productivity (Larcher, 2000; Pereira *et al*., 2008; Singh *et al.*, 2016), are mainly responsible for the establishment of regional patterns in phenological rhythms. In addition, heterogeneity in conditions and resources in the same area generates variations in phenological rhythms at the intraspecific level (Vicente *et al*., 2003). According to Vicente *et al*. (2003), zoochoric species tend to predominate in the composition of humid forests, this dispersal strategy being generally influenced by precipitation rates. Higher levels of water availability in these environments provides better conditions for investment in fleshy fruits, which, interacting with frugivorous fauna, provide more efficient dispersal in closed environments where the influence of wind is reduced (Baider *et al*., 1999; Reys *et al*., 2005; Moreira *et al*., 2009; Moura *et al*., 2011).

In recent years, there has been an increase in the number of phenological studies, both in the Atlantic Forest (e.g. Bencker and Morellato, 2002; Andreis *et al*., 2005; Pereira *et al*., 2008) and in the Amazon (e.g. Ruiz and Alencar, 1999; Schongart *et al*., 2002; Wallace and Painter, 2002; Bentos *et al*., 2008). However, the scarcity of phenological studies in different regions of the Atlantic Forest of the Brazilian Northeast makes it difficult to observe the possibility of patterns influenced by local climatic peculiarities.

In Sergipe, studies in phenology are almost non-existent, despite the importance of these studies in understanding the dynamics and availability of resources at the community level, as well as in the specific case of zoochoric species, in understanding fluctuations in the availability of food resources for the fauna (Morellato, 1991).

Faced with this need to carry out phenological studies for the Northeast region, a description of the phenological cycles of woody species with zoochoric dispersion syndromes was carried out in the National Forest (FLONA) of Ibura, municipality of Nossa Senhora do Socorro, state of Sergipe. We sought to understand how, and if, the reproductive and vegetative cycles of these species are influenced by climatic seasonality. We also intended to explore if there are phenological variations between two different areas in the Ibura FLONA: (1) an area of native forest; and (2) an area of regeneration in the eucalypt plantation subforest (*Corymbia citriodora*). In addition, a characterization of the woody vegetation present in these two areas was carried out.

## Methodology

### Study area

The Ibura FLONA is located in the municipality of Nossa Senhora do Socorro, in the state of Sergipe (10°50’19”S; 37°08’03”W). With an area of approximately 144 ha, it is bounded in the north by the Cotinguiba River and in the east by the BR-101 (Brasil, 2005) (Figure 1).

Classified as a seasonal semi-deciduous forest (Brasil, 2005), the vegetation of the Ibura FLONA has a history of anthropic pressure, including deforestation and the introduction of exotic species, presenting two main phytophysionomies. The most preserved forest habitat shows a continuous canopy and in a more advanced stage of succession compared to the other subareas, containing a predominance of native shrub and tree species with heights varying between 4 and 15 m. The other phytophysionomy is represented by a regeneration area in process of secondary succession, on the site of an old eucalypt plantation (*Corymbia citriodora*) abandoned for approximately 30 years, being over time re-colonized by species of the subarea of forest (Figure 1).

According to Santana *et al*. (2017), the Ibura FLONA has a total of 328 species, representing 88 families. The families with the greatest species richness are Fabaceae, Myrtaceae, Rubiaceae, Asteraceae, Euphorbiaceae, Malvaceae, and Orchidaceae.

### Rainfall

Rainfall data for the definition of rainy and dry seasons were obtained from the PROCLIMA-CPTEC/INPE (2015) database for the period from November 2013 to May 2016 in the municipality of Nossa Senhora do Socorro. The dry and rainy seasons were established according to recorded accumulations less than or greater than 100 mm, respectively. Monthly average accumulated precipitation for the last decade characterized the dry season from September to February, and the rainy season from April to August. During the sampling period, the months with the lowest and highest cumulative rainfall were December (9.03 mm) and July 2014 (157.9 mm), respectively (Figure 2).

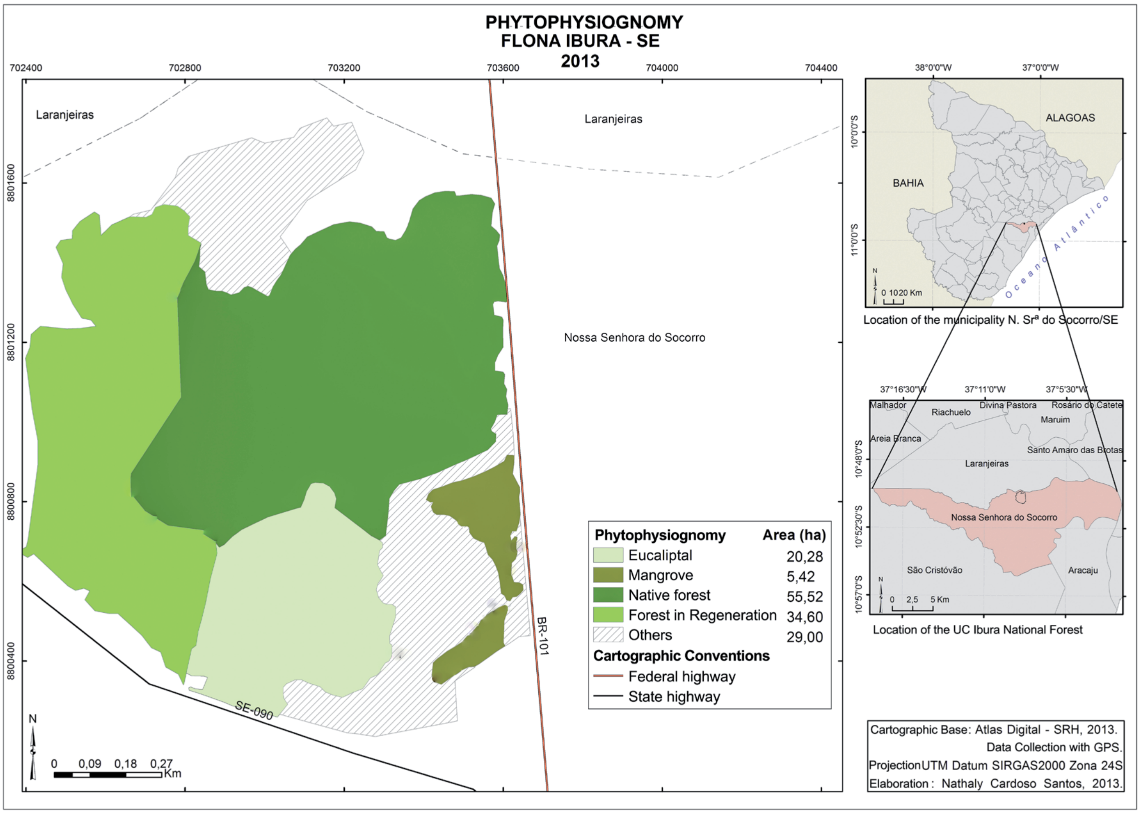


**Figure 1.** Description of the phytophysionomies and location of the study area in the Ibura National Forest, in the municipality of Nossa Senhora do Socorro, state of Sergipe, Northeastern Brazil.

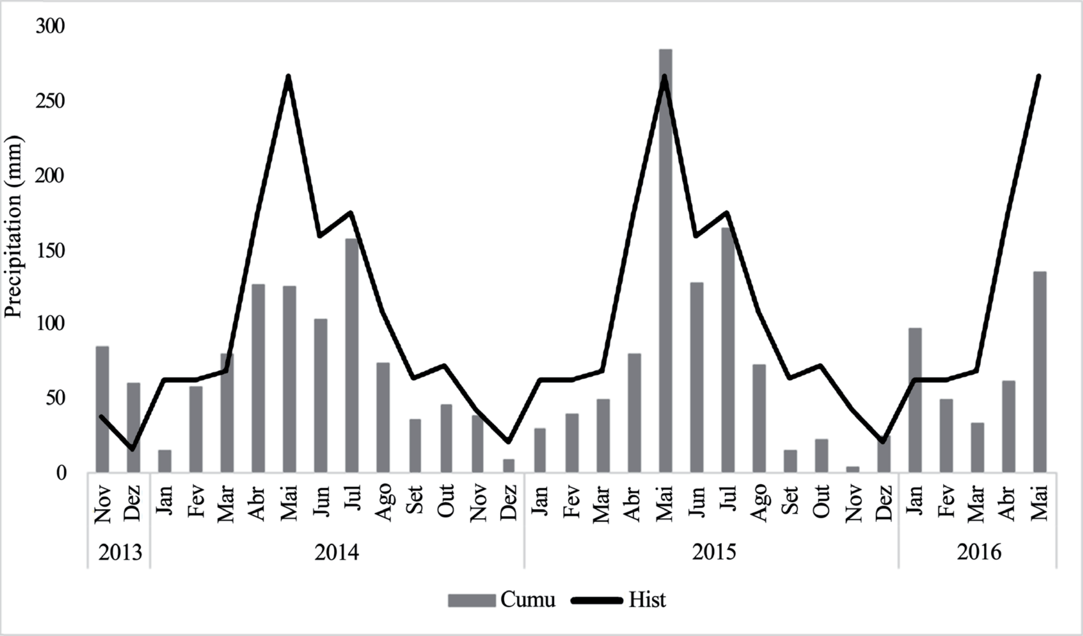


**Figure 2.** Distribution of average monthly precipitation (mm), considering historical (2003-2013) and accumulated (November 2013 to May 2016) data for the municipality of Nossa Senhora do Socorro, state of Sergipe, Northeastern Brazil (PROCLIMA-CPTEC/INPE 2015). Legend: Cumu = average cumulative monthly; Hist = historical monthly average.

## Sampling

The phenological data were collected in twenty plots of 20 m x 20 m (400 m²), homogeneously distributed, ten plots in the most preserved forest area and the remainder in the former eucalypt plantation (Figure 1), totaling 8,000 m² of sampled area.

All individuals of the species with zoochoric dispersal strategies (Santana *et al*., 2017) were sampled and were included in the inclusion criteria (diameter ≥ 10 cm, measured in height from the ground of 1.5 m). Young individuals and those who were unable to visualize the cup were discarded.

Fertile samples of the species evaluated in the field were collected, pressed and identified according to Martins-da-Silva *et al*. (2014) and following the description in the Ibura FLONA (Santana *et al*., 2017). Later, the samples were deposited in the Herbarium of the Federal University of Sergipe (ASE).

## Phenological observations

Phenological observations were carried out biweekly in the period from November 2013 to May 2016. In the forest area observations were made from November 2013, while in the eucalypt area they began in March 2014.

Measurements of the phenological rhythms were performed on each field day with a follow up of the observed individuals. Phenophases were categorized as: (i) flowering, flower buds and anthers present; (ii) fruiting, immature and mature fruits present; (iii) leaf fall; (iv) leaf budding. Each reproductive or vegetative trait was evaluated individually by direct semi-quantitative methods, where interval measurement scales were used (five categories of 0–4, with intervals of 25% of amplitude) for each individual (Fournier, 1974).

Leaf activity patterns were classified in three groups, based on Morellato (1991): deciduous species, budding and leaf fall happening in only one season of the year, presenting total absence of leaves; semi-deciduous species, 50% leaf loss, never being totally without leaves; and perennial, leaf drop almost imperceptible.

The characterization of the types of reproductive patterns (flowering and fruiting) was divided into three: annual, peaking once a year; supra annual, peaking every two years; and continuous, prolonged continuous peak almost all year round (Newstrom *et al*., 1994).

The intensity of the phenophases was calculated using the Fournier (1974) intensity index: $[(\Sigma \text{ Fournier} / 4N) - 1] \times 100$, where Σ Fournier = the sum of the categories of Fournier for each individual and N = Number of individuals in the sample. The reproductive variables were calculated according to the percentage of individuals of each species, and of each phenophase observed, according to this formula.

The Rayleigh test was performed to evaluate whether the phenophases followed seasonal influences, that is, for the significance of the mean direction; in this test, the mean vector “r” indicates the degree of seasonality (Ayres *et al*., 2007). We used Oriana 2.0 software (Kovach, 2011) for circular statistics. In order to determine possible synchrony between phenological events and climate, individual relationships between flowering and fruiting and temperature and precipitation were tested by simple linear regression analysis (Ayres *et al*., 2007) using R software (R Development Core Team, 2013). Temperature data were obtained from the INMET (2017) database for the period from November 2013 to May 2016, for the region studied. In the collection period the average temperature varied between 25 and 28ºC.

# Results

The phenotypes of 963 individuals tagged within the plots were examined, comprising 473 in the forest area and 490 in the eucalypt area. In total, 46 species belonging to 30 families were recorded, 39 species in the forest area and 37 in the eucalypt area (Table 1).

The families with highest abundance were the Sapindaceae, Rubiaceae, Myrtaceae, Malpighiaceae and Salicaceae. The sum of the number of individuals in the first three families represents 61% of the total sampled for the area. The families Myrtaceae (11 spp.) and Sapindaceae (four spp.) had the highest values of richness, and the family Rubiaceae also stood out with four species (*Chomelia obtusa, Chomelia pubescens, Genipa americana* and *Randia armata*). However, the last two species were removed from the phenological analysis, because they only produced immature fruits during nine months, distorting the values of the species with short cycles and of the months with few species producing fruits. This procedure was necessary, considering that these species had many individuals evaluated, influencing the average result of the community.

The most abundant species in the forest area were *Allophylus edulis, Cupania impressinervia, Myrcia splendens, C. obtusa,* and *Byrsonima sericea.* The eucalypt area differed slightly to the forest area, showing the dominance of *A. edulis*, *C. obtusa, B. sericea, Tapirira guianensis,* and *Casearia javitensis* (Table 1). These species occurred in greater abundance in both areas, making up 42% of the total forest area and 66% of the total eucalypt area.

During the sampling period, 326 individuals underwent reproductive phenophases one or more times in the forest area, against 362 individuals in the eucalypt area. The development of flowers and fruits varied between species. In the forest area the species with the greatest numbers of individuals where reproductive phenophases occurred were *A. edulis* (37 individuals or 65% of the total individuals of this species) *C. impressinervia* (29; 74%), *M. splendens* (24; 67%), *B. seri-*

*cea* (25; 86%), *C. obtusa* (17; 49%), *C. javitensis* (16; 62%), *Eugenia punicifolia* (15; 83%), and *Miconia albicans* (14; 100%). A variation in the species sequence was observed in the eucalypt area: *A. edulis* (98 individuals; 94%), *C. obtusa* (71; 71%), *B. sericea* (32; 64%), *T. guianensis* (30; 73%), *C. javitensis* (27; 90%), *M. albicans* (18; 82%), and *C. impressinervia* (11; 41%). It is important to note that in the total set of all individuals showed above that flowered or fruited, the seven species in the eucalypt area represent 79% of the total, compared with 82% (eight species) in the forest area.

The phenology of the Ibura FLONA species showed some well-established seasonal patterns, mainly for reproductive cycles. In terms of reproductive phenophases, most species were classified as annual, with only *C. obtusa* presenting a continuous reproductive pattern.

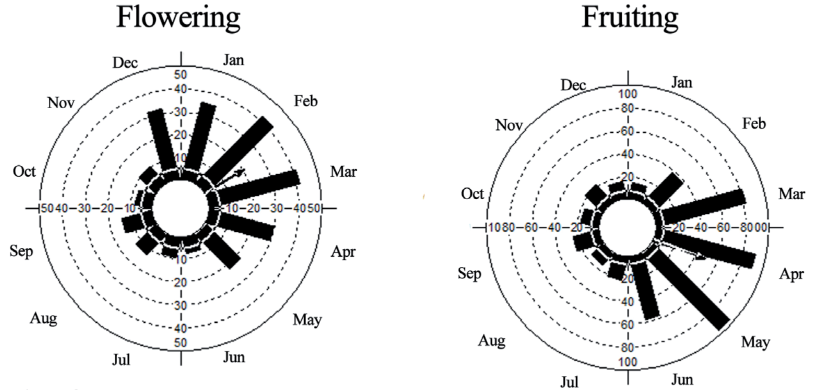
The reproductive phenophases of the species taken together have some peaks of synchrony. For flowering, for example, there was greater synchrony of individuals with buds or flowers from December to March in the years observed. This pattern was especially apparent in the years of 2014 and 2015, respectively (Figure 3).

Analyzing separately the intensity of flowering of the species between the areas, we verified that the species of the forest area began to bloom before, and obtain greater peaks of flowering between December and February. In the native forest, flowering peaks were observed between January and April, after the beginning of flowering in the eucalypt area in all years of the analysis. Therefore, when we examine these cycles together (eucalypt and native forest) the flowering period in the Ibura FLONA is extended, since the number of flowering months increases from four to six months in duration (Figure 3).

Consequently, fruiting presented higher peaks of synchrony between the end of the dry season and part of the rainy season (March-June). The areas presented the same fruiting period, but there was a little difference in the monthly peaks of synchrony of the species between these areas. In general, most species fruited between February and June (Figure 3), maturing between April and July.

In the study area, flowering in the eucalyptus community showed a lower degree of seasonality (z = 42.10; r = 0.40; p < 0.01). Statistically, the average angle for flowering was 58.28°, which corresponds to the beginning of February, between the dry and rainy seasons (Figure 3). In the forest area a higher degree of seasonality was observed (z = 110.39; r = 0.50; p < 0.01), with the average angle for

Forest in regeneration



Native forest

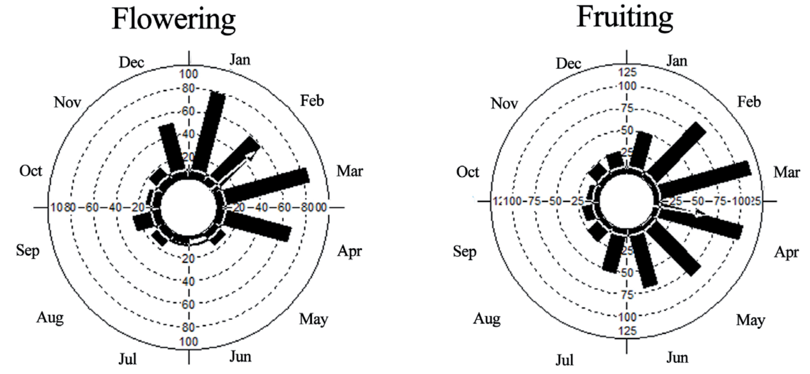


**Figure 3.** Synchrony of reproductive and vegetative phenophases of the woody zoochoric species evaluated in the Ibura National Forest, Nossa Senhora do Socorro, state of Sergipe, Northeastern Brazil. Circular statistics used software Oriana 2.0.

flowering of 50.24°, which corresponds to the beginning of January and February (Figure 3). The statistical results for fruiting indicate similar degrees of seasonality for both areas; eucalyptus plantation ($z = 109.85$; $r = 0.42$; $p < 0.01$) with average angle of 111.46°, which corresponds to mid-April; and the forest ($z = 140.10$; $r = 0.46$; $p < 0.01$) with average angle of 99.155°, also corresponding to mid-April (Figure 3). Most of the species showed fruit maturation between June and August. Some species such as *A. edulis, Campomanesia aromatica, Campomanesia ilhoensis, B. sericea, C. javitensis, E. punicifolia* and *Erythroxylum citrifolium* had fruit which matured rapidly, over a period of only two months.

Based on the regression, precipitation did not explain the flowering in relation to either in the eucalypt area ($F = 1.24$; $r^2 = 0.045$; $p = 0.27$) or the forest ($F = 1.43$; $r^2 = 0.048$; $p = 0.24$). According to the regression, fruiting at the community level is positively related to precipitation for both eucalypt ($F = 6.04$; $r^2 = 0.188$, $p < 0.02$) and forest areas ($F = 7.34$; $r^2 = 0.20$, $p < 0.01$). Comparison of the phenophases with respect to temperature showed a positive correlation for both flowering and fruiting (eucalyptus: flowering $F = 11.19$; $r^2 = 0.31$; $p < 0.01$; fruiting $F = 6.66$; $r^2 = 0.21$; $p = 0.01$) (forest: flowering $F = 12.02$; $r^2 = 0.30$; $p < 0.01$; fruiting $F = 5.42$; $r^2 = 0.16$; $p = 0.02$). Therefore, temperature had a significant positive effect on flowering and fruiting, while precipitation was the most important factor positively associated with fruiting.

Based on the Fournier intensity index (1974), the first year of observation of the eucalyptus area produced a high fruiting peak that should be considered atypical, influenced by the high intensity of individuals that reproduced (Figure 4).

In general, leaf fall was observed throughout the year, varying between individuals, but with greater intensity during the season with low precipitation, especially from December to February. In this period, the Ibura FLONA showed a synchrony of approximately 6% of intensities of the individuals shedding leaves in the forest area and 5% in the eucalypt area, with a peak of 10% in the eucalypt area and 16% in the forest being observed for the beginning of 2014. In the same period of 2015, leaf fall intensity was low in the eucalypt area, with the number of individuals losing leaves decreasing to approximately 3%, while in the forest it remained at 6% (Figure 4).

Leaf budding spikes showed greater intensity among the species than leaf fall, with higher peaks at the end of the dry period, that is from February to May of both years, reaching approximately 14% intensity in both areas (forest and eucalypt). It is important to highlight the leaf budding

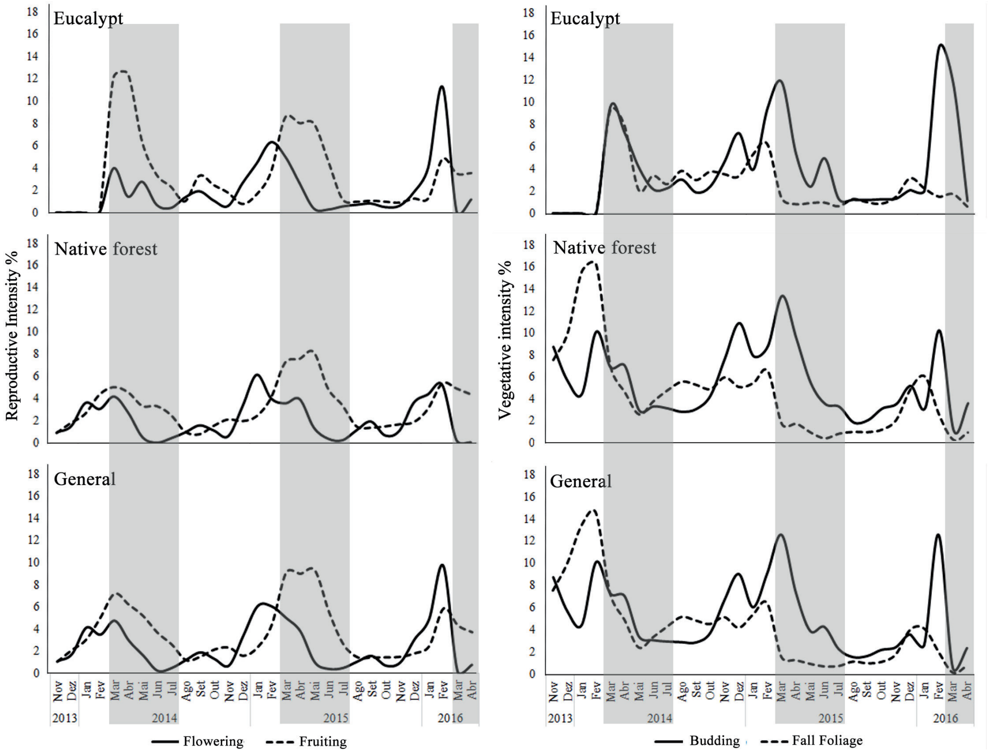


**Figure 4.** Cumulative intensity of reproductive and vegetative phenophases of the woody zoochoric species evaluated in the Ibura National Forest, Nossa Senhora do Socorro, state of Sergipe, Northeastern Brazil. The gray band represents the periods with higher precipitation.

peaks with lower intensity between November and January, together with the flowering of *T. guianensis* in this period (Figure 4). In the Ibura FLONA there were many individuals going through leaf changes (i.e., leaf fall and budding), the high proportion of semi-deciduous plants skews the statistics and flattens out the intensity peaks.

Budding peaks coincided with the beginning of flowering and leaves sprouted after this phenophase or during bud emergence. In species of the genus *Campomanesia* and in *C. javitensis*, the emergence of the leaves was observed after the flowers emerged, flowering occurred when the individuals were completely leafless. However, the great majority of leaves appeared at the time of flowering and leaf growth continued until the fruit appeared (Figure 4).

Species of the *Campomanesia* (Myrtaceae) have similar flowering periods;  these species can be distinguished only in months, and begin to bloom between December and January. On the other hand, species of the genera *Eugenia* and *Psidium* (Myrtaceae) did not present reproductive period. Some species, such as *T. guianensis, B. sericea, M. albicans,* and *M. splendens* flowered for long periods, while other species bloomed for a shorter period, for a maximum of one month.

Analyzing all species together, there were flowering and fruiting during all the months of observation, most had peaks during the end of the dry season and the beginning of the rainy season (Figure 4). Among the observed species, some presented long fruiting periods, taking up to four months for fruit development. The species with fruiting during four months or more presented variations in their fruiting period.

Similarly to the species that presented high intensity in synchrony of flowering (e.g., *C. aromatica, C. javitensis*, and *E. punicifolia*), the species *B. sericea*, *Campomanesia ilhoensis, M. albicans, M. splendens, Syagrus coronata,* and *T. guianensis* continued flowering even after the emergence of the fruits, which contributed to extending the reproductive period of the species.

## Discussion

The phenology in the study area shows seasonal influence, both for flowering and fruiting. When correlated precipitation with the phenophases, it was possible to observe a statistical relation where in periods with more rain, fruiting presented high peaks. Temperature is another important factor, strongly affecting flowering, with the highest peaks in the hotter periods.

It is interesting to note that flowering synchrony for individuals was higher in the forest area, showing that the species present in the eucalyptus area still have some deficit in flower development. It is necessary to evaluate which factors are responsible for this difference, since it was not the influence of precipitation or temperature, possibly it is a response to the presence of eucalyptus or the high incidence of luminosity that continues to limit the reproduction of the species in the eucalyptus understorey (Lange *et al.,* 2016).

Similar results regarding the cycles of flowering and fruiting for the period observed were found in other studies carried out in tropical forests (Mikich and Silva, 2001; Marques and Oliveira, 2004; Marchioretto *et al*., 2007; Machado *et al*., 2013). In tropical regions, such as Northeastern Brazil, the development of flowering for most species is stimulated by increased radiation and decreased precipitation, while fruiting is associated with increased precipitation and humidity (Marques and Oliveira, 2005; Luna-Nieves *et al*., 2017). Certain specific strategies in the reproductive behavior of the species were observed in the areas analyzed in the Ibura FLONA. One of these strategies was the small time difference between the flowering peaks in the two areas, the flowers emerging first in the forest area.

We also observed asynchrony between the individuals of some species, causing some of them to initiate their reproductive cycles at different intervals of days or weeks. These two strategies may contribute to the extension of the period of flowering and fruiting of a species, and to decrease the competition of pollinators or dispersers (Stephenson, 1982). Prolonging the reproductive cycle, especially among individuals, may facilitate the attraction of more pollinators, increase visitor rates, and pollen exchange flow between plants (Augspurger, 1981, 1980; Primack, 1980). Conversely, plants that develop their cycles over a short period and offer a large number of flowers in this period can decrease the number of pollinators, which can increase the probability of self-pollination, especially in hermaphrodite species (Bawa and Opler, 1975; Stephenson, 1982). Another important factor that can contribute to the reproductive difference between the areas is the distinction in species composition and forest structure (Santana *et al.*, unpublished data). The presence of different species among the areas contributed to the observed pattern. In relation to the forest structure, the fact that the native forest has a more closed canopy than the Eucalypt area, for example, may change abiotic conditions, such as light and temperature. Some species cannot reproduce in an area when the individual's structural or ripening conditions are not ideal, and thus different habitat conditions may act directly on the phenological cycle (Fuchs *et al*., 2003; Luna-Nieves *et al*., 2017).

Structural differences are observed between the forest and eucalypt areas in the Ibura FLONA. After 30 years of being abandoned, the eucalypt area has recovered the basal area and average height, and it is dominated by individuals belonging to pioneer species, not yet reaching the successional stage of the forest area (Santana *et al*., unpublished data). Apparently the eucalypt area has also managed to

**Table 1.** List of woody species evaluated in the Ibura National Forest, Nossa Senhora do Socorro, state of Sergipe, Northeastern Brazil. Ann = Annual, Con = Continuous, D = Deciduous; P = Perennial; PeVe = Vegetative Pattern; S = Semi-deciduous; Sub = sub-bush; Sup = Supranual.* = New Events recorded by Santana *et al.* (2017).

| Family/Species | Eucalypt | Forest | Habit | PaRe | PaVe |
|---|---|---|---|---|---|
| **ANACARDIACEAE** | | | | | |
| *Mangifera indica* L. | 1 | 2 | Tree | Ann | S |
| *Tapirira guianensis* Aubl. | 41 | 17 | Tree | Ann | S |
| **ARALIACEAE** | | | | | |
| *Schefflera morototoni* (Aubl.) Maguire, Steyerm. & Frodin | 4 | 9 | Tree | Ann | S |
| **ARECACEAE** | | | | | |
| *Syagrus coronata* (Mart.) Becc. | 13 | 10 | Shrub | Con | P |
| **BORAGINACEAE** | | | | | |
| *Cordia taguahyensis* Vell. | 4 | 3 | Tree | Ann | S |
| *Cordia toqueve* Aubl. | 3 | 1 | Sub | Ann | S |
| **BURSERACEAE** | | | | | |
| *Protium heptaphyllum* (Aublet) Marchand | 4 | 24 | Tree | Ann | S |
| **CAPARACEAE** | | | | | |
| *Cynophalla flexuosa* (L.) J. Presl | 5 | 0 | Tree | Ann | S |
| **EBENACEAE** | | | | | |
| *Diospyrus inconstans* Jacq.* | 1 | 3 | Tree | Ann | S |
| **ERYTHROXYLACEAE** | | | | | |
| *Erythroxylum citrifolium* A. St. – Hil | 2 | 0 | Sub | Ann | D |
| **FABACEAE** | | | | | |
| *Swartzia acutifolia* Vogel* | 0 | 2 | Tree | Ann | D |
| *Swartzia dipetala* Willd. ex Vogel* | 0 | 1 | Tree | Ann | D |
| **HYPERICACEAE** | | | | | |
| *Vismia guianensis* (Aubl.) Pers. | 0 | 1 | Sub | Ann | S |
| **LAMIACEAE** | | | | | |
| *Vitex rufescens* A. Juss. | 0 | 2 | Tree | Ann | S |
| **LECYTHIDACEAE** | | | | | |
| *Eschweilera ovata* (Cambess.) Miers. | 2 | 8 | Tree | Ann | S |
| **MALPIGHIACEAE** | | | | | |
| *Byrsonima sericea* DC. | 50 | 29 | Tree | Ann | S |
| **MALVACEAE** | | | | | |
| *Apeiba tibourbou* Aubl. | 1 | 2 | Tree | Ann | S |
| **MELASTOMATACEAE** | | | | | |
| *Miconia albicans* (Sw.) Triana | 22 | 14 | Sub | Ann | S |
| **MORACEAE** | | | | | |
| *Ficus* sp. | 1 | 3 | Tree | Ann | D |
| *Sorocea hilarii* Gaudich.* | 3 | 12 | Tree | Ann | S |
| **MYRTACEAE** | | | | | |
| *Campomanesia aromatica* (Aubl.) Griseb. | 16 | 21 | Tree | Sup | D |

**Table 1.** Continuation.

| Family/Species | Eucalypt | Forest | Habit | PaRe | PaVe |
|---|---|---|---|---|---|
| *Campomanesia dichotoma* (O.Berg) Mattos | 1 | 12 | Tree | Ann | D |
| *Campomanesia ilhoensis* Mattos | 3 | 26 | Shrub | Ann | D |
| *Eugenia brejoensis* Mazine | 0 | 10 | Shrub | Ann | S |
| *Eugenia candolleana* DC. | 1 | 3 | Tree | Sc | S |
| *Eugenia punicifolia* Kunth. | 1 | 18 | Tree | Ann | D |
| *Eugenia schottiana* O. Berg | 1 | 2 | Shrub | Ann | S |
| *Marlierea excoriata* Mart. | 1 | 0 | Shrub | Sc | S |
| *Myrcia splendens* (Sw.) DC. | 10 | 36 | Sub | Ann | D |
| *Myrcia tomentosa* (Aubl.) DC. | 1 | 2 | Shrub | Ann | D |
| *Psidium decussatum* DC. | 0 | 5 | Shrub | Ann | S |
| **PIPERACEAE** | | | | | |
| *Piper amalago* L.* | 1 | 0 | Sub | Ann | S |
| **RHAMNACEAE** | | | | | |
| *Ziziphus joazeiro* Mart. | 4 | 1 | Shrub | Ann | S |
| **RUBIACEAE** | | | | | |
| *Chomelia obtusa* Cham. & Schltdl. | 100 | 35 | Sub | Ann | S |
| *Chomelia pubescens* Cham. & Schltdl* | 0 | 9 | Sub | Ann | D |
| **SALICACEAE** | | | | | |
| *Casearia javitensis* Kunth | 30 | 26 | Sub | Ann | D |
| *Casearia sylvestris* Sw. | 12 | 3 | | Ann | S |
| *Prockia crucis* P.Browne ex L. | 1 | 0 | Shrub | Ann | D |
| **SAPINDACEAE** | | | | | |
| *Allophylus edulis* (A. St.-Hil., Cambess. & A. Juss.) Radlk. | 104 | 57 | Tree | Ann | S |
| *Allophylus racemosus* Sw.* | 0 | 2 | Sub | Ann | D |
| *Cupania impressinervia* Acev.-Rodr. | 27 | 39 | Tree | Sc | S |
| *Cupania oblongifolia* Mart.* | 5 | 15 | Tree | Ann | S |
| **SAPOTACEAE** | | | | | |
| *Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn. | 2 | 0 | Shrub | Sc | S |
| **SCHOEPFIACEAE** | | | | | |
| *Schoepfia brasiliensis* A.DC. | 0 | 5 | Shrub | Ann | P |
| **URTICACEAE** | | | | | |
| *Cecropia pachystachya* Trécul | 11 | 3 | Tree | Ann | S |

stabilize reproductive cycles, with most species flowering and fruiting. The variations observed in the low synchrony of the flowering in the eucalypt area may be directly related to the structural differences between the native forest, for example, more closed canopy, by virtue of more advanced successional stage.

The species evaluated here for their phenology can be considered as potential colonizers for the restoration of areas of eucalypt plantation, as well as degraded areas, given their rapid development and their ability to develop flowers and fruits, as well as their contribution to the structural recovery of the understory (Santana *et al*., unpublished data).

Regarding the vegetative phenology of the Ibura FLONA, the results showed that the species did not present a well-defined pattern in leaf fall, mainly due to the varied results observed among the species. However, deciduous species showed higher intensity and well-established patterns of leaf fall at the end of the dry season and budding at the beginning of the rainy season, unlike some semi-deciduous species, in which leaf fall was distributed throughout the year. The pattern of full leaf change by deciduous species of the Ibura FLONA during the dry season is related to strategies or adaptations to overcome water deficit in periods of lower rainfall, this observation is also presented by other studies (Pirani *et al*., 2009; Silvério and Lenza, 2010).

Most species had a well-defined reproductive pattern with cycles influenced by seasonal conditions. The association with seasonality as the main factor in the regulation of vegetative and flowering behavior is best described for environments with well-defined dry seasons (Borchert, 1980; Talora and Morellato, 2000). In particular, these species may be using the temperature as a stimulus in the regulation of leaf budding (Morellato *et al*., 1989; Talora and Morellato, 2000; Singh *et al*., 2016), but it was not possible to establish this relation for the FLONA species, since we did not find much variation in temperature for the study area.

Tree species of an area of highland pasture (*Altitude breccia* in Pernambuco, characterized by being a humid environment in the middle of the Caatinga) also presented a peak of flowering occurring during the dry season, followed by fruiting at the end of this season (Locatelli and Machado, 2004; Machado *et al*., 2013). Although fruiting occurred in different months, the reproductive cycles of these tree species begin with flowering in the dry season and continue until the fruiting in the rainy season, similar to the one found in this study.

Thus, we have shown that the phenological rhythms of the species are directly influenced by abiotic factors, mainly by precipitation rates, and such results can be confirmed by studies carried out in regions with the different climatic conditions characteristic of the Northeast. In dense ombrophilous forests in the South of the country, flowering is also observed occurring between the end of the drought and the beginning of the rains, and fruiting during a period of greater precipitation (Pereira *et al*., 2008; Liebsch and Mikich, 2009; Luna-Nieves *et al*., 2017).

In the present study it was possible to show a relation between the patterns found in the humid forests of the Northeast with other forest areas located in the subtropical zone. These patterns occur with reproductive periods in different months, but all the papers describe a reproductive relationship related to seasonality. However, some exceptions can be found, such as the species in the dry forest areas of the Caatinga in Northeastern Brazil, for example, which presented flowering peaks beginning in the rainy season and fruiting during the dry season and early rainy season (Barbosa *et al*., 1989; Batalha *et al*., 1997; Souza *et al*., 2014). Cerrado tree species, which are mainly zoochoric, were also observed flowering at the beginning of the rainy season (Batalha and Mantovani, 2000).

These reproductive patterns are directly related to, and are influenced by, the high levels of species richness and abundance of zoochoric species. The Ibura FLONA shows a predominance of zoocory among tree species (69%) for the forest area (Santana *et al.*, 2017). This pattern, in turn, affects local biodiversity, where the high richness of zoochoric species in tropical forests, in addition to climatic conditions, can also be related to the presence of a great diversity of generalist dispersers that directly influence the wide distribution of the Atlantic Forest (Lee, 1988).

Studies of the reproductive patterns of species with zoochoric dispersal strategies, or others, are important in order to describe the mechanisms which these species develop to attract their pollinators and dispersers, as well as the need for species to reproduce and leave descendants (Moreira *et al*., 2009). In this context, phenological patterns are important not only for studies of plant ecology but also for complementary functional studies of frugivores. These reproductive traits help us to understand the periods of dispersal of seeds or fruits, emphasizing the importance of these plants to dispersers and vice versa (Gurevitch *et al*., 2009; Lee, 1988). Comparing the statistical and descriptive results of the studied areas, it was possible to verify that the existing conditions in the Ibura FLONA and the presence of native vegetation near the eucalyptus plantation allowed colonization of the understory with individuals common to the forest, and the presence of eucalyptus did not prevent the colonization of most indigenous species.

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