TEMPORAL DISTRIBUTION OF FLORAL RESOURCES FOR BEES IN AN URBAN ENVIRONMENT IN NORTHEASTERN BRAZIL

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ABSTRACT

The decline of pollinators has generated a global concern due to their negative effects on pollination. Declining floral resources due to habitat loss and degradation has been suggested as one of the key factors of this decline. Knowing the flora and distribution of floral resources in a given environment can help maintain these populations of pollinators. Therefore, the objectives of this study were to determine the floristic composition and to describe the patterns of temporal distribution of floral resources used by bees in different vegetation extracts in an urban environment in northeast Brazil. We found 210 plant species that were distributed in 54 families, among which, Fabaceae was the most representative. Plants classified as melitophilous, most of which, natives, represented 84% of the plant community. The study of their floral phenology pointed that these species presented flowers throughout the year. Plants providing nectar and/or pollen were more common and had a seasonal distribution despite the low concentration (r). Herbaceous plants showed greater richness and number of individuals with nectar and/or pollen flowers, showing a seasonal distribution for both resources. However, this can be a worrying factor, considering that it is precisely this extract that suffers most in urban areas, mainly due to the pruning of plants.

Keywords: Phenology, Nectar, Pollen.

RESUMO

O declínio dos polinizadores tem gerado uma preocupação global devido aos seus efeitos negativos na polinização. A diminuição dos recursos florais devido à perda e degradação do habitat tem sido sugerida como um dos fatores-chave deste declínio. O conhecimento da flora e distribuição dos recursos florais num determinado ambiente pode ajudar a manter estas populações de polinizadores. Portanto, os objetivos deste estudo foram determinar a composição florística e descrever os padrões de distribuição temporal dos recursos florais utilizados por abelhas em diferentes extratos de vegetação em um ambiente urbano no nordeste brasileiro. Encontramos 210 espécies de plantas que foram distribuídas em 54 famílias, entre as quais, Fabaceae foi a mais representativa. As plantas classificadas como melitófilas, a maioria das quais, nativas, representavam 84% da comunidade vegetal. O estudo da sua fenologia floral apontou que estas espécies apresentaram flores ao longo do ano. As plantas que forneciam néctar e/ou pólen eram

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mais comuns e tinham uma distribuição sazonal, apesar da baixa concentração (r). As plantas herbáceas mostraram a maior riqueza e número de indivíduos com flores de néctar e/ou pólen, mostrando uma distribuição sazonal para ambos os recursos. Contudo, isto pode ser um fator preocupante, considerando que é precisamente este estrato que mais sofre nas zonas urbanas, principalmente devido à poda das plantas.
Palavras-chave: Fenologia, Néctar, Pólen.

INTRODUCTION

Floral resources play an important role in regulating animal activity and population dynamics (Raubenheimer et al., 2009). For pollinators who rely heavily, or entirely, on food obtained from flowering plants, the availability of floral resources in the environment is a measure of the dynamic processes of the population (Roulston & Goodell, 2011) and energetic demands (Heinrich, 1975), which together shape the spatial distribution, abundance, and quality of ecosystem services for pollination.

Pollinators are environmental service providers and mainly include insects, birds, and bats. They visit the flowers in search of resources, and during the visits, they transfer the pollen grains among cospecific flowers (Willmer, 2011). Bees are among the most important pollinators in the tropics (Silberbauer-Gottsberger & Gottsberger, 1988; Bawa, 1990; Renner & Feil, 1993; Rincón et al., 1999; Giannini et al., 2020). In Brazil, more than 60% of crops depend on or benefit from pollination provided by bees (Giannini et al., 2015; Wolowski et al., 2019). This intrinsic relationship between plants and most bees is mainly caused by the fact that their brood diets originate from flowers, and consequently, there is a dependence on nectar and pollen for future generations of bees (Roubik, 1989; Proctor et al., 1996; Michener, 2007).

The loss of floral resources is one of the main factors responsible for the decline of bees (Scheper et al., 2014) and the provision of adequate floral resources (pollen, nectar, and oil) is considered to be decisive for successful habitat management for native bees (Alves-dos-Santos et al., 2007; Dicks et al., 2010; Scheper et al., 2014).

Urbanization has caused the fragmentation of habitats and loss of natural areas (McDonald et al., 2019). This fragmentation reduces the availability of food as well as nesting sites, especially for bees that are fodder insects (Kremen et al., 2007). In urban environments, botanical species with different flowering periods are normally used in gardening, which favors the supply of resources for pollinators throughout the year (Mouga et al., 2015). Therefore, an increase in plant diversity and abundance, consequently, an increase in floral resources is essential to mitigate the loss of pollinator diversity and the supply associated with pollination functions in urban environments (Hülsmann et al., 2015; Sutter et al., 2017; Kaluza et al., 2018).

The climatic seasonality influences the patterns of floral phenology, and consequently the distribution of floral resources offered in a community, influencing the reproduction and growth of plants (Bawa, 1983; Morellato et al., 2000; Morellato et al., 2010). In tropical regions, in areas with well-defined dry and rainy seasons, precipitation is considered the main factor influencing the phenology of species (Morellato, 2003; Morellato et al., 2010). However, climate change in urban environments has changed the phenological patterns of some plants species (Memmott et al., 2007; Zhou et al., 2016).

Changes in the temporal distribution of resources used by bees help to determine their dependence on certain plant species over a year, within a specific season, or even during a day (Feinsinger, 1983; Taura & Laroca, 2001). Therefore, evaluating the variation in phenological patterns of plant populations and their association with abiotic factors (temperature, humidity, and rainfall) helps to understand the adaptive responses of plants to climate change (Bencke & Morellato, 2002; Morellato et al., 2010; Rubim et al., 2010).

Plants from different vegetation strata often complementarily provide floral resources for urban pollinators (Aleixo et al., 2014). Trees are known to provide important floral resources for pollinators in urban areas because of the greater availability of nectar (Maruyama et al., 2019; Wenzel et al., 2020), and herbs and shrubs can support a large number of pollinators at different times of the year (Nascimento et al., 2020). However, few studies have been conducted to elucidate the complementarity or relative importance of the distribution of floral resources of vegetation strata in urban areas.

Evaluating the temporal distribution of floral resources is one of the first steps to understanding the relationships between the composition of the plant community and the use of floral resources by the urban bee fauna (Aleixo et al., 2014). Therefore, the objective of this study was to evaluate the floral phenology and the temporal distribution patterns of the floral resources used by bees, in different vegetation strata; and their relationships with three environmental variables (temperature, average rainfall, and relative humidity) in an urban environment in Northeast Brazil.

MATERIAL AND METHODS

Study area

The study was covered between August 2018 and July 2019 in a 1000 m radius around an experimental meliponary of Laboratory of Bee Studies (LEA / UFMA [2°33′07.7″S, 44°18′22.8″W]) located at the Dom Delgado University Campus/Universidade Federal do Maranhão, in São Luís, Maranhão, Brazil.

The climate of São Luís is tropical hot and humid - Aw (Köppen 1948) with a predominantly rainy season, from January to June, and a dry season, from July to December. The rainfall index varies from 1,250 to 2,000 mm. Temperatures are high throughout the year (26 °C, on average), with small annual variation (INMET, 2019). The months with the highest average rainfall are March and April, whereas the lowest are October and November (Fig. 1).

The island of São Luís was covered by a latifoliate forest, babaçual (*Attalaea speciosa* Mart.) and mangrove forest (Gottsberger et al., 1988); however, in the last few decades, with the increase of urban area and the constant deforestation, the local vegetation has completely changed. Currently, capoeiras predominate, with the presence of some babaçus and savannah spots, and on the coast, there are pioneer formations (field and restinga), in addition to mangroves (Bezerra, 1990). The study area, for example, is composed of a large number of herbaceous plants, arboreal plants, ornamental plants, and fragments of mangroves that are inserted along the banks of the Bacanga River. This vegetation is distributed near buildings, houses, streets, avenues, squares, gardens and small patches of vegetation.

Floristic composition and distribution of pollination systems in vertical stratification

The floristic composition was studied in an area represented by a radius of 1,000 m. Within this area, the plant species were sampled in all vertical strata, and classified according to their habit: arboreal, shrubby, herbaceous, and liana, as suggested by Silva et al. (2012).

The floristic composition was identified through random sampling across the experimental area with vegetation. Fertile branches were collected (with flowers and/or fruits), and their characteristics were noted in a field notebook. Later, this material was herborized according to the usual techniques of Peixoto & Maia (2013). The botanical material was sent to the Herbarium of Maranhão, in the Department of Biology of the

Universidade Federal do Maranhão (Herbarium MAR) for identification where they were deposited.

The syndrome for each species was designated according to the pollinating agent: bees, birds, beetles, butterflies, moths, bats, flies, wasps, and wind. This characterization was performed through consultation with the literature on aspects of floral biology, reproductive biology, floral visitors, and defined pollination syndromes for each specie (full species references list see Supplementary Material – Table S1). For plants that had not yet been classified regarding these aspects, we used field observations, and in some cases, we followed the method proposed by Faegri & Pijl (1979), which considers floral characteristics such as size, shape, symmetry, color, anthesis, and odor to determine floral syndrome.

Additionally, all plants were further classified as native, cultivated, and naturalized. For this, the site 'Flora do Brasil' and specialized literature (Richardson et al., 2000; Zenni & Ziller, 2011; Souza & Lorenzi, 2012) were consulted. The classification system adopted was APG IV (2016), and the revision and updates of the species names were completed with the database made available by International Plant Names Index (www.ipni.org).

Flowering phenology and temporal distribution of attractive floral resources for bees

Data on the phenology of blooming were also collected in the same area. The sample area was visited every month, for 3-5 consecutive days between August 2018 and July 2019, and the number of all flowering individuals per species was registered to estimate the availability of floral resources. To differentiate individuals in the herbaceous stratum, we verified the number of stems or rosettes was counted (Pereira et al., 2004), because the delimitation of individuals in this stratum is often difficult, given that several species are clonal and occur in aggregations.

We collected flowers and took them to the laboratory in order to verify floral nectaries as well as oil glands (elaiophores). In addition, to obtain additional information about the floral biology of your sampled species, we reviewed the literature that had already been conducted.

The spatial (strata: habit) and temporal (months) distribution of floral resources were analyzed only species used by bees. The classification of plant species according to their main available resource was based on nutritive resources (Pollen [**Po**], Nectar [**Ne**]**,** and Oil **[Ol**]). Plants that provided two resources (**Ne + Po**) in the same flower were analyzed separately from those that provided only Po, Ne, or Ol resources (Aleixo et al., 2014, with modifications).

Statisical analysis

To evaluate the distribution of attractive floral resources for bees throughout the year, and consequently, the seasonality of flowering, we used the number of flowering individuals and performed a Rayleigh test of uniformity (Z) for circular distribution (Zar, 1999), with a significance level of 5% ($p < 0.05$). Additionally, we assessed the seasonability of flowering events for each functional group of flowering plants, according to the resources it provides and the strata it belongs. For this, we calculated the "r" index following Morellato et al., (2000). Values of "r" vary from 0 to 1, in which low values (closer to 0) indicates an even distribution of flowering events throughout the year, whereas high values (closer to 1) indicates a seasonal pattern. Circular statistics were performed using Oriana - Circular Statistics version 4 (Kovach Computing Services, Pentraeth, Wales, UK).

To verify if the number of blooming individuals who provided floral resources (pollen, nectar, pollen + nectar, and floral oil) has changed over time in relation to abiotic factors (temperature, humidity, and average rainfall), Pearson's linear correlation (R) was used.

These correlation analyses were performed using R 4.0.2 (R Development Core Team, 2020).

RESULTS

Floristic composition

We identified 210 plant species distributed in 170 genera and 54 families (Table S1). The most representative families that contributed to flowering species in the area were Fabaceae (49), Asteraceae (20), and Malvaceae (15). In the other families, 126 species are distributed, 21 of which had only one species (Table S1).

In general, plants pollinated by bees predominated (71.30%), followed by those pollinated by wind (5.26%), butterflies (4.78%), birds (2.39%), bats (1.4%), beetles, and wasps with less than 1% each (0.95% and 0.48%, respectively). Mixed pollination, performed by more than one pollinator, was second in the order of representativeness with 13.39% of plants, and in most, bees were also possible pollinating agents. Therefore, in the present study, approximately 84% of the plant species in the region used the ecosystem services of bees (n = 175), adding plants pollinated only by bees and plants with mixed pollination with the participation of bees. Of the 175 species of used by bees plants found in the region, 81.14% were native plants, 10.28% naturalized, and 8.57% cultivated.

Distribution of resources used by bees

Of the 175 species of melitophile plants, 44% provided nectar as a floral resource, 20,57% provided pollen, 32,57% provided both resources (nectar and pollen), and 8,85% provided oil. In general, the floral resources used by bees in the region were available throughout the observation period (Fig. 2). Plants that provided only nectar showed peak flowering in the dry season (September), and also presented a seasonal distribution (Z = 517.977; $p < 0.0001$; r = 0.674) (Fig. 2B). The flowering of plants that provided only pollen showed a significant peak (Z = 201.762; $p < 0.0001$) in April, revealing a seasonal pattern (r = 0.608) (Fig. 2B). Plants that offered both resources (nectar and pollen) showed seasonality tendency, with a significant average date in September (Z = 91.854; p < 0.0001), but with a low concentration (r = 0.292) (Fig. 2C). Regarding floral oil, it obtained peak availability in April and was available in almost every month, except February. The average date of the individuals supplying floral oil was significant and corresponded to July (Z = 10.189; $p < 0.001$; r = 0.499) (Fig. 2D).

Throughout the year, we observed a greater richness of species in the flowering in the herbaceous stratum, with peak flowering during the transition between the dry and rainy periods (June and July) (Fig. 3). According to the analysis of the distribution of floral resources in relation to vertical stratification, it was observed that the most common floral resources made available to bees were pollen and nectar (Table 1). Herbaceous species presented a higher number of blooming individuals, followed by the arboreal, shrub, and liana strata (Table 1). All strata presented a seasonal distribution in all studied resources (pollen, nectar, nectar + pollen, and oil), except for the shrub stratum in plants that provided nectar and pollen (Fig. 4). The herbaceous stratum showed a higher number of individuals with flowers that provided only nectar (n = 3212), only pollen (n = 1702), or both resources (n = 2409) throughout the study period, presenting a seasonal distribution (Z = 401.603, $p < 0.0001$; Z = 325.941, $p < 0.0001$ and Z = 246.928, $p < 0.001$, respectively) (Fig. 4). *Mimosa pudica* L., *Borreria verticillata* (L.) G.Mey., *Turnera subulata* Sm., *Tridax procumbens* L., and *Crotalaria retusa* L. Colla were the main nectar and/or pollen supplying species during the peak blooming period in this stratum (Table S1).

Floral oil was available in all the strata studied, but for only five species in total, with the tree stratum represented by two species (*Byrsonima crassifolia* (L.) Kunth and *Malpighia glabra* L., both from the Malpighiaceae family), the other strata were represented by only one species (herbaceous: *Cipura paludosa* Aubl; Liana: *Momordica charantia* L.; Shrub: *Niedenzuella multiglandulosa* (A.Juss.) W.R.Anderson).

Although most extracts showed seasonal distribution in the floral resources studied (Tab. 1), plants with nectar and pollen showed low concentrations in the herbaceous (r = 0.32), arboreal (r = 0.166), and shrubby (r = 0.137) strata, showing the uniform distribution of these resources throughout the year.

The number of blooming individuals providing only nectar was negatively correlated with humidity and rainfall (R = -0.61; p = 0.033; R = -0.58; p = 0.046, respectively), and those providing only pollen was positively correlated with humidity and rainfall (R = 0.72; p = 0.008 and R= 0.66; p = 0.02, respectively) (Tab. 2). Temperature was not correlated with any of the floral resources studied.

DISCUSSION

We verified that most of the plants that were found in the Dom Delgado Campus and surroundings have traits related to pollination by bees, that is, they depend on the bees for reproduction. Bees are responsible for approximately 84% of the pollination of plants that occur in the area, and although it is an urban location with a high rate of anthropization, it still hosts abundant resources for pollinators, with high local biodiversity providing more nectar and pollen throughout the year, than natural environments (Kaluza et al., 2016; Somme et al., 2016) as was verified by Aleixo et al. (2014) in an urban area.

Of the 84% of the melitophyllous plants in the region, 81.13% are native, which shows that the urban growth in this region and the consequent increase in plant richness in cities does not always happen through the introduction of exotic plant species (Acar et al., 2007; McKinney, 2008; Aleixo et al., 2014). In some cases, exotic plants can be considered attractive to generalist native bees due to the ability of some to produce mass flowering, other excessive nectar production, and often appear in high density or dominate the flower community in disturbed environments (Bjerknes et al., 2007; Stout & Morales, 2009). However, this mass flowering and dominance of a certain area can increase competition for pollinators (Stout & Morales, 2009), thus reducing some species of plants native to the environment.

Among the floral resources studied, nectar was the most frequent resource among individuals of plants on the Campus and surroundings, which is a common characteristic verified in several studies (e.g., Silberbauer-Gottsberger and Gottsberger, 1988; Machado & Lopes, 2004; Quirino & Machado, 2014). According to Faegri & van der Pijl (1979), nectar is considered a primary attraction because it serves as an energetic food for many animals that visit the flowers repeatedly, allowing the pollination of these plants.

The herbaceous stratum showed the greater richness of flowering species throughout the year, with peak flowering in the transition between the dry and rainy periods (June and July). However, these months did not show a peak in the abundance of any of the studied resources, demonstrating that in this period, there were many species with a reduced number of blooming individuals. In this stratum, the predominance of short-lived annual species makes the floristic composition more dynamic, because to maintain the herbaceous flowers throughout the year, the species must be constantly added, removed, and replaced (Aleixo et al., 2014). Moreover, because it was an urban area, this stratum was periodically pruned, which made it impossible to monitor the flowering of these species, making it difficult to determine the real period of flowering, as was observed during this study.

Few studies have evaluated the reproductive phenology of the herbaceous stratum in Angiosperm, and consequently, the resources offered by it (Batalha & Mantovani, 2000; Munhoz & Felfili, 2005; Silva et al., 2012; Aleixo et al., 2014). This is because of the difficulties in observing herbaceous species in the period when they are not in bloom, making it very difficult to observe possible survival strategies. According to Rathcke & Lacey (1985), herbaceous plants that need more resources for reproduction, only begin flowering after a period of accumulation of carbohydrates; therefore, these should produce flowers later and for a shorter period. In this stratum, the species *M. pudica*, *Borreria verticillata* (L.) G. Mey, *Turnera subulata* Sm., *Tridax procumbens* L., *C. retusa*, and *Priva bahiensis* A. DC, which are considered important representatives in the maintenance of the apicultural pasture in the region because of the large number of flowering individuals during the year.

The arboreal strata were also well represented, offering resources throughout the study period. The species *S. siamea*, *L. leucocephala*, *M. caesalpiniifolia*, *Terminalia catappa* L., *A. mangium*, and *Clitoria fairchildiana* R.A.Howard were in bloom during the entire year; thus, they contributed to the distribution and availability of floral resources for local bees, of these only *M. caesalpiniifolia* and *C. fairchildiana* are part of the native flora of Brazil. According to Janzen (1980), arboreal species present two adaptive strategies depending on the need for cross-pollination and the distance between the plants. The first is seasonal flowering, in which there is an abundant production of flowers for short periods, attracting non-specialized insects. The second is continuous flowering, in which the arboreal plant species produce few flowers daily for long periods, attracting specialized pollinators. This last strategy seems to be the one used by *S. siamea*, *L. leucocephala*, *Terminalia catappa* L. and *A. mangium*, as most of the arboreal individuals of these blooms throughout the year. However, although *M. caesalpiniifolia* and *C. fairchildiana* blossom practically all year round, it was observed that a greater number of *M. caesalpiniifolia* individuals bloomed in the rainy season, and *C. fairchildiana* in the dry season. However, in contrast to the herbaceous plants that suffer periodically because of being pruned, trees were kept in urban areas mainly for the need to maintain shading and decrease thermal sensations.

The heterogeneous distribution in the availability of floral resources used by pollinators in different vertical strata of vegetation can generate a vertical mosaic (Silva et al., 2012), in which one stratum complements the resource distribution of the others. Although herbaceous plants showed greater richness and abundance of flowering species, flowering trees in urban areas play an important role as a food source, as their flower density per area exceeds that of most herbaceous species (Hausmann et al., 2015; MacIvor et al., 2014), especially when they are mass flowering trees, such as *M. caesalpiniifolia* (Maia-Silva et al., 2015), which is an important source of pollen and nectar in the region.

As verified in other studies (Talora & Morellato 2000; Morellato et al., 2000; Aleixo et al., 2014; Gostinski et al., 2018), flowering is directly linked to rainfall. These correlations are typical of tropical environments where flowering, and consequently, the availability of resources are strongly associated with seasonal variations in rainfall (van Schaik et al., 1993); however, in urban environments, these flowering peaks can be severely affected, because that part of its original vegetation has been removed (Aleixo et al., 2014).

In this study, we observed that plants that provide nectar as a floral resource, correlated negatively with humidity and rainfall, demonstrating that with the increase of precipitation and humidity, the availability of this resource decreases. On the other hand, plants that only offer pollen were positively correlated with humidity and rainfall, demonstrating that with increased rainfall and humidity, the availability of this resource increased.

The flowering of nectariferous plants during the dry period is considered advantageous because it prevents the flowers from suffering mechanical damage and the nectar from being diluted by rainwater, which results in a highly energetic food (Aleixo et al., 2014; Lawson & Rands, 2019). Bees that pollinate flowers generally have high sugar concentrations (Pyke & Waser, 1981; Baker & Baker, 1983), and diluted nectar has been shown to discourage pollinators from visiting these flowers (Cnaani et al., 2006; Lawson & Rands, 2019); thus, diminishing the reproductive success of these plants.

The distribution of polliniferous plants in periods of higher rainfall and humidity can be explained by the fact that exposure to low relative humidity causes pollen grains to lose water and decrease in volume, causing an explosion shortly after germination (Corbet et al., 2019), making pollen grains unviable.

In arboreal plants that have deep root systems or reserve organs, they can be independent of the effects of seasonality (Sarmiento & Monasterio, 1983; Tannus et al., 2006; Oliveira, 2008), because these organs allow them to reproduce during the water shortage period, and store reserves during the rainy season to support dry season activities (Oliveira & Gibbs, 1994; Oliveira, 2008). Rain and other climatic changes work more as triggers, signaling and synchronizing the occurrence of flowering in some species (Oliveira, 2008).

Seasonality influences the distribution of floral resources in species of the herbaceous stratum, which present short life cycles and are limited by water availability, because of the presence of surface underground systems (Monasterio & Sarmiento, 1976; Sarmiento, 1983; Mantovani & Martins, 1988). In this study, rainfall and humidity were important for the distribution of plants that offered pollen or nectar, and these made their resources available during the whole year, despite presenting a decrease during the rainy period, which coincided with the weeds in this stratum.

The distribution of floral oil did not show any correlation with the abiotic factors studied (rainfall and temperature). Most studies on floral phenology of plants that offer oil as a reward show that this resource is available during the dry period (Barros, 1992; Pereira & Freitas, 2002; Benezar & Pessoni, 2006), except that of Mendes et al. (2011), who studied *Byrsonima umbellata* Mart ex A. Juss., and found that this species blooms at the beginning of the rainy season, extending into the dry season, with flowering peaks during the transition period.

Floral oil, despite being the least common resource in the region, is very important for bees of the Centridini Tribe, who use this resource as a source of food for their larvae and also to coat their brood cells (Anderson, 1979; Rêgo & Albuquerque, 1989; Vogel, 1990; Sigrist & Sazima, 2004; Rêgo & Albuquerque, 2006; Alves-dos-Santos et al., 2007). The greatest abundance of individuals who offered floral oil was observed in the arboreal stratum, and the Malpighiaceae family was the main contributor to the availability of this resource during the entire observation period. According to Vogel (1990), most Neotropical species in this family have oil glands, called elaiophores, and although oil is the main resource offered by most Neotropical species of Malpighiaceae, pollen also attracts a great diversity of visitors that can act as pollinators (Pedro, 1994).

The temperature did not correlate with the distribution of any of the studied resources (**Ne**, **Po**, **Ne + Po** and **Ol**), as verified by Aleixo et al. (2014). This can be attributed to small variations in the average temperature. Even between dry and rainy periods, this variation was small. The proximity of the region to the Equator makes its variation in solar incidence small, and consequently, variations in average temperature. According to Stöckli et al. (2011), phenology is much more than a simple linear correlation with average annual temperatures. For a model to make realistic phenological predictions, it must combine several factors, such as temperature, light, and humidity.

Increasing the abundance of floral resources is not necessarily an effective strategy for achieving pollinator conservation targets, but instead, carefully identifying the resources of specific target groups is critical to the success of pollinator conservation and pollination (Sutter et al., 2017). When using only exotic plant species, generalist insect populations suffer little from these impacts; however, the same does not occur with specialist insect populations, which are strongly affected by the removal of native plants (Zanette et al., 2005; Nates -Parra et al., 2006; Frankie et al., 2009; Bergerot et al., 2010).

The high proportion of plants with flowers pollinated by bees in our study area reinforces the concerns about the potential consequences of the decline of pollinators (especially bees), for the native flora, especially in disturbed areas, where there is a decrease of areas for nesting. Variation in the flowering distribution of individual plants that supply pollen and/or nectar among strata throughout the year is important for the maintenance of bee populations, given that pollen and nectar are essential foods for their survival. Despite the flowering peaks at different times of the year for plants that offer these resources, it was found that they are offered throughout the year, even in the case of an urban environment, in which a substantial part of the original plants was removed for urban growth. The complementarity of floral resources between different strata of vegetation and species of melitophilic importance is a crucial path for the success of measures aimed at the conservation of the diversity of bees and other pollinators.

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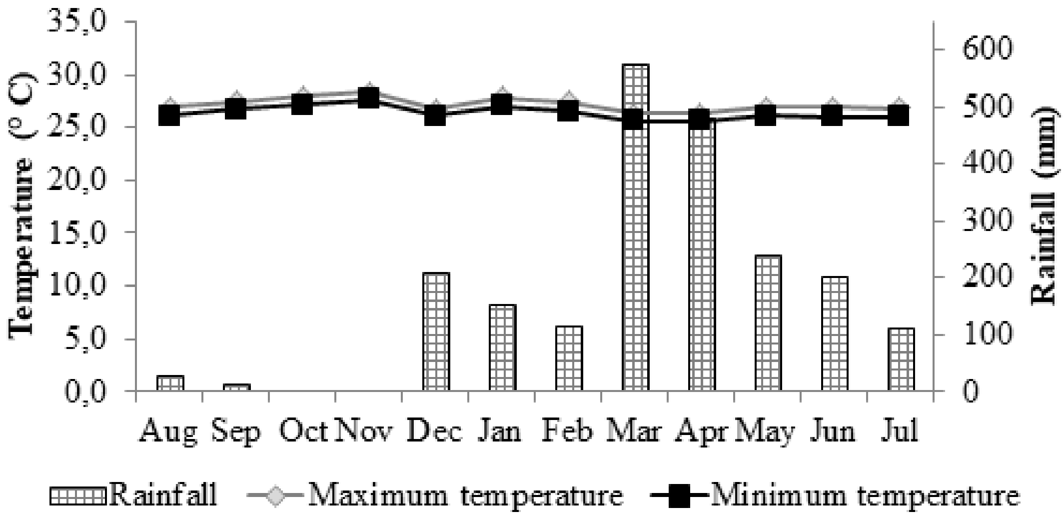


Fig. 1. Temperature distribution (°C) and average monthly rainfall (mm) in São Luís - MA, Brazil, between August 2018 to July 2019. Source: INMET (http://www.inmet.gov.br/portal/)

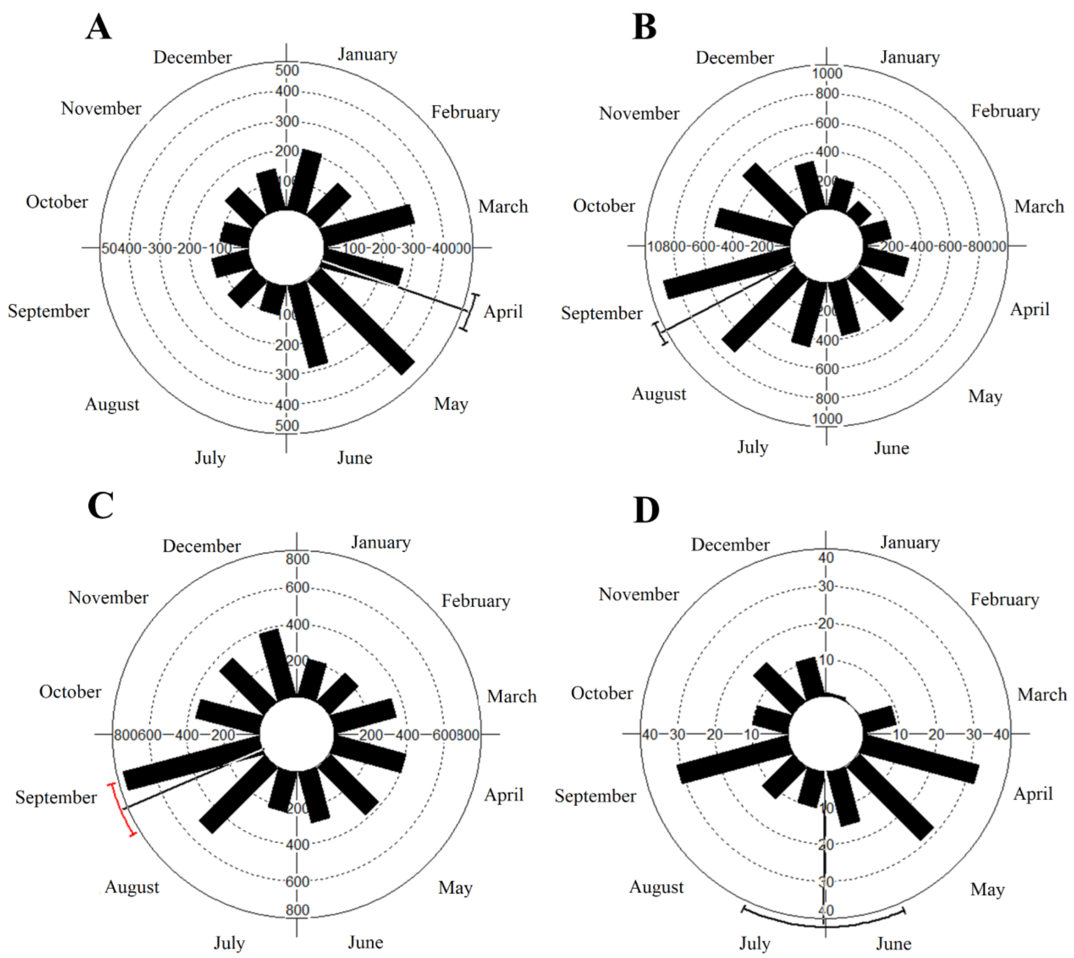


Fig. 2. Circular histogram representing the distribution of floral resources available to bees, represented by the number of individual plants in bloom between August 2018 and July 2019 at the campus of Dom Delgado and surroundings, São Luís - MA, Brazil. (A) Pollen. (B) Nectar. (C) Nectar and Pollen. (D) Floral oil. The line at the top of the vector indicates the standard deviation.

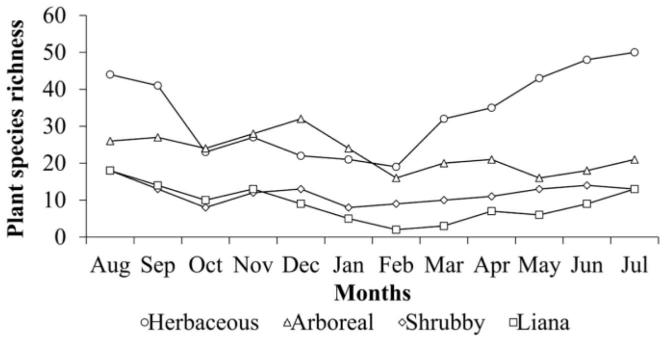


Fig. 3. Distribution of the richness of plant species pollinated by bees in different vertical strata from August 2018 to July 2019 on the campus of Dom Delgado and surroundings, São Luís - MA, Brazil.

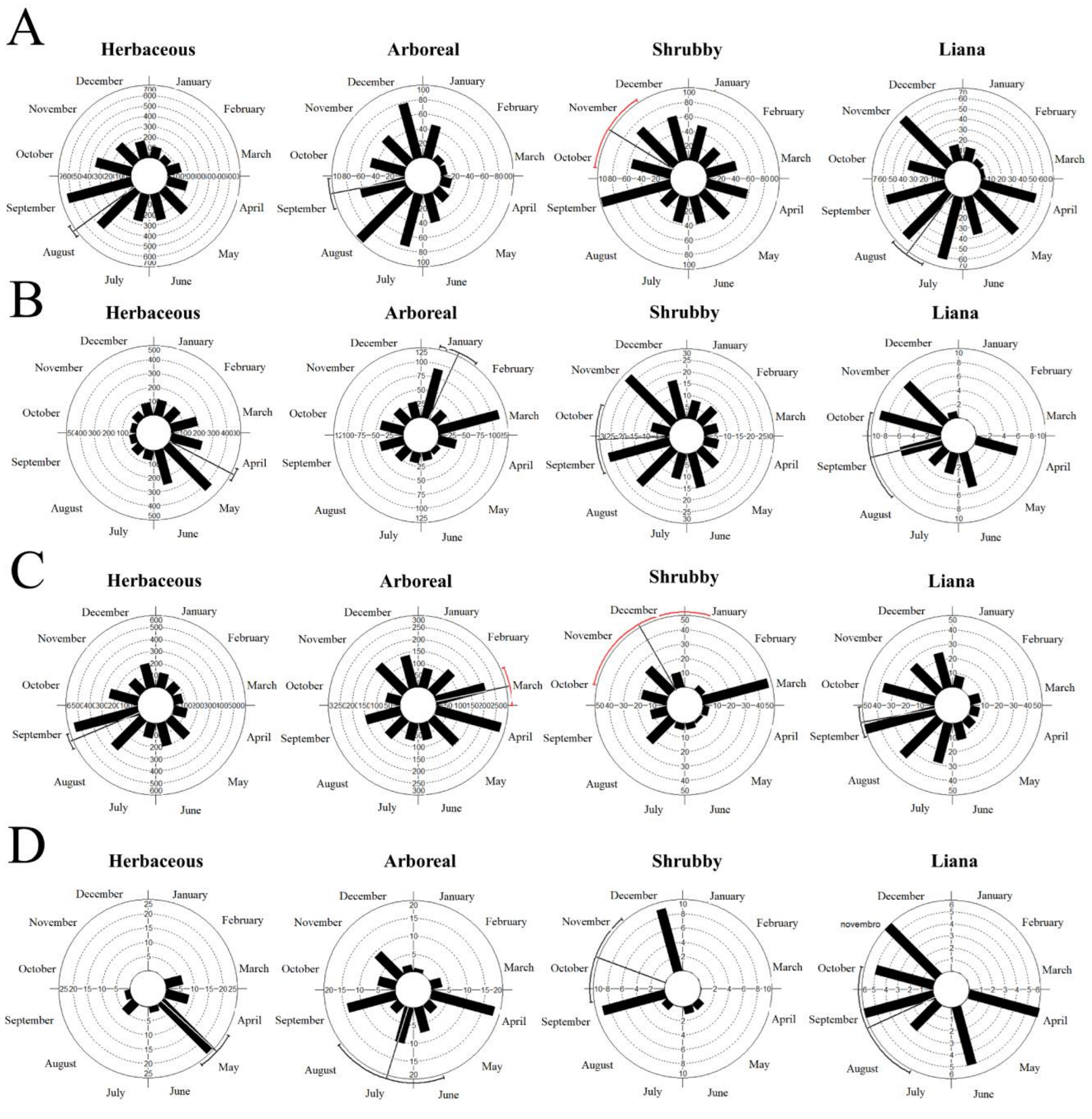


Fig. 4. Circular histogram representing the distribution of floral resources available to bees in the vertical stratification between August 2018 and July 2019 on the campus of Dom Delgado and surroundings, São Luís - MA, Brazil. (A) Pollen. (B) Nectar. (C) Nectar and Pollen. (D) Floral oil. The line at the top of the vector indicates the standard deviation.

TABLE 1: Rayleigh test of uniformity (Z) for circular distribution of floral resources available to bees in vertical climatic stratification between August 2018 and July 2019 on the campus of Dom Delgado and surroundings, São Luís - MA, Brazil.

	Nectar			
Test	**Herbaceous**	**Arboreal**	**Shrubby**	**Liana**
Number of Observa-tions	3212	544	609	463
Average date	August	September	November	August
Concentration (r)	0,354	0,35	0,129	0,317
Rayleigh Test (Z)	401,603	66,656	10,085	46,672
Rayleigh Test (p)	p<0,0001	p<0,0001	p<0,0001	p<0,0001
	Pollen			
	Herbaceous	**Arboreal**	**Shrubby**	**Liana**
Number of Observa-tions	1702	474	166	41
Average date	April	January	September	September
Concentration (r)	0,438	0,28	0,273	0,412
Rayleigh Test (Z)	325,941	37,259	12,345	6,959
Rayleigh Test (p)	p<0,0001	p<0,0001	p<0,0001	p=0,0007
	Nectar and Pollen			
	Herbaceous	**Arboreal**	**Shrubby**	**Liana**
Number of Observa-tions	2409	1585	151	242
Average date	September	March	December	September
Concentration (r)	0,32	0,166	0,137	0,505
Rayleigh Test (Z)	246,928	43,687	2,82	61,807
Rayleigh Test (p)	p<0,0001	p<0,0001	0,06	p<0,0001
	Oil			
	Herbaceous	**Arboreal**	**Shrubby**	**Liana**
Number of Observa-tions	47	75	21	31
Average date	May	July	October	September
Concentration (r)	0,747	0,249	0,553	0,355
Rayleigh Test (Z)	26,199	4,64	6,418	3,909
Rayleigh Test (p)	p<0,0001	p=0,01	p=0,001	p=0,019

TABLE 2: Pearson correlation between the number of individuals that provided floral resources and the climatic factors between August 2018 and July 2019 on the campus of Dom Delgado and surroundings, São Luís - MA, Brazil.. *p<0,05.

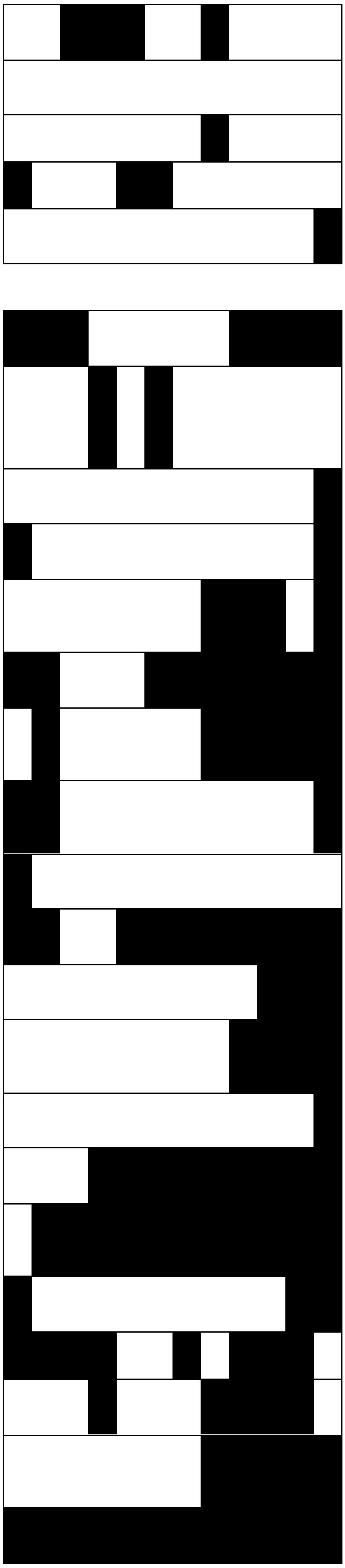
	Nectar		**Pollen**		**Nectar and Pollen**		**Oil**	
	P	**R**	***p***	**R**	***p***	**R**	***p***	**R**
Temperature	0,423	0.25	0,139	-0.45	0.986	0.0053	0,464	-0.23
Humidity	0,033*	-0.61	0,008*	0.72	0,255	-0.36	0,681	0.13
Rainfall	0,046*	-0.58	0,0191*	0.66	0,560	-0.19	0,585	0.17

Supplementary Material: Temporal distribution of floral resources used by bees in an urban environment in northeastern Brazil

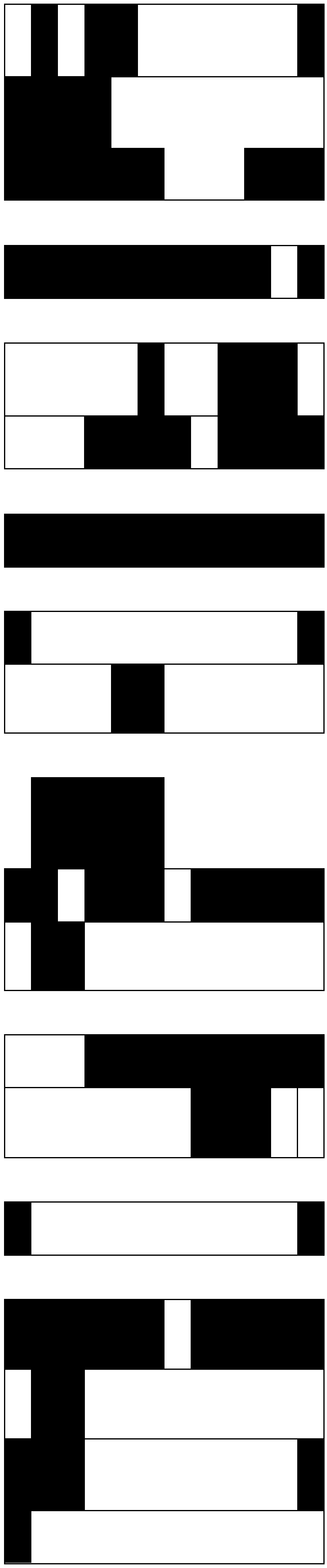
TABLE S1 - Floristic composition and phenogram of flowering plants between August 2018 and July 2019 at the Federal University of Maranhão and surroundings, located in the municipality of São Luís- MA, Brazil. Ne = nectar; Po = pollen; Ol = oil. * information about bee visits to flowers, regarding field observations. ** classification of predominant pollination system based on gender. *** classification followed Faegri and Pijl (1979).

Family	Species	Habit	Resource	Flower color	Origin	Pollination	REF	ago	sept	oct	nov	dec	jan	feb	mar	apr	may	jun	jul
Acanthaceae																			
	Avicennia germinans (L.) L.	Arboreal	Ne	white	native	bee | fly	1, 2	■	■	■	■	■	■						■
	Justicia calycina (Nees) V.A.W.Graham	Herbaceous	Ne	red	native	bird	**	■	■	■	■	■	■	■	■	■	■	■	■
	Ruellia paniculata L.	Herbaceous	Ne	lilac	native	bee | bird	3	■	■	■	■	■					■	■	■
Aizoaceae																			
	Sesuvium portulacastrum (L.) L.	Herbaceous	Ne	pink	native	bee | butterfly	4		■	■	■	■			■	■			
Alismataceae																			
	Limnocharis flava (L.) Buchenau	Herbaceous	Po	yellow	native	bee	5					■	■				■		
Amaranthaceae																			
	Alternanthera brasiliana (L.) Kuntze	Herbaceous	Ne	yellow	native	bee	6	■	■	■	■						■	■	■
	Alternanthera tenella Colla	Herbaceous	Ne	yellow	native	bee	7	■	■	■	■		■		■	■	■	■	■
	*Blutaparon vermicular*e (L.) Mears	Herbaceous	Ne	yellow	native	bee	*				■	■		■				■	■
Anacardiaceae																			
	Anacardium occidentale L.	Arboreal	Ne	pink | cream	native	bee	6, 8	■		■	■	■				■	■	■	■
	Mangifera indica L.	Arboreal	Ne+Po	cream	cultivated	bee	9	■	■		■	■							■
	Spondias mombin L.	Arboreal	Ne+Po	cream	native	bee	**				■								
Apocynaceae																			
	Allamanda cathartica L.	Shrubby	Ne	yellow	native	bee | butterfly	3	■	■	■	■	■	■	■	■	■	■	■	■
	Mandevilla hirsuta (Rich) K. Schum	Liana	Ne	yellow	native	bee | butterfly | birds	10, 11, 12, 13	■			■	■				■	■	■	
	Mandevilla scabra K. Schum.	Liana	Ne	yellow	native	bee | butterfly | birds	**	■	■										
	Nerium oleander L.	Arboreal	Ne	pink	cultivated	bee	3	■	■	■	■	■	■	■		■	■	■	■
	Prestonia coalita (Vell.) Woodson	Liana	Ne	yellow	native	bee | butterfly	14	■											■

Arecaceae						
Adonidia merrillii (Becc.) Becc.	Arboreal	Po	cream	cultivated	bee	***
Astrocaryum vulgare Mart.	Arboreal	Po	cream	native	beetle	15
Attalea speciosa Mart.	Arboreal	Po	cream	native	beetle	16
Cocos nucifera L.	Arboreal	Po	cream	naturalized	bee	3
Syagrus cocoides Mart.	Arboreal	Ne	cream	native	bee | beetle	**
Asteraceae						
Centratherum punctatum Cass.	herbaceous	Ne	purple	native	bee	3
Chromolaena maximiliani (Schrad. ex DC.) R.M.King & H.Rob.	Shrubby	Ne	lilac	native	butterfly	*
Eclipta prostrata (L.) L.	herbaceous	Ne+Po	white	native	bee	3
Elephantopus mollis Kunth	herbaceous	Ne+Po	white	native	bee	6
Eleutheranthera ruderalis (Sw.) Sch.Bip.	herbaceous	Ne	yellow	naturalized	-	-
Emilia fosbergii Nicolson	herbaceous	Ne+Po	red	native	bee | butterfly	3
Emilia sonchifolia (L.) DC	herbaceous	Ne+Po	lilac	native	butterfly	6, 17
Lepidaploa remotiflora (Rich.) H.Rob.	herbaceous	Ne	lilac	native	bee	18
Mikania cordifolia (L.f.) Willd.	liana	Ne+Po	cream	native	bee	6
Praxelis diffusa (Rich.) Pruski	herbaceous	Ne+Po	lilac	native	bee | butterfly	3, 19
Pectis brevipedunculata Sch.Bip.	herbaceous	Ne+Po	yellow	native	bee	*
Porophyllum ruderale (Jacq.) Cass.	herbaceous	Ne	cream	native	bee	3, 18
Rolandra fruticosa Kuntze	herbaceous	Ne	white	native	bee	18
Solidago chilensis Meyen	herbaceous	Ne	yellow	native	bee	20
Sphagneticola trilobata (L.) Pruski	herbaceous	Ne+Po	yellow	native	bee	6, 21
Synedrella nodiflora (L.) Gaertn.	herbaceous	Ne+Po	yellow	native	bee	3
Tagetes erecta L.	herbaceous	Ne	yellow	naturalized	bee	22
Tilesia baccata (L.) Pruski	Shrubby	Ne	yellow	naturalized	bee	23
Tithonia diversifolia (Hemsl.) A. Gray	Shrubby	Ne+Po	yellow	naturalized	bee	6, 24
Tridax procumbens L.	herbaceous	Ne+Po	yellow	native	bee	6
Bignoniaceae						

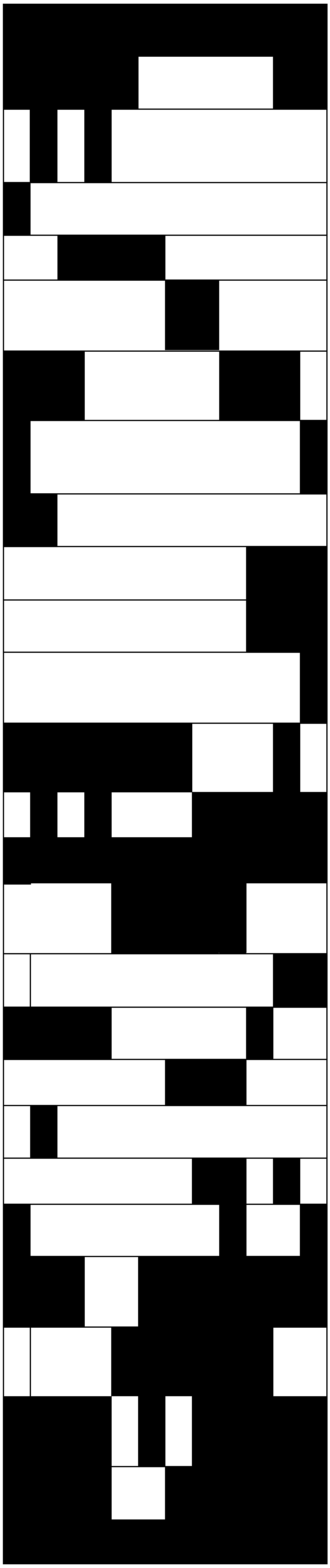


Handroanthus impetiginosus (Mart. ex DC.) Mattos	Arboreal	Ne	pink	native	bee	**
Tabebuia aurea Benth. & Hook.f. ex S.Moore	Arboreal	Ne	yellow	native	bee	25
Bignonia aequinoctialis L.	liana	Ne	pink	native	bee	**
Bixaceae						
Bixa orellana L.	Shrubby	Po	light pink	native	bee	6, 26, 27
Boraginaceae						
Euploca polyphylla (Lehm.) J.I.M.Melo & Semir	herbaceous	Ne	white	native	bee	3
Varronia globosa Jacq.	Shrubby	Ne	white	native	bee | butterfly	3
Caricaceae						
Carica papaya L.	Arboreal	Ne	white	naturalized	bee | moth	6
Chrysobalanaceae						
Hirtella racemosa Lam.	Shrubby	Ne	lilac	native	butterfly	**28
Licania tomentosa Fritsch	Arboreal	Ne+Po	white	native	bee	6
Combretaceae						
Laguncularia racemosa C.F.Gaertn.	Arboreal	Ne+Po	white	native	bee | fly | butterfly | wasp	22, 29
Terminalia catappa L.	Arboreal	Ne+Po	cream	naturalized	bee	6
Terminalia lucida Hoffmanns. ex Mart.	Arboreal	Ne	cream	native	bee	**
Commelinaceae						
Commelina erecta L.	herbaceous	Po	blue	native	bee	6, 30, 31
Tradescantia pallida (Rose) D.R. Hunt	herbaceous	Ne+Po	purple	cultivated	bee	6, 31
Connaraceae						
Rourea induta Planch.	Shrubby	Ne+Po	white	native	bee	32
Convolvulaceae						
Ipomoea asarifolia Roem. & Schult.	herbaceous	Ne+Po	purple	native	bee	6, 33
Ipomoea bahiensis Willd.	herbaceous	Ne+Po	lilac	native	bee	3
Ipomoea hederifolia L.	liana	Ne+Po	red	native	bee | butterfly | birds	3
Ipomoea maurandioides Meisn.	liana	Ne+Po	purple	native	bee	**



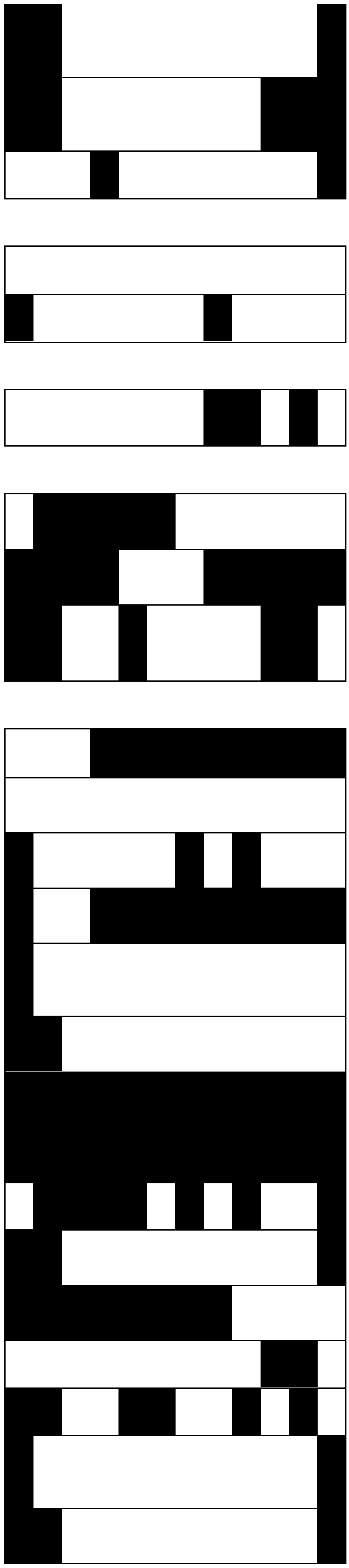
Merremia aegyptia (L.) Urb.	liana	Ne+Po	white	native	bee	3
Merremia umbellata (L.) Hallier f.	liana	Ne+Po	yellow	native	bee	3
Cucurbitaceae						
Luffa cylindrica M.Roem.	liana	Ne+Po	yellow	cultivated	bee	3
Momordica charantia L.	liana	Po | Ol	yellow	naturalized	bee	3
Cyperaceae						
Bulbostylis capillaris (L.) Kunth ex C.B.Clarke	herbaceous	Po	brown		wind	***
Cyperus sp.	herbaceous	Po	gree-nish	native	wind	***
Rhynchospora nervosa Boeckeler	herbaceous	Po	cream	native	wind	***
Scleria bracteata Cav.	herbaceous	Po	gree-nish		wind	***
Euphorbiaceae						
Cnidoscolus urens (L.) Arthur	herbaceous	Ne	white	native	bee | butterfly | birds	31, 34
Dalechampia pernambucensis Baill.	liana	Ne	yellow	native	bee	**
Euphorbia heterophylla L.	herbaceous	Ne	white	native	bee	3
Euphorbia hirta L.	herbaceous	Ne	gree-nish	native	bee	3
Euphorbia hyssopifolia L.	herbaceous	Ne	white	native	bee	3
Jatropha gossypiifolia L.	Shrubby	Ne+Po	red	native	bee | birds	3
Jatropha multifida L.	Shrubby	Ne	red	cultivated	bee | fly	35
Ricinus communis L.	Shrubby	Po	red	naturalized	bee | wind	3, 36
Fabaceae						
Acacia mangium Willd.	Arboreal	Ne+Po	yellow	naturalized	bee	37
Adenanthera pavonina L.	Arboreal	Ne	yellow	naturalized	bee	3
Albizia lebbeck (L.) Benth.	Arboreal	Ne+Po	yellow	naturalized	bee	3, 22
Andira surinamensis (Bondt) Splitg in Pulle	Arboreal	Ne	purple	native	bee	**
Ancistrotropis peduncularis (Fawc. & Rendle) A. Delgado	liana	Ne	pink	native	bee	38
Arachis pintoi Krapov. & W.C.Greg.	liana	Ne	yellow	native	bee	**
Bauhinia monandra Kurz	Arboreal	Ne+Po	white | red	exotic	bee	3
Dioclea violacea Mart. ex Benth.	liana	Ne	lilac	native	bee	**

Caesalpinia pulcherrima (L.) Sw.	Arboreal	Ne	orange	naturalized	birds	6
Calliandra brevipes Benth.	Shrubby	Po	pink	native	bee	6, 39
Calopogonium caeruleum (Benth.) C.Wright	liana	Ne	lilac	native	bee	**
Calopogonium mucunoides Desv.	herbaceous	Ne	lilac	native	bee	3
Cassia fistula L.	Arboreal	Po	yellow	cultivated	bee	6, 9
Centrolobium tomentosum Guill. ex Benth.	Arboreal	Ne	yellow	native	bee	6, 40
Centrosema brasilianum (L.) Benth.	liana	Ne	purple	native	bee	3
Centrosema plumieri (Turpin ex Pers.) Benth.	liana	Ne	white	native	bee	**
Centrosema pubescens Benth	liana	Ne	lilac	native	bee	3
Chamaecrista diphylla (L.) Greene	herbaceous	Po	yellow	native	bee	41
Chamaecrista flexuosa (L.) Greene	herbaceous	Po	yellow	native	bee	**
Chamaecrista nictitans (L.) Moench	herbaceous	Ne	yellow	native	bee	3
Clitoria fairchildiana R.A.Howard	Arboreal	Ne	purple	native	bee	3
Crotalaria pallida Aiton	herbaceous	Ne	yellow	naturalized	bee	6
Crotalaria retusa L.	herbaceous	Ne	yellow	naturalized	bee	3
Delonix regia (Bojer) Raf.	Arboreal	Ne+Po	red	cultivated	birds	6
Desmodium barbatum (L.) Benth	herbaceous	Ne	pink	native	bee	**
Desmodium incanum (G.Mey) DC.	herbaceous	Ne	lilac	native	bee	3
Dipteryx alata Vogel	Arboreal	Ne	lilac	native	bee	42
Enterolobium timbouva Mart.	Arboreal	Ne+Po	cream	native	bee	*
Indigofera hirsuta L.	herbaceous	Ne	red	native	bee	3
Inga edulis Mart.	Arboreal	Ne+Po	cream	native	bee | birds	43
Leucaena leucocephala (Lam.) de Wit	Arboreal	Ne+Po	white	naturalized	bee	44
Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	Arboreal	Ne	yellow	native	bee	6, 45
Macroptilium atropurpureum (L.) Urb.	herbaceous	Ne	red	native	bee	3
Mimosa caesalpiniifolia Benth.	Arboreal	Ne+Po	white	native	bee	3
Mimosa pudica L.	herbaceous	Po	pink	native	bee	3

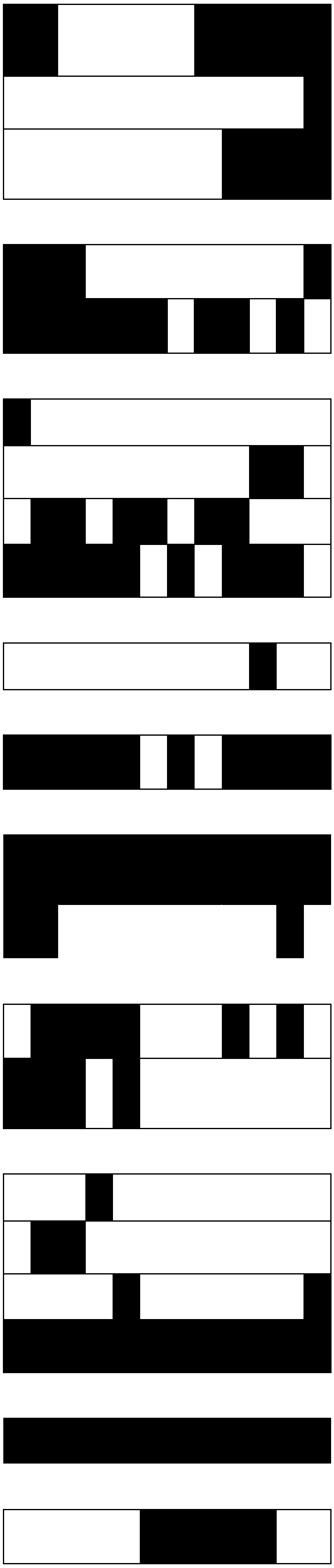


Mimosa sensitiva G. Lodd.	herbaceous	Po	pink	native	bee	3												■
Neptunia plena (L.) Benth.	herbaceous	Ne+Po	yellow	native	bee	3	■	■			■		■	■	■	■	■	
Parkia platycephala Benth.	Arboreal	Ne	red	native	bat	**		■										
Pithecellobium dulce (Roxb.) Benth.	Arboreal	Ne	yellow	native	bee	3	■	■	■	■	■		■				■	
Rhynchosia minima (L.) DC.	liana	Ne	yellow	native	bee	3		■										
Samanea inopinata (Harms) Barneby & J.W.Grimes	Arboreal	Ne	pink	native	bee	46					■	■						
Senna alata (L.) Roxb.	Shrubby	Po	yellow	native	bee	**				■								
Senna fruticosa (Mill.) H.S.Irwin & Barneby	Arboreal	Po	yellow	native	bee	**	■											
Senna georgica H.S.Irwin & Barneby	Shrubby	Po	yellow	native	bee	**		■									■	
Senna obtusifolia (L) H.S Irwin & Barneby	herbaceous	Po	yellow	native	bee	3	■											■
Senna pendula (Humb.& Bonpl.ex Willd.) H.S.Irwin & Barneby	liana	Po	yellow	native	bee	**			■	■	■							■
Senna siamea (Lam) H. S. Irwin & Barneby	Arboreal	Po	yellow	naturalized	bee	3	■	■	■	■	■	■	■	■	■	■	■	■
Senna silvestris (Vell.) H.S.Irwin & Barneby	Arboreal	Po	yellow	native	bee	3		■	■		■	■		■	■			
Tamarindus indica L.	Arboreal	Ne	white	cultivated	bee	3					■	■		■				
Zornia reticulata Sm.	herbaceous	Ne	yellow	native	bee	**								■	■			■
Gentianaceae																		
Coutoubea spicata Aubl.	herbaceous	Po	white	native	bee	47										■	■	■
Heliconiaceae																		
Heliconia acuminata A. Rich.	herbaceous	Ne	orange	native	birds	**21	■	■										
Hydroleaceae																		
Hydrolea spinosa L.	herbaceous	Po	purple	native	bee	48, 49	■	■		■								
Hypericaceae																		
Vismia guianensis (Aubl.) Choisy	Shrubby	Ne+Po	yellow	native	bee	3	■	■	■	■	■			■				
Iridaceae																		
Cipura paludosa Aubl.	herbaceous	Po | Ol	blue	native	bee	3, 16	■	■						■	■	■	■	
Lamiaceae																		
Gmelina arborea Roxb.	Arboreal	Ne	yellow	cultivated	bee | birds	35	■	■			■	■					■	■
Hyptis atrorubens Poit.	herbaceous	Ne+Po	white	native	bee	3										■	■	

Marsypianthes chamaedrys (Vahl) Kuntze	herbaceous	Ne+Po	lilac	native	bee	3
Mesosphaerum suaveolens (L.) Kuntze.	herbaceous	Ne	lilac	native	bee	3
Ocimum basilicum L.	herbaceous	Ne	white	native	bee	**6
Lythraceae						
Cuphea sp.	herbaceous	Ne	purple	native	bee	**6
Punica granatum L.	Shrubby	Po	orange	cultivated	bee	50
Loganiaceae						
Spigelia anthelmia L.	herbaceous	Ne+Po	lilac	native	bee	3
Malpighiaceae						
Malpighia glabra L.	Arboreal	Po | Ol	pink	cultivated	bee	6
Byrsonima crassifolia (L.) Kunth	Arboreal	Po | Ol	yellow	native	bee	3
Niedenzuella multiglandulosa (A.Juss.) W.R.Anderson	Shrubby	Po | Ol	yellow	native	bee	**
Malvaceae						
Apeiba tibourbou Aubl.	Arboreal	Po	yellow	native	bee	6, 51
Ceiba pentandra (L.) Gaertn.	Arboreal	Ne	white	native	bat	52
Gossypium herbaceum L.	Shrubby	Ne+Po	yellow	native	bee	**
Guazuma ulmifolia Lam	Arboreal	Ne+Po	cream	native	bee	6, 53
Hibiscus acetosella Welw. ex Ficalho	Shrubby	Ne+Po	wine	native	bee	**
Malachra fasciata Jacq.	herbaceous	Ne	white	native	bee	*
Melochia parvifolia Kunth	Shrubby	Ne	white	native	bee	**
Melochia pyramidata L.	herbaceous	Ne+Po	purple	native	bee	3
Pachira aquatica Aubl.	Arboreal	Ne	green	native	bat	6
Pavonia cancellata (L.) Cav.	herbaceous	Ne+Po	yellow	native	bee	3
Sida castanocarpa Krapov.	herbaceous	Ne+Po	yellow	native	bee	**
Sida jussiaeana DC.	herbaceous	Po	yellow	native	bee	**
Sida rhombifolia L.	herbaceous	Po	yellow	native	bee	6, 21
Sterculia striata A.St.-Hil. & Naudin	Arboreal	Ne	cream	native	bee	6, 22, 45
Waltheria indica L.	herbaceous	Ne+Po	yellow	native	bee	3
Melastomataceae						

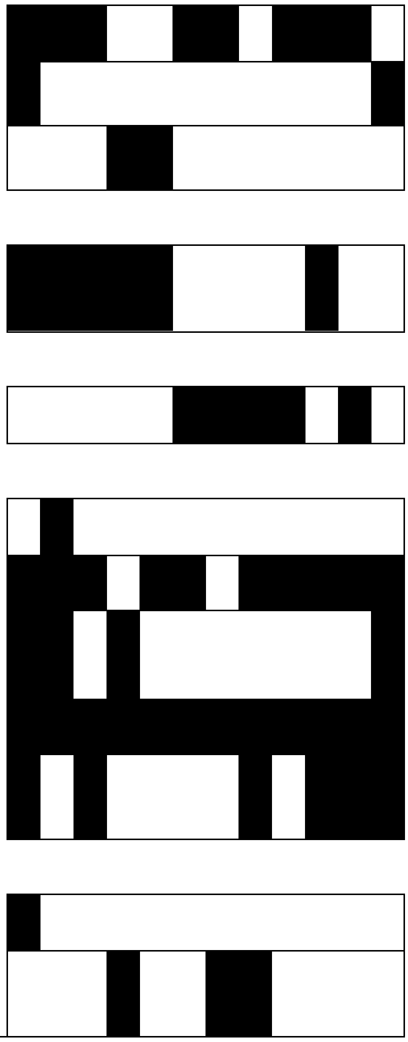


Heterocentron elegans Kuntze	herbaceous	Po	pink	cultivated	bee	*
Miconia cf. albicans (Sw.) Steud.	Shrubby	Po	white	native	bee	**
Pterolepis trichotoma (Rottb.) Cogn.	herbaceous	Po	pink	native	bee	54
Meliaceae						
Azadirachta indica A.Juss.	Arboreal	Ne+Po	white	cultivated	bee	3
Carapa guianensis Aubl.	Arboreal	Ne	cream	native	bee | butterfly	55
Myrtaceae						
Eugenia biflora. DC.	Shrubby	Po	white	native	bee	**
Myrcia cuprea (O.Berg) Kiaersk.	Shrubby	Po	white	native	bee	**
Psidium guajava L.	Arboreal	Po	white	native	bee	3, 56
Syzygium cumini (L.) Skeels	Arboreal	Ne+Po	cream	naturalized	bee	6, 57
Moraceae						
Ficus benjamina L.	Arboreal	Po	orange	naturalized	wasp	**58
Moringaceae						
Moringa oleifera Lam	Arboreal	Ne+Po	white	cultivated	bee	3
Nyctaginaceae						
Bougainvillea spectabilis Willd.	Shrubby	Ne	pink	native	butterfly	6
Boerhavia coccinea Mill.	herbaceous	Ne+Po	pink	naturalized	bee | fly	3
Onagraceae						
Ludwigia erecta (L.) H.Hara	herbaceous	Ne+Po	yellow	native	bee	*
Ludwigia octovalvis (Jacq.) P.H.Raven	liana	Ne+Po	yellow	native	bee	3
Passifloraceae						
Passiflora foetida L.	liana	Ne	white	native	bee	**
Passiflora glandulosa Cav.	liana	Ne	red	native	bird	*
Passiflora laurifolia L.	liana	Ne	purple	native	bee	**
Turnera subulata Sm.	herbaceous	Ne+Po	yellow	nativa	bee	3
Phytolaccaceae						
Petiveria alliacea L.	Shrubby	Ne	white	naturalized	bee	59
Piperaceae						
Peperomia pellucida (L.) Kunth.	herbaceous	Po	greenish	native	wind	**18



Piper tuberculatum Jacq.	Shrubby	Po	white	native	wind | fly	3	
Plantaginaceae							
Scoparia dulcis L.	Herbaceous	Po	white	native	bee	3	
Poaceae							
Cenchrus echinatus L.	Herbaceous	Po	gree-nish	native	wind	**	
Eragrostis ciliaris (L.) R.Br.in Tuckey	Herbaceous	Po	white	naturalized	wind	**	
Eragrostis tenella (L.) P.Beauv.	Herbaceous	Po	white	naturalized	wind	**	
Paspalum ligulare Nees	Herbaceous	Po	-	native	wind	**	
Paspalum maritimum Trin.	Herbaceous	Po	-	native	wind	**	
Polygalaceae							
Asemeia ovata (Poir.) J.F.B.Pastore & J.R.Abbott	Herbaceous	Ne	purple	native	bee	**	
Securidaca diversifolia (L.) S.F.Blake	Liana	Ne	purple	native	bee	***	
Rhizophoraceae							
Rhizophora mangle L.	Arboreal	Po	white	native	wind | bee | fly	2, 60, 61	
Rubiaceae							
Borreria latifolia (Aubl.) K.Schum.	Herbaceous	Ne	white	native	bee	3	
Borreria verticillata G.Mey.	Herbaceous	Ne	white	native	bee | butterfly	3, 62	
Ixora coccinea L.	Shrubby	Ne	red	cultivated	butterfly	6	
Guettardaangelica Mart.	Shrubby	Ne	white	native	butterfly | moth	**3	
Mitracarpus strigosus P.L.R. Moraes, De Smedt & Hjertson	Herbaceous	Ne+Po	white	native	bee | butterfly	3	
Morinda citrifolia L.	Arboreal	Ne	white	cultivated	butterfly	3	
Richardia grandiflora (Cham. & Schltdl.) Steud.	Herbaceous	Ne+Po	white	native	bee	3, 63	
Salicaceae							
Casearia grandiflora Cambess.	Shrubby	Ne+Po	cream	native	bee | fly	**	
Sapindaceae							
Talisia esculenta Radlk.	Arboreal	Ne+Po	cream	native	bee	3	
Scrophulariaceae							
Capraria biflora L.	Herbaceous	Ne	white	native	butterfly	64	

Solanaceae						
Solanum crinitum Lam.	Shrubby	Po	purple	native	bee	**6
Solanum jamaicense Mill.	Shrubby	Po	white	native	bee	**6
Solanum subinerme Jacq.	Shrubby	Po	purple	native	bee	**6
Talinaceae						
Talinum paniculatum (Jacq.) Gaertn.	Herbaceous	Ne+Po	pink	native	bee	6
Urticaceae						
Cecropia sp.	Arboreal	Po	cream	native	wind	**6
Verbenaceae						
Duranta erecta L.	Shrubby	Ne	lilac	naturalized	butterfly	6, 57
Lantana camara L.	Shrubby	Ne	orange	native	butterfly	6, 17
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Herbaceous	Ne+Po	pink	native	bee	3
Priva bahiensis DC.	Herbaceous	Ne	white	native	bee	3
Stachytarpheta cayennensis (Rich) Vahl	Herbaceous	Ne	lilac	native	butterfly	65
Vitaceae						
Cissus erosa Rich.	Liana	Ne	red	native	bee	18
Cissus verticillata (L). Nicolson & C.E Javis	Liana	Ne	yellow	native	bee	62



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