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Bee Flora and Use of Resources by Africanized Bees

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Abstract

Beekeeping is affected by adverse climatic conditions and availability of floral resources. This study aimed to survey and characterize the flora in São João do Piauí, a semi-arid region in Piauí, Brazil, and to identify species providing resources to bees. Flowering plants were observed for 18 months, and records were taken of flowering date, growth habit, visitation and resources collected by bees. Melissopalinological analysis of honey produced in the area was performed. A total of 67 flowering plant species were recorded, of which 49 were considered as bee plants, with a predominance of herbs and shrubs. The low rainfall reduces the number of flowering species, which makes important the conservation and multiplication of species which bloom in dry season, such as *Ipomoea glabra*, *Myracrodruon urundeuva*, *Sida cordifolia* and *Ziziphus joazeiro*, as well as species that contribute to honey production such as *Mimosa tenuiflora*, *Mesosphaerum suaveolens* and *Croton sonderianus*.

Keywords: nectar, pollen, floral resources.

1. INTRODUCTION AND OBJECTIVES

The Northeast region of Brazil has been highlighted for its great potential in beekeeping activity, with the state of Piauí as one of the largest honey producers in the country (IBGE, 2018). However, beekeeping, as well as other agricultural activities, can suffer significant losses due to the climatic conditions of the region, especially the large spatial and temporal variability of rainfall (Marengo, 2008; Silva et al., 2011).

Although flowering occurs abundantly during the rainy season in caatinga regions, flowering species significantly reduce in number in the dry season, thus reducing the natural supply of available food to bees (Rodarte et al., 2008; Silva et al., 2008; Silva Filho et al., 2010). This situation worsens when the drought season is prolonged in the region in years considered very dry, as that which occurred in 2012 when the amount of rainfall was irregular, poorly distributed and below the historical average of the Northeast (Santos et al., 2012). As a result, several beekeepers lost their colonies, which migrated in search of food sources in other areas. The decrease of honey production in states such as Pernambuco and Piauí reached 70% compared to the previous year (Vidal, 2014).

Beekeepers need to provide supplementary food, water of good quality and adequate shading to the colonies to avoid or minimize losses during the drought period (Pereira et al., 2011; Pereira et al., 2014). Part of these needs can be met by plant species that bloom in dry season and provide a good level of shading; thus, preserving and planting these species in areas explored by bees is recommended (Lopes et al., 2011; Santos et al., 2017). In this context, studies of local bee flora diversity are important because they make it possible to identify the species that constitute the region's beekeeping pasture and to recognize those that contribute to the food supply for bees during the off-season.

Thus, this study aimed to: a) identify the flora exploited by bees in the municipality of São João do Piauí, in the semi-arid

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region of Piauí state; b) characterize the species regarding their growth habit, the resources offered to the bees, and the flowering period; and c) identify the species that contribute to producing honey in the region and to maintaining the swarms during dry seasons.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted at Monte Orebe Experimental Farm, located in São João do Piauí (08° 21' 29" S and 42° 14' 48" W) in Southern Piauí, approximately 460 km from the capital city of Teresina. Semi-arid is the predominant climate of the region, with caatinga shrub vegetation and trees with varying densities. The semi-arid climate is characterized by the presence of high temperatures and irregular rainfall, with average annual temperatures between 26 °C and 28 °C, predominating long dry periods (Andrade Jr et al., 2004). According to INMET ([2015?]), the average total rainfall in the municipality from 2004 to 2013 was 625 mm, with the highest concentration in four months (Figure 1).

An average temperature of 28.8 °C, with a minimum of 22.9 °C and a maximum of 35.7 °C, an average air humidity of 51.5% with a minimum of 24.8% and a maximum of 53.3% were recorded during the study period by a meteorological station installed on the experimental farm. The cumulative rainfall was 254 mm and 702 mm in 2012 and 2013, respectively.

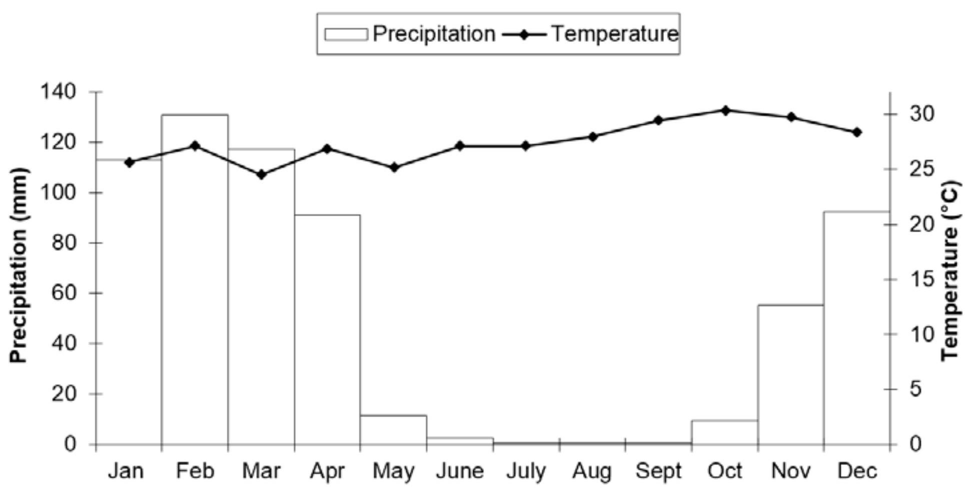

Figure 1. Precipitation and temperature data for São João do Piauí, PI, Brazil, ten-year period average (2004-2013).
Source: INMET, 2015.

2.2. Survey of beekeeping flora

Direct collections and observations of flowering plant species were performed in the area for 18 months (April 2012 to September 2013). Collections were performed monthly from April 2012 to January 2013, as little material was available to collect in the very dry vegetation. Biweekly collections were performed when there was a higher volume of precipitation in the subsequent period and consequently a greater number of flowering plants (February to September 2013). The trail on which the botanical species were collected was approximately 2,500 m long and 5 m wide and surrounded the experimental apiary. The trail was coursed in the morning and afternoon the same day or in two days to observe the times when resources were offered to bees by plant species.

All species that presented reproductive material were collected by the Preferred Collection Method (PCM), according to Castro (1994), considering a number of five samples per species. We observed and took notes on the species that were in bloom, the ones that were visited by bees, and the bees' behavior in the collection of floristic resources.

The collected plant species were characterized as to the growth forms in herbaceous, shrub, sub-shrub, liana and tree.

Identification of botanical species was performed by comparing with similar and previously identified materials, and by consulting the appropriate literature and experts. The identified materials were deposited at the Embrapa Mid-North Herbarium. The botanical classification system from the Angiosperm Philogeny Group (APG III, 2009) was adopted.

2.3. Preparation of the pollen slides

The collected flower samples were stored in 70% alcohol Eppendorf tubes and then placed in a refrigerator. Pollen grains were removed from the inflorescences in the laboratory to prepare slides, following the methodology proposed by Barth (1970a; 1970b; 1970c; 1970d), with some adaptations.

2.4. Melissopalinological analysis

In order to compare the pollen present in honey with the pollen of the inventoried botanical species, a sample of 50 mL centrifuged honey produced in beehives of the evaluated area was collected in May 2013, period in which honey is harvested at the experimental farm.

The slides were prepared following the methodology proposed by Barth (1989). The pollen types were qualitatively analyzed by comparing the pollen slides of the botanical species collected in the studied area and with the help of specialized literature. Quantitative analysis was performed by counting 300 pollen grains per sample, determining the occurrence classes, which according to Louveaux et al. (1978) are: dominant pollen (DP, > 45% of total grains), accessory pollen (AP, 16% to 45%), important isolated pollen (IIP, 3% to 15%) and occasional isolated pollen (OIP, < 3%).

3. RESULTS AND DISCUSSION

A total of 67 flowering species were identified, of which 49 provide some type of resource (nectar, pollen or resin) for bees (Table 1). Fabaceae, Malvaceae, and Euphorbiaceae botanical families presented the largest number of representatives visited by the bees. These families also stood out with a significant number of melitophilous species in other surveys conducted in the Northeast (Chaves et al., 2007; Lopes et al., 2016; Lorenzon et al., 2003; Rodarte et al., 2008; Santos et al., 2006; Silva et al., 2014a). The area was predominantly herbaceous (26), followed by shrubs (13), lianas (11), subshrubs (10) and tree species (7) (Table 1).

The herbaceous and shrub species bloom most intensely in the rainy and early dry seasons, respectively (Figure 2). Herbaceous plants as apicultural plants are important in the rainy months mainly due to the considerable number of species that provide pollen and nectar during this period and to the presence of flowers closer to the hives (Rodarte et al., 2008). However, the contribution of the herbaceous stratum in the bee pasture is often restricted to the rainy season in regions of high seasonality such as caatinga (Araújo et al., 2005, Reis et al.; 2006). A greater number of flowering herbaceous species were observed in the months of March and April 2013 (the end of the rainy season) in this study.

Table 1. Growth form, blooming period, visitation and resources collected by bees of flowering species in São João do Piauí, Piauí, Brazil, from April 2012 to September 2013.

Family/Species	Growth form	Flowering season	Visitation by bees	Collected resource*
Amaranthaceae				
Alternanthera philoxeroides (Mart.) Griseb.	Herb	Apr, May	Y	N[1]
Alternanthera tenella Colla	Herb	Feb, May	-	N[2]
Anacardiaceae				
Myracrodruon urundeuva Allemão	Tree	May, June, July	Y	P/N [1,2,4,5,6,7]
Spondias tuberosa Arruda	Tree	Jan	-	N[2,6]
Apocynaceae				
Calotropis procera (Aiton) W. T. Aiton	Shr	Jan, Feb, Mar, Apr, June, July, Aug, Sept, Oct, Nov	Y	P/N[1]
Bignoniaceae				
Clytostoma campanulatum Bureau & K. Schum.	Lia	Apr	-	N[8]
Cuspidaria sp.	Shr	Dec	-	N[8]
Fridericia dichotoma (Jacq.) L.G. Lohmann	Lia	Apr, May, June	-	P/N[3]
Neojobertia candolleana (Mart. ex DC.) Bureau & K. Schum.	Lia	Apr	-	N[5]
Bombacaceae				
Pachira aquatica Aubl.	Tree	June, July	-	
Boraginaceae				
Heliotropium indicum L.	Herb	May, June, July, Aug, Sept, Oct	-	**[11]
Euploca procumbens (Mill) Diane & Hilger	Herb	Mar	-	
Burseraceae				
Commiphora leptophloeos (Mart.) J. B. Gillett	Tree	Jan	-	P/N[2,6,7]
Combretaceae			-	
Combretum leprosum Mart.	Shr	Mar, Apr	Y	P/N[1,2,3,6,7]

Table 1. Continued...

Family/Species	Growth form	Flowering season	Visitation by bees	Collected resource*
Commelinaceae				
Commelina obliqua Vahl.	Herb	Apr	-	
Convolvulaceae			-	
Evolvulus brevifolius (Meisn.) Ooststr.	Lia	Dec	-	
Evolvulus sp.	Lia	Mar, Apr	-	
Ipomoea asarifolia (Desr.) Roem. & Schult.	Lia	Apr, May, June, July, Aug, Sept	-	P[3,7]
Ipomoea bahiensis Willd. Ex. Roem. & Schult.	Lia	Apr	-	N[4,5,7]
Ipomoea glabra (Aubl.) Choisy	Lia	May, June, July, Aug, Sept	Y	N[1]
Ipomoea wrightii A. Gray	Lia	Feb	-	
Jacquemontia sphaerostigma (Cav.) Rusby.	Herb	Mar	-	
Euphorbiaceae				
Croton betaceus Baill.	Sub	Feb, Apr	Y	N[1]
Croton campestris A. St.-Hil.	Shr	Jan, Feb, Mar	-	N[7]
Croton mucronifolius Müll. Arg.	Shr	Mar	Y	N[1]
Croton sonderianus Müll. Arg.	Shr	Jan, Mar	Y	P/N[1,2,4,5,6,7]
Croton zehntneri Pax e K. Hoffm.	Sub	Dec	-	N[10]
Jatropha pohliana Müll. Arg.	Shr	Feb	-	N[7]
Manihot sp.	Sub	Jan	-	
Fabaceae/Caesalpinioideae				
Bauhinia forficata Link	Shr	Apr	-	**[11]
Caesalpinia microphylla Mart. ex G. Don	Shr	Jan, Feb	-	N[4]
Chamaecrista supplex (Mart. Ex Benth.) Britton & Rose ex Britton & Killip.	Herb	Mar, Apr	-	P[2]
Senna lechriosperma H. S. Irwin & Barneby	Sub	Apr	-	**[12]
Senna obtusifolia (L.) S. Irwin & Barneby	Sub	Feb, Apr, May	-	P[2,7]
Poincianella pyramidalis (Tul.) L. P. Queiroz	Tree	Feb, Apr	Y	P[1]
Fabaceae/Faboideae				
Macroptilium lathyroides (L.) Urb.	Herb	Feb, Apr, May	-	
Stylosanthes guianensis (Aubl.) Sw.	Herb	Apr	-	P/N[9]
Fabaceae/Mimosoideae				
Mimosa arenosa (Willd.) Poir.	Shr	Abr	Y	P/N[1,2]
Mimosa quadrivalvis L.	Herb	Mar, Apr	-	P/N[2]
Mimosa sp.	Shr	Apr	-	
Neptunia oleracea Lour.	Sub	Feb, Apr	-	
Mimosa tenuiflora (Willd.) Poir.	Tree	Mar, Apr, July, Aug, Nov	Y	P/N[1,2,3,6]
Schrankia leptocarpa DC.	Herb	Jan	Y	N[1,7]
Hydroleaceae				
Hydrolea spinosa L.	Herb	Aug	-	
Lamiaceae				
Mesosphaerum suaveolens (L.) Kuntze	Herb	Apr	Y	N[1,2,6]
Malpighiaceae				
Banisteriopsis sp.	Shr	Aug, Sept	-	
Banisteriopsis stellaris (Griseb.) B. Gates.	Shr	Apr, July	-	P/N[9]
Stigmaphyllon sp.	Lia	May	-	
Stigmaphyllon tomentosum A. Juss.	Lia	Apr	-	
Malvaceae				
Herissantia crispa (L.) Brizicky	Sub	Apr	Y	N[1,7]
Herissantia tiubae (K. Schum.) Brizicky	Sub	May, June, July	Y	P/N[1,2]
Pavonia cancellata (L.) Cav.	Herb	May, July	-	P/N[2,3,7]
Sida cordifolia L.	Herb	Apr, May, June, July	Y	P/N[1,2,7]
Sida rhombifolia L.	Herb	Mar, Apr, Sept, Oct, Nov	Y	N[1,3]
Sida urens L.	Herb	Feb	-	**[11]
Waltheria indica L.	Sub	May, Jul, Aug, Sept	-	P/N[3,4,9]

Table 1. Continued...

Family/Species	Growth form	Flowering season	Visitation by bees	Collected resource*
Nyctaginaceae				
Boerhavia coccinea Mill.	Herb	Apr	Y	P/N[1,5,7]
Oxalidaceae				
Oxalis corniculata L.	Herb	Apr, May	Y	N[1]
Oxalis divaricata Mart. ex Zucc.	Herb	Mar	-	N[2]
Passifloraceae/Turneroideae				
Piriqueta rosea (Cambess.) Urb.	Herb	Mar	-	
Turnera pumilea L.	Herb	Mar, Apr	Y	P[1]
Turnera ulmifolia L.	Herb	Jan, Feb, Mar, Apr, May, July, Aug, Sept	Y	N[1,4,7]
Polygalaceae				
Polygala paniculata L.	Herb	Apr	-	
Rhamnaceae				
Ziziphus joazeiro Mart.	Tree	Aug, Sept	Y	P/N/R [1,2,4,5,6,7]
Rubiaceae				
Borreria verticillata (L.) G. Mey.	Herb	Apr, May	-	N[2,4,5,6,7]
Diodella teres (Walter) Small	Sub	Mar	-	P/N[2,3,4]
Staelia sp.	Herb	Apr		

Herb: Herbaceous; Tree: Trees; Shr: Shrubs; Sub: Subshrubs; Lia: Lianas; Y: Yes; -: No; N: Nectar; P: Pollen; R: Resin.
* When bee visitation and resource collection were not observed in this study, the information was obtained in the literature.
** Bee visitation reported in the literature, but with no information on collected resources.
[1]Observation of this study; [2]Maia-Silva et al. (2012); [3]Lopes et al. (2016); [4]Santos et al. (2006); [5]Silva et al. (2014b); [6]Santos et al. (2005); [7]Silva et al. (2014a); [8]Scudeller et al. (2008); [9]Andena et al. (2005); [10]Silva et al. (2009); [11]Almeida et al. (2003); [12]Milet-Pinheiro & Schlindwein (2008).

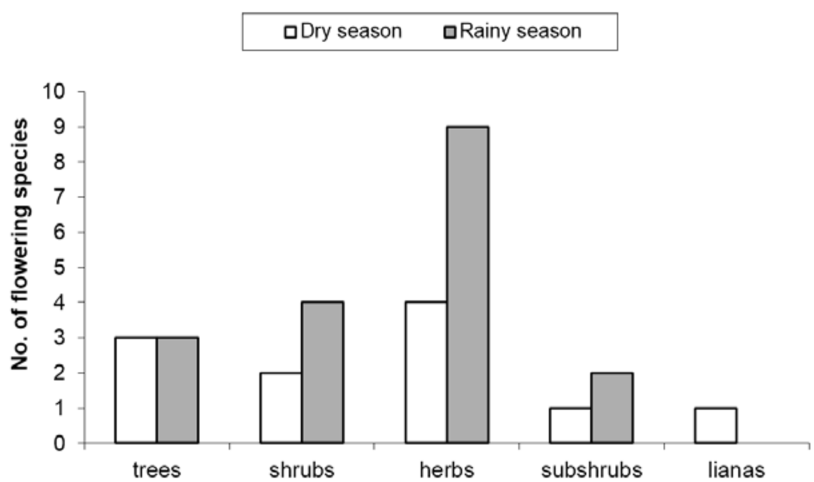

Figure 2. Distribution of plant species collected in São João do Piauí, Piauí, Brazil, in relation to growth form in dry and rainy seasons from April 2012 to September 2013.

This study found that the rainfall regime had great influence on the flora of the region, with the increase in precipitation significantly increasing the number of flowering species (Figure 3). The maximum number of flowering species occurred in April 2013, at the end of the rainy season. Noteworthily, the accumulated rainfall from January to April in this year was 431 mm, almost three times higher than in the same period of 2012 (159 mm). The months with the lowest offer of floral resources were October and November.

A reduction in food supply to bees caused by climate factors contributes to a decrease in beekeeping production, which has been especially observed in periods of severe drought in the Northeast (Alcoforado Filho & Gonçalves, 2000; Vidal, 2014).

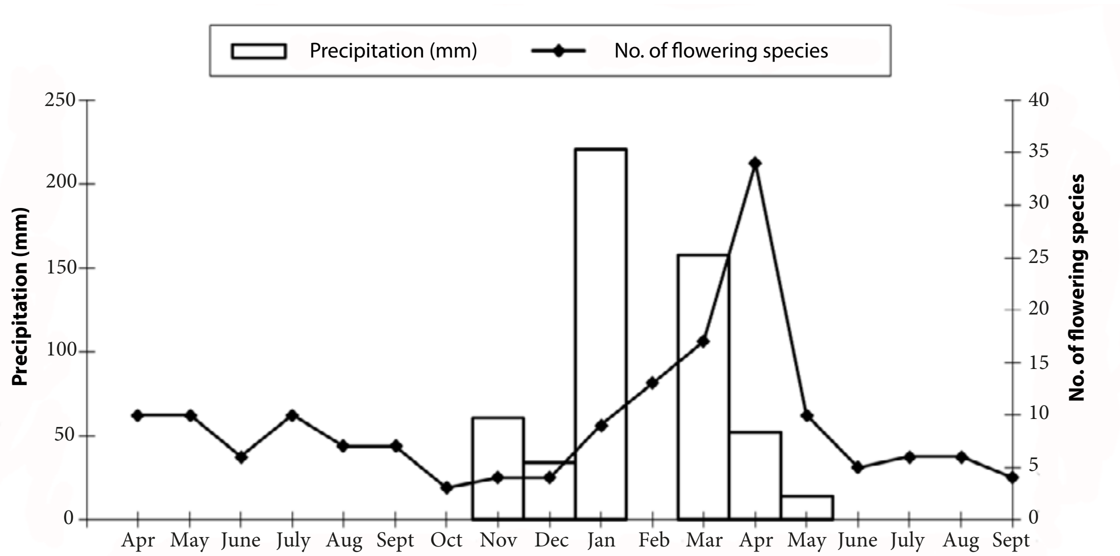

Figure 3. Precipitation and number of plant species in bloom in São João do Piauí, Piauí, Brazil, from April 2012 to September 2013.

In addition to the low rainfall, the high temperatures recorded in the period (average maximum of 35.7 °C) and the low relative humidity (average minimum of 24.8%) may have been limiting factors to bee visitations. This may justify why some species recognized as apicultural plants were not visited by bees in this study (Table 1). According to Crane (1983), climatic factors interfere with nectar secretion, which may influence the collection of this resource by bees. In this context, Malerbo-Souza & Silva (2011) found that relative humidity values below 40% are limiting for nectar collection by *Apis mellifera*.

Regarding the type of resource offered to bees, it became evident that 73% of the sampled species offer some type of food resource (Table 1). According to observed and literature data, 22 species provide nectar, 5 provide pollen, and 17 provide both resources. Resin supply was only observed in *Ziziphus joazeiro* Mart.

Santos et al. (2006) found that 72.5% of the species observed in the caatinga region of Pernambuco only offered nectar, while in a survey conducted in a cerrado area in Piauí, Lopes et al. (2016) found that 88.6% of the sampled species offered both pollen and nectar to bees. These results demonstrate the great variability in the resources available for bees in different locations, which reinforces the importance of studies on flora to evaluate the region's apicultural potential.

Among the species that flowered in the rainy season, *Combretum leprosum*, *Croton sonderianus, Turnera ulmifolia*, *Mimosa tenuiflora, Mimosa arenosa*, *Ipomoea glabra, Mesosphaerum suaveolens* and *Sida cordifolia* are recognized as nectar and pollen sources and are important to produce honey in caatinga regions (Maia-Silva et al., 2012; Santos et al., 2005; Santos et al., 2006).

In the dry season, the species *Myracrodruon urundeuva, Z. joazeiro, I. glabra, M. tenuiflora* and *T. ulmifolia* stand out (Table 1), which are important to maintain the colonies, as their flowering occurs in a period considered critical for bees in the semi-arid region (Alcoforado Filho & Gonçalves, 2000; Pereira et al., 2006). *Commiphora leptophloeos* stands out for its importance for native nesting bee species (Martins et al., 2004). Thus, it is important for the beekeeper to preserve, conserve and promote species multiplication, which contribute to maintain colonies during drought, reducing spending on the use of artificial feeding at times when the supply of floral resources to bees is sharply declining.

Although known for flowering in the dry season, *M. tenuiflora* flowered at different times of the year in this study, providing floral resources to bees in both dry and rainy seasons. This species is characterized by fast growth and by providing large quantities of pollen to the bees (Maia-Silva et al., 2012).

The occurrence of plants with different flowering periods in the area explored by bees is important because it enables food supply at different times of the year. *Z. joazeiro*, *M. urundeuva* and *M. tenuiflora* are among the species with the highest flowering period.

The presence of bees was observed in some botanical species during the 18 months of study, except for December when the species that were in flowering received no visitation. In a similar study, Lorenzon et al. (2003) did not observe bee visitation to plant species in the months of August and October.

The qualitative melissopalinological analysis of honey collected in the apiary of the studied area showed the diversity of nectar sources visited by *A. melifera* in its foraging activity. Eight pollen types were identified and distributed in six families (Table 2). Five types belong to species in which bee visits were observed, while the others belong to botanical species considered melitophilous by other authors (Table 1). The family with the greatest diversity of pollen types was Fabaceae, which also stands out as an important source of bee resources in other studies conducted in the Northeast (Rolim, 2015; Santos et al. 2006; Sodré et al.; 2008; Trovão et al., 2009;). The bees mainly collected resources in the herbaceous (62.5%) stratum, followed by shrub (25%) and tree (12.5%) stratums. These results highlight the importance of herbaceous sources as suppliers of food resources for bees in the Northeast, especially in the caatinga region (Lopes et al., 2016; Lorenzon et al., 2003; Santos et al., 2006).

The presence of *C. sonderianus* pollen was not identified, a species collected in this study (Table 1) and recognized as potential for bees, mainly as a nectar supplier (Maia-Silva et al., 2012; Pereira et al., 2006; Silva et al., 2008). This absence is probably due to the discontinuity in rainfall in February 2013 (Figure 3), exactly in the flowering period of this species, which may have affected flowering and the consequent supply of nectar. The presence of pollen types from species that flower in the dry season, *M. tenuiflora* and *S. rhombifolia*, confirm the importance of these species to maintain colonies in drought periods.

Dominant pollen was absent in the quantitative pollen analysis (Table 2). We highlight the participation of *M. tenuiflora*, *M. arenosa* (Fabaceae) and *M. suaveolens* (Lamiaceae) species in honey production. These species are important sources of pollen and nectar for bees (Maia-Silva et al., 2012; Pereira et al., 2006). The melissopalinological analysis confirms the importance of the Fabaceae family as a source of food resources for *A. mellifera* and indicates that the region's flora provides a diversified bee pasture and a heterofloral honey.

Table 2. Pollen spectrum of *Apis mellifera* honey samples collected in São João do Piauí, Piauí, in 2013. Occurrence classes: DP: dominant pollen (>45%); AP: accessory pollen (16%–45%); IIP: important isolated pollen (3%–15%) and OIP: occasional isolated pollen.

Family	Pollen Types	Occurrence (%)			
		DP	AP	IIP	OIP
Amaranthaceae	*Alternanthera tenella*			9.0	
Combretaceae	*Combretum leprosum*			6.0	
Fabaceae	*Macroptilium lathyroides*			4.0	
	Mimosa arenosa			11.0	
	Mimosa tenuiflora		42.0		
Lamiaceae	*Mesosphaerum suaveolens*		21.0		
Malvaceae	*Sida rhombifolia*				1.0
Rubiaceae	*Borreria verticillata*			6.0	

4. CONCLUSIONS

The municipality of São João do Piauí, located in the Piauí semi-arid region, has diverse flora with a significant number of bee nectar and pollen suppliers, especially the Fabaceae, Malvaceae and Euphorbiaceae families.

Herbaceous and shrub species predominate among the plants visited by the bees, which bloom mainly during the rainy season. These strata are greatly affected by climatic conditions, with a significant reduction in the number of flowering species in periods of low rainfall.

The period with the highest number of species in flowering is from February to April, with an emphasis on the *Combretum leprosum*, *Croton sonderianus*, *Turnera ulmifolia*, *Mimosa tenuiflora*, *Mimosa arenosa*, *Ipomoea glabra*, *Mesosphaerum suaveolens* and *Sida cordifolia* species, which provide pollen and nectar to the bees. *Ipomoea glabra*, *Myracrodruon urundeuva, Sida cordifolia* and *Ziziphus joazeiro* species are among those which flower in the dry season with pollen and nectar supply, therefore being important to maintain colonies during this period.

The honey produced in the region has varied botanical sources, important participation by herbaceous species and a significant contribution from the Fabaceae family in the composition.

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