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REPRODUCTIVE PHENOLOGY OF THREE SPECIES OF MARANTACEAE IN THE MUNICIPAL NATURAL PARK OF MENDANHA HILL, RIO DE JANEIRO, RJ

Rejane Gomes Pimentel

<http://lattes.cnpq.br/9530331168069325>

Moizés Barros Cordeiro

<http://lattes.cnpq.br/7710266276575928>

Amauri Costa Pinheiro

<http://lattes.cnpq.br/4526674458242018>

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Abstract: The phenological events of three species from the Marantaceae family were studied in the Mendanha hill Municipal Natural Park, namely: *Maranta cristata* Ker. Gawl., *Maranta leuconeura* (E. Morren.) and *Goepfertia monophylla* (Vell) Borchs & S. Suárez. Observations were carried out over 67 months (October 2014 to April 2020). The flowering and fruiting of the species are seasonal, annual and regular. Flowering of *M. cristata* and *M. leuconeura* occurs from August to March and fruiting from August to April. The flowering period of *G. monophylla* occurs from November to February, with fruiting between January and March. The flowering peak of all species occurs in the months of November to January and the fruiting peak in the months of January and February, during the rainy season. The species have capsule-type fruits, with ca. 10 mm long, with one seed. For species of the Marantaceae family, in the Mendanha hill, the correlation is significantly positive between the phenophases (flowering and fruiting) and the abiotic factors (average temperature and precipitation).

Keywords: Marantaceae, Mendanha, phenology.

INTRODUCTION

Studies of plant life cycle events and the relationship with biotic and abiotic factors, as well as the interrelationship between the phases characterized by these events in one or between different species are characterized by phenology (Lieth, 1974). The organization of phenological dates provides important ecological information about the average duration of the different phenophases (bud emission, leaf emission, buds, flowering, fruiting and dispersal) of species in an area, and about the location and climate-determined differences in the dates phenological (Larcher, 2000). The onset and duration of the distinct developmental phases

vary from year to year, depending on climatic conditions (Newstron *et al.*, 1994, Larcher, 2000). Phenological studies with plant species from tropical forests show an annual or supra-annual flowering pattern among shrub and tree species, however, for herbaceous species, flowering is continuous, with variations in intensity throughout the year (Newstron *et al.*, 1994). Phenological studies can provide information on continuous observations of marked individuals in the field, however, most studies contain basic information, making use of periodic observations (Mantovani & Martins, 1988).

The first records of the phenological phases relating to the flowering and fruiting periods for the Mendanha hill were recorded by Francisco Freire Alemão through observations of the “jequitibá” tree (*Cariniana legalis* (Mart.) Kuntze (Lecythidaceae), for a period of 20 years (1846 to 1867). Records indicate the presence of the flowering episode between the months of September, November, December and January, but it is not clear whether the observations were made for the same individual (Cunha, 1964). phenological analyzes on species from the Bignoniaceae family were also recorded, showing an annual flowering pattern for tree and climbing species (lianes) observed in the Mendanha hill Municipal Natural Park (PNMSM), Rio de Janeiro, RJ (Pimentel *et al.*, 2024).

This is the first phenological study for species of the Marantaceae family in the PNMSM. The study was carried out on three species characterized by herbaceous habits, with Pantropical distribution. These species occupy the understory of tropical forests, being an important component of this stratum in most plant formations in Brazil (Braga, 2005; Martinelli *et al.*, 2013). Phenological studies carried out for Marantaceae species occurring in the Atlantic Forest of Rio de Janeiro are scarce and are included in the results referring

to data on Reproductive Biology, in works that emphasize floral visitors and pollinators, only including the flowering time and /or fruiting showing a variety of patterns: in general, flowering and fruiting periods are annual, with a single episode per year (Kennedy, 1978, 2000; Davis, 1987; Ramirez & Seres, 1994; Locatelli & Machado, 1999; Leite & Machado, 2007).

The objective of this work was to record the time in which phenological events related to the flowering and fruiting of three herbaceous species from the Marantaceae family occur. The main questions raised were: 1. Which species of Marantaceae occur in the Mendanha hill Municipal Natural Park? 2. Do the species exhibit seasonal phenological behavior? 3. At what time of year do phenophases occur? 4. Is there synchrony in flowering and fruiting between species? 5. Do climatic factors influence flowering and fruiting?

MATERIAL AND METHODS

Study area: The study was carried out from October 2014 to April 2020 in the Mendanha hill Municipal Natural Park (PNMSM), Rio de Janeiro, RJ, Brazil, totaling 67 months of observations.

The Park has 1339.50 ha and is located in the Gericinó-Mendanha massif with an altitude between 250 and 900 m (Bernardes, 2015; Pontes, 2008, 2015). The predominant climate is mesothermal, with dry winter (June to September) and rainy summer (December to March) (Filho *et al.*, 2021). Precipitation and temperature data were obtained by the National Institute of Meteorology (INMET).

Species characterization: The species selected for the study were: 1. *Maranta cristata* Ker. Gawl. It is a small plant, reaching 0.4 m in height, reptile, with oblong, variegated leaves, white on the adaxial side along the main vein and vinaceous on the abaxial side, and can be found on the edges and interiors of the

forest. 2. *M. leuconeura* E. Morren. It has 0.3 m, reptant, rounded leaves with red spots on the adaxial side and light green color on the abaxial side, forms small terminal tubercles on the roots, can only be found at the edge of the forest where it forms large populations. *M. cristata* and *M. leuconeura* have white flowers, with a thin, thin floral tube (3-10 mm). 3. *G. monophylla* (Vell) Borchs & S. Suárez – is a musoid herb forming rosettes, reaching between 1.5-2.0 m, has green leaves on both sides and a wavy leaf blade due to prominent secondary veins. Its flowers are white, with a thin and long floral tube (3-20 mm), available in inflorescences with a long peduncle, with green bracts, with orange spots. It can be found from the edge to the interior of the forest, but always on the banks of watercourses.

The species were found in shady and humid environments. The observation method was through walks to observe the marked individuals. The populations are found on the banks of the sinner and Fundão rivers in the PNMSM. Exsiccates of the species were deposited in the Herbarium of ``Universidade Rural Federal do Rio de Janeiro`` (RBR).

For the phenological study, ten individuals were marked and numbered in different populations of the species: *Maranta cristata* and *M. leuconeura*. For *G. monophylla*, 15 individuals were marked. Fortnightly observations were carried out, noting the beginning, end and characteristics of the observed events, such as: presence and absence of flowers, fruits and seeds (maturation and dispersion). For *G. monophylla* the distance between individuals can reach 500 meters.

Flowering patterns were described according to Newstron *et al.* (1994) and Ruiz and Alencar (1999), considering the frequency, regularity, duration of each phenophase, date and synchrony.

Morphological observations regarding the growth, size and color of fruits and seeds

resulting from natural pollination were carried out in the field and in the laboratory with the aid of a stereoscopic microscope and a caliper. The fruits were monitored from the beginning of development until maturation.

The activity index (or percentage of individuals) was used to estimate synchrony, indicating the proportion of sampled individuals that are manifesting a certain phenological event. The adopted classification covers the following classes: asynchronous (<20%); synchronous (20% - 60%) and highly synchronic (> 60%) (Bencke and Morellato, 2002).

The Spearman correlation test (r_s) was performed between the number of individuals of a species, as well as the species of the family, in each phenophase, and the climatic variables (average temperature and precipitation), with records of 67 months, to The Statistica 6.0 program was used (Statsoft, 1991).

RESULTS AND DISCUSSION

The Marantaceae species that occur in the Atlantic Forest of the Mendanha hill Municipal Natural Park have seasonal, annual and regular flowering. In *Maranta cristata* and *M. leuconeura*, flowering is continuous and extensive (>5 months), while for *Goepertia monophylla* flowering is intermediate (1 to 2 months). The flowering peak for the three species occurs between the months of November and January, a period characterized by hot and rainy weather. The records taken over 67 months of observations are summarized in Figures 2 and 3. Studies carried out with species of the Marantaceae family in the Amazon and the Atlantic Forest show that the flowering period occurs during the rainy season (Kennedy, 1978; Barreto & Freitas, 2007; Leite and Machado, 2007;).

The species have overlapping flowering periods, with *M. cristata* and *M. leuconeura* starting to produce buds and flowers

practically together, occurring seven days before flowering. The buds are retained inside the bracts, being released as they develop. The flowers are gathered in synflorescences that are emitted sequentially. Studies on floral biology and pollination show that *M. cristata*, *M. leuconeura* and *G. monophylla* provide few anthesis flowers per day, emitting 2 to 4 flowers/inflorescence, but each plant can flower for around 100 days (Pimentel & Cordeiro, 2024; Pimentel *et al.*, 2024). For Newstron *et al.* (1994), the long flowering period with few flowers in anthesis per day favors inter-plant flights and promotes a higher rate of cross-fertilization.



Figure 2: a.-c. *Maranta cristata* Ker. Gawl., d.-e'. *Maranta leuconeura* (E. Morren.) and f.-h. *Goepertia monophylla* (Vell) Borchs & S. Suárez in the Mendanha hill Municipal Natural Park.

Source: Rejane Gomes Pimentel

The flowering period of *M. cristata* and *M. leuconeura* is synchronous (20 to 80%), occurring from August to March. However, in 2015, *M. cristata* showed biannual and

continuous flowering, also producing flowers from June to August (transition from the dry to the rainy season, Figures 2 and 3).

Goeppertia monophylla has annual, intermediate and slightly synchronous flowering, between the months of November and February, representing 20 to 40% of flowering plants in the years 2014 to 2020 (Figures 2 and 3). *G. monophylla* flowers synchronously and sequentially when related to the species of *M. cristata* and *M. leuconeura*, with the flowering period coinciding. The floral buds of *G. monophylla* are emitted between 15 and 30 days before flowering and each inflorescence has a longevity of 60 days. The flowers are gathered in inflorescences that have a long peduncle, emitting ten flowers per day/inflorescence and each plant can emit up to two inflorescences simultaneously (Pimentel *et al.*, 2024).

Studies on reproductive biology for the Marantaceae family show that in general, the flowering period can be more intense during the rainy season, as in *Calathea latifolia* (*Goeppertia latifolia*) Wild. Former Link Klotzsch in Panama. (Aeckerman *et al.* 1983), *C. insignis* Petersen (Kennedy 1983), and *C. macrosepala* K. Schum. in Costa Rica (Stiles, 1978), but there are records of species that flower during the dry season, such as *Thalia geniculata* L. (Davis, 1987) and *Calathea lutea* Schult. (Stiles, 1978) in Costa Rica and *Saranthe klotzschiana* (Koern.) Eichl., in Brazil (Locatelli *et al.*, 2004).

The *Maranta* species studied here share floral visitors and pollinators, being pollinated by small bees and flies (ca. 10 mm) (Pimentel & Cordeiro, 2024), while *G. monophylla* is pollinated by a species of hummingbird (*Phaethornis ruber* (Linnaeus, 1758) and by large bees such as *Eulaema pseudocingulata* (Oliveira, 2006) (Pimentel *et al.*, 2024).

The two species of *Maranta* can be found on the edge of the forest, however *M. cristata* can

also be observed in the interior of the forest and on the banks of rivers. *G. monophylla* can be found both on the edge and in the interior of the forest, but always on the banks of the Pecador and Fundão rivers. Phenological studies between species that occur on the edge and in the interior reveal a tendency for greater reproductive activity on the edge, due to the greater incidence of light and a possible decrease in interactions with pollinators and dispersers (Arberti & Morellato, 2010; Reznik *et al.*, 2012). In addition to climatic conditions, edge effects can act on plants, altering their reproductive phenological activity, with consequences for the availability of resources for pollinators and frugivores (Aizen *et al.*, 2002; Aguilar *et al.*, 2006; Reznik *et al.*, 2012).

M. leuconeura and *M. cristata* have an annual, seasonal and extensive flowering period, while *G. monophylla* was intermediate. All species provided few flowers per day (1 to 10) per inflorescence, occurring between the dry and rainy periods (Pimentel *et al.*, 2024, Pimentel & Cordeiro, 2024). In the Atlantic Forest, there is no defined reproductive pattern; when seasonality is less pronounced, plants present continuous cycles, independent of climatic variables (Morellato *et al.*, 2000).

Additional observations carried out in the study area show that other species of Marantaceae occur in the Park such as: *Ctenanthe setosa* (Roscoe) Eichler, *Ctenanthe* sp., *Stromanthe tonckat* (Aubl.) Eichler, *Maranta divaricata* Roscoe, *Saranthe leptostachya* (Regel & Körn.) Eichler and *Goeppertia* sp. The species have flowering and fruiting with an annual pattern, occurring between the months of November and February, however, *S. tonckat* can flower continuously in different months of the year, with a peak in the months of November to February, It is worth noting that these species have fewer individuals than the plants included in the study.

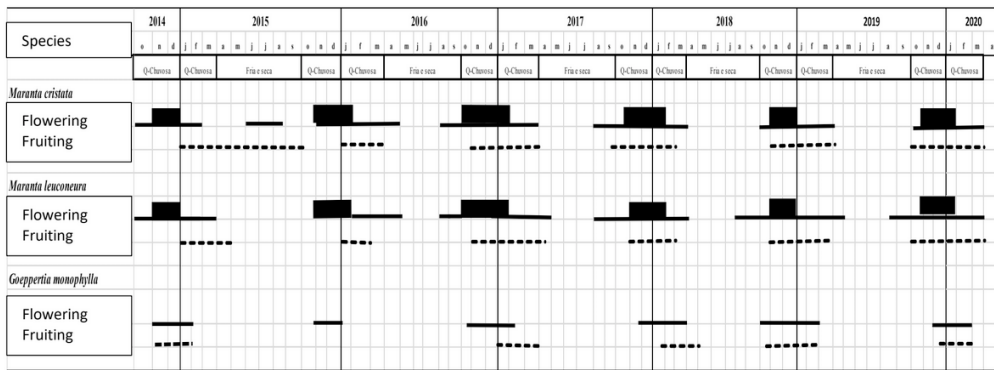


Figure 2: Diagram of occurrence of phenological events for *Maranta cristata* Ker. Gawl., *Maranta leuconeura* (E. Morren.) and *Goepertia monophylla* (Vell) Borchs & S. Suárez (Marantaceae) in the Mendanha hill Municipal Natural Park, Rio de Janeiro, RJ (2014-2020).

Source: Rejane Gomes Pimentel

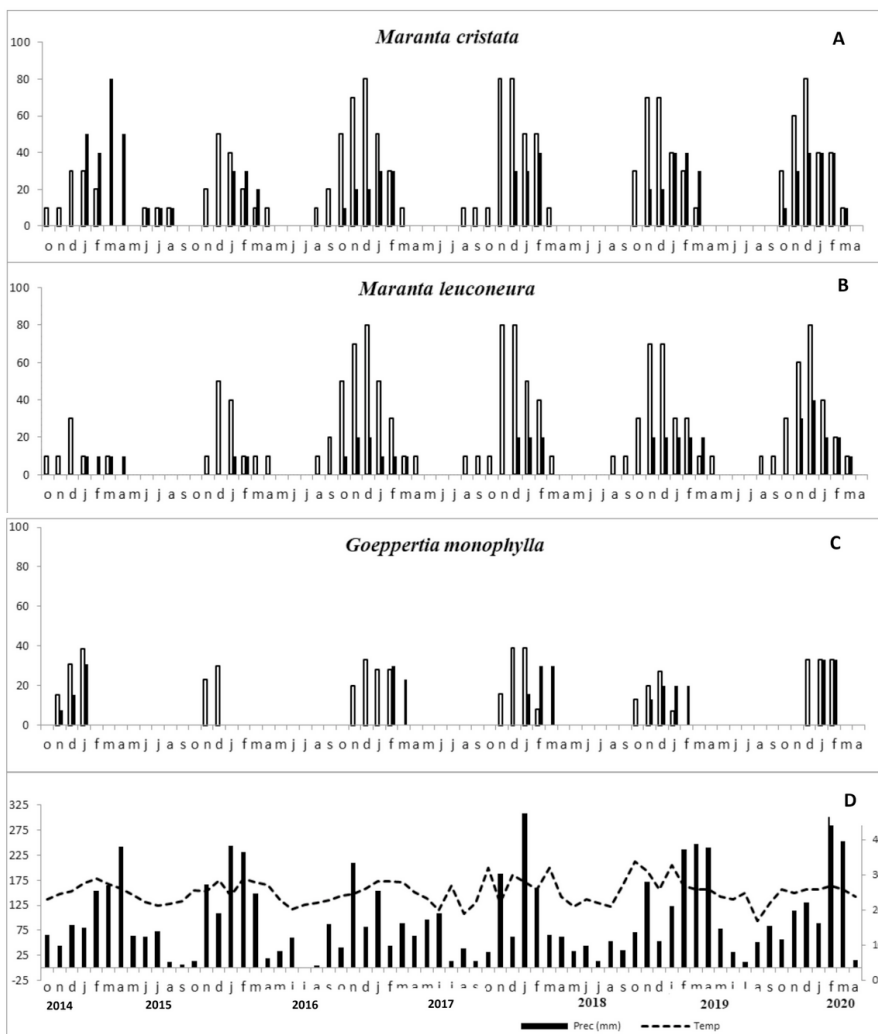


Figure 3. Flowering (white) and fruiting (black) activity. A. *Maranta cristata* Ker. Gawl., B. *Maranta leuconeura* (E. Morren.) and C. *Goepertia monophylla* (Vell) Borchs & S. Suárez in the Mendanha hill Municipal Natural Park, Rio de Janeiro, RJ. D. Precipitation and temperature data for the Vila Militar region, Rio de Janeiro, RJ from 2014 to 2020.

Source: Rejane Gomes Pimentel

In the years 2014 to 2016 there was an overlap in the flowering periods of the three species under study in the months of November and December. Some studies have demonstrated that synchrony in flowering between sympatric species leads to sharing and/or competition for pollinators (Levin & Anderson 1970, Sakai, 2000).

Among taxonomically related plant species, pollinator sharing can result in hybridization, reduced reproductive success, and pollen loss (Campbell & Motten, 1985). Competition, in turn, can interfere with the number of pollinators and visits to flowers and lead individuals to reproductive isolation (Murcia, 1995).

Fruiting – Fruiting for the species is seasonal, annual and regular, occurring during the season with greater rainfall and higher temperatures (Figure 2 and 3). *M. cristata* and *M. leuconeura* show fruit maturation and seed release in the months of January to April (2015). *M. cristata* presents 40% to 80% of individuals in fruiting during this period, while *M. leuconeura* presents only 10%. This year, it was possible to observe a second flowering episode for *M. cristata* in the months of June to August (10%), restarting the fruiting period in October and lasting until February 2017 (Figures 2-3).

Studies carried out with Marantaceae species show that the fruiting period can be observed mainly in the rainy season (June to September), as recorded for *Stromanthe porteana* (A. Gris) in the Atlantic Forest of Dois Irmãos State Park in Recife (Leite & Machado, 2007). According to Nolasco *et al.* (2013), most ornithophilous plants in the Atlantic Forest have annual flowering and fruiting, being more intense during the rainy season (Lopes, 2002). In the understory of humid forests, this annual pattern is common in Marantaceae. The continuous flowering pattern observed in *Ischnosiphon gracilis*

(Rudge) Koern. and *S. porteana* A. Gris has an important ecological function, as it maintains a guild of floral visitors throughout the year, in addition to representing an important source of nutrients for these animal visitors during periods of reduced flowering in the community (Murcia, 1995; Leite & Machado, 2007; Costa *et al.*, 2008).

Fruit development - Fruit development occurs in 30 days for *Maranta* species and 60 days for *G. monophylla* (Pimentel *et al.*, 2024, Pimentel & Cordeiro, 2024). The peak of ripe fruit production coincides with the March rains and many fruits and seeds are dispersed and germinated, making it possible to observe the presence of seedlings around 100 mm tall for the species of *M. cristata* and *M. leuconeura* still with the seminal remains.

The fruits are of the capsule type, approximately 10 mm long, brown in color (*Maranta*), with just one seed that occupies practically the entire fruit. The seeds are brown in color with a white aril in the species of *M. cristata* and *M. leuconeura* and dark brown in *G. monophylla* (Figure 4).

In the rachis of the inflorescences of *M. cristata* and *M. leuconeura* it is possible to observe the presence of a motor pulvinus close to the bracts and during the development of the fruits, the rachis moves towards the ground and the fruits are deposited on the ground, being covered by leaf litter. In addition to the basal curvature, which presents a pulvinus, it is also possible to observe the curvature of the rachis in the position of each cymula, that is, in *M. cristata* the rachis can present up to four curvatures, while *M. leuconeura* can present up to two curvatures. In *G. monophylla*, most flowers become senescent the next day after anthesis. In March, all inflorescences have darkened, moist bracts, with the peduncle curved towards the ground, with few fruits. Some fruits were observed with signs of herbivory, and some caterpillars could be

observed in the bracts.

The species have an underground stem (rhizome) indicating the presence of sexual and asexual reproduction for the populations studied. It is possible to observe the formation of thickets with interconnected individuals. The populations of *M. cristata* and *M. leuconeura* found at the edge of the forest form “carpets” with individuals very close together, while in the interior of the forest *M. cristata* has sparser populations.

Goepertia monophylla, on the other hand, presents individuals that are more distant from each other, and for the first species the distance varies from 1 to 5 meters while in *G. monophylla* the distance can vary from 10 to 50 meters. They can present vegetative reproduction through the development of an underground stem (rhizome). According to Costa et al. (2008), vegetative reproduction is quite common in Marantaceae, with records in the genus *Calathea/Goepertia* (Huylensbroeck and Debergh, 1989; Barreto & Freitas, 2007).

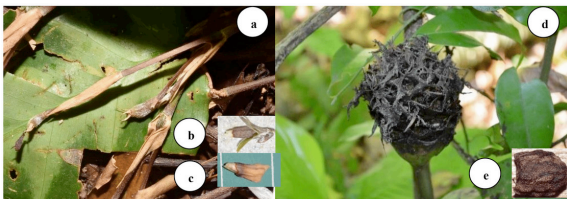


Figure 4: Fruits and seeds of: a-b. *Maranta cristata* Ker. Gawl., c. *Maranta leuconeura* (E. Morren.); d-e. *Goepertia monophylla* (Vell) Borchs & S. Suárez in the Mendanha hill Municipal Natural Park.

Source: Rejane Gomes Pimentel

Correlation with abiotic factors – the Spearman correlation index pointed to the Marantaceae family, in the Mendanha hill-RJ, a significantly positive correlation between flowering and fruiting with abiotic factors (average temperature and precipitation). Analyzing the three species separately, this

index also showed a significant positive correlation for all species studied (Table 1). In studies carried out on *G. crocata* and *C. lutea* (Aubl.) Schult., they show that flowering is not correlated with precipitation and this fact is probably due to the type of environment in which it occurs, close to watercourses, where water is available throughout the year (Stiles, 1978; Huylensbroeck and Debergh, 1989).

| | Flowers | Fruit development |
|-----------------------------|-------------------------------|-------------------------------|
| Marantaceae | Tmed (0,493)* PPT (0,483)* | Tmed (0,560)* PPT (0,561)* |
| <i>Maranta cristata</i> | Tmed (0,450)* PPT (0,414)* | Tmed (0,463)* PPT (0,588)* |
| <i>Maranta leuconeura</i> | Tmed (0,429)* PPT (0,441)* | Tmed (0,485)* PPT (0,534)* |
| <i>Goepertia monophylla</i> | Tmed (0,396)* PPT (0,347)* | Tmed (0,405)* PPT (0,254)* |

Table 1: Spearman correlation index (rs) obtained in the correlation analysis between climatic factors (average temperature and precipitation) and flowering and fruiting phenophases for Marantaceae species in the Mendanha hill Municipal Natural Park, RJ. In parentheses, the value of the Spearman correlation index (rs) for $P < 0.05$. (Tmed = average temperature; PPT = precipitation; * = significant). From the table (0.05 two-sided), $n=67$ pairs, $rs= 0.235$.

Source: Rejane Gomes Pimentel

FINAL CONSIDERATIONS

The Marantaceae species studied here are native to the Atlantic Forest and can be used as ornamental plants in humid and shaded places. They present annual flowering and fruiting phenophases, making floral nectar and pollen resources available to different groups of animals: bees, hummingbirds, butterflies, beetles and flies in different months of the year, with a peak in the months of November and December, corresponding to the hot and rainy season.

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