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Resources Collected by two *Melipona* Illiger, 1806 (Apidae: Meliponini) Species Based on Pollen Spectrum of Honeys from the Amazon Basin

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Abstract

This study aimed to identify the pollen grains found in honeys of *Melipona* (*Michmelia*) *seminigra pernigra* Moure & Kerr and *Melipona* (*Melikerria*) *interrupta* Latreille in two communities of the Tapajós-Arapiuns Extractive Reserve, Lower Amazon (Pará, Brazil) between December 2016 and November 2017. Twenty-four samples of honey were processed, 12 samples from *M. seminigra pernigra* collected in the Suruacá community and 12 samples from *M. interrupta* in the Vila Franca community. After acetolysis, 103 pollen types were identified, distributed across 22 families, plus eight indeterminate types. Fifty-nine types were exclusive to M. *seminigra pernigra*, 29 types were exclusive to *M. interrupta* and 15 pollen types were shared between both species. Anacardiaceae, Burseraceae, Melastomataceae, and Myrtaceae were the most attractive pollen families, providing key resources for maintenance of these bee populations. The sharing of pollen types between both bee species revealed a high similarity in preference for certain resources. *M. seminigra* showed greater diversity (H' = 1.928) than *M. interrupta* (H' = 1.292). Furthermore, the diversity (H') and equitability (J') indexes showed a more homogeneous pattern in the pollen spectrum of honeys from *M. seminigra* in most months studied. These data suggest that meliponiculturists should consider the diversity of plant species found in the two communities and keep them close to the meliponary, which will favor honey management and production, as well as the local biodiversity.

Introduction

The pollination exercised by stingless bees in the Amazon is considered to be a great ecological benefit to this biome. The Amazon region contains a rich fauna of these insects, guaranteeing the production of fruits and seeds through pollination, and promoting the conservation of plant species and the survival of their colonies (Ferreira & Absy 2017a, b; Absy et al., 2018; Rezende et al., 2019).

Meliponiculture is an activity that has been gaining prominence in the Northern region of Brazil, because it exploits the potential of native flora and helps to generate income through family farming, allowing for the commercialization of bee by-products, such as honey, pollen, and propolis, while also being in accordance with the precepts of sustainable natural resource use (Absy et al., 2013).

The genus *Melipona* Illiger is only found in Neotropical America – South America, Central America, and the Caribbean Islands –, being most diversified in the Amazon basin (Michener, 2007). In this group can be found the principal native stingless bees used in the practice of meliponiculture in the Amazon region (Brito et al., 2013; Ferreira & Absy 2017a). These bees are popularly known as jandaíra, jandaíra-preta, and jandaíra-da-Amazônia, names that can be attributed to numerous different species of meliponines, depending on the region (Nogueira-Neto, 1997; Silveira et al., 2002; Oliveira et al.,

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2013). The trophic resources collected by *Melipona* species in the Brazilian Amazon have been studied by various groups of researchers since the 1970s (Absy & Kerr, 1977; Absy et al., 1980; Marques-Souza, 1996; Marques-Souza et al., 2002; Oliveira et al., 2009; Ferreira & Absy, 2013, 2015, 2017a, b; Rezende et al., 2019) using melissopalynological methods. Through pollen analysis is possible to determine the botanical and geographical origin of the product, the flowering period of the plants, and their value as suppliers of nectar and pollen for bees (Barth, 1989; Jones & Bryant, 2004; Novais et al., 2009; Vossler et al., 2014).

In the Amazon, several riverside communities have developed activities to raise native bees. In the Tapajós-Arapiuns Extractive Reserve (Resex), located in the Lower Amazon region, Pará, Souza et al. (2018) found a high diversity of meliponines being utilized: *Frieseomelitta longipes* (Smith), *Friseomellita silvestrii* (Friese), *Melipona* (*Melikerria*) *interrupta* Latreille, *Melipona* (*Michmelia*) *seminigra pernigra* Moure & Kerr, *Scaptotrigona* sp. and *Tetragona clavipes* (Fabricius). However, according to the local meliponiculturists, the main obstacles to developing meliponiculture in the region include the lack of: legislation regarding the activity, technical assistance and training for the proper management of products from bees, and melissopalynological studies focused on local stingless bees products.

Based on this, the current study aimed to identify, through analysis of pollen grains present in honey, the plants used by *M. seminigra pernigra* and *M. interrupta* in two communities in Resex Tapajós-Arapiuns in the Lower Amazon region (Pará, Brazil). With this, it will be possible to subsidize stingless beekeeping strategies and increase regional meliponiculture activity, as these are the principal productive bees managed by meliponiculturists in Resex.

Material and methods

Study area

The study was carried out within the Tapajós-Arapiuns Extractive Reserve, in the communities of Suruacá (2°54’00”S 55°09’52”W) and Vila Franca (2°21’21”S 55°00’24”W). The Resex has a land area of 647,610 hectares and is distributed between the territories of Santarém and Aveiro, in the western part of the state of Pará (ICMBio, 2014). The Reserve was created in 1998 (Brasil, 1998) in the category of sustainable use within the Conservation Unit (UC) (Law No. 9,985, 18 July 2000).

The Reserve contains 72 communities and lies within the basins of two principal rivers, Tapajós and Arapiuns. The community of Vila Franca is situated on the left bank of the Arapiuns River, while the community of Suruacá is on the right bank of the Tapajós River, and access to both is exclusively by river.

Suruacá is one of the largest communities in the Resex Tapajós-Arapiuns, with a total of 127 resident families, or about 500 inhabitants. The community economy is based on the cultivation of cassava and its derivatives. In addition to the cultivation of cassava, economic activities include fishing, hunting, raising small animals, handicrafts, small-scale logging, extraction, processing of oils (*andiroba* and *copaiba*), rubber cultivation, and meliponiculture.

In the community of Vila Franca, there are 74 families totaling 298 people. The indigenous culture is still persistent and traditions of flour, *taruba*, *cachaça*, *manicuéra*, handicrafts, and cultural dances remain. Agroextractivism is the principal economic activity. Most Vila Franca families survive from the production of cassava flour, corn, or tapioca, and from the sale of handicrafts and products extracted from the forest. Meliponiculture was introduced into the community 10 years ago and contributes as an extra economic activity for some meliponiculturists (Projeto Saúde e Alegria, 2015).

Identification of stingless bees

To identify the bees, five worker bees were collected from beehives located in the meliponaries of communities Suruacá and Vila Franca, with the aid of killing jar for insects. Next, the specimens were packed, assembled, and labeled according to the usual entomological standards and sent to be identified by a specialist in the Laboratory of Bionomics, Biogeography, and Insect Systematics (BIOSIS) at the Federal University of Bahia (UFBA), where they remain deposited.

Collection of honey samples

Twenty-four honey samples were collected between December 2016 and November 2017, 12 from *M. interrupta* in the community of Suruacá and 12 from *M. seminigra* in Vila Franca. The honey samples were always obtained from the same bee hive every month, using sterile plastic pipettes. About 10 mL of honey were conditioned in plastic pots, sealed with a lid and properly identified. The samples were kept in a refrigerator at a temperature of about 10 °C until the beginning of laboratory processing.

Chemical processing of honey samples

The honey samples were treated according to Louveaux et al. (1978) and acetolysed (Erdtman, 1960). We also followed the recommendation of Jones and Bryant (2004) for honey dilution with 95% ethanol (ETOH).

Following the acetolysis process, at least three slides of each sample were prepared using Kisser’s glycerinated gelatin (Salgado-Labouriau, 1961) and sealed with paraffin (J. Müller modified in Erdtman 1952). After the completion of the analysis, they were deposited in the Pollen Library of the Laboratory of Botany and Palynology (LaBPal) at IBEF/UFOPA.

Analysis of pollen grains in the honey and statistical indexes

The methodology used to count pollen grains followed Moar (1985), with a minimum of 500 grains per sample. All of the different pollen types found were microphotographed at 100× magnification. In order to identify the pollen types, palynological bibliographies (Roubik & Moreno, 1991; Carreira et al., 1996) were used, and the pollen library at the National Institute of Amazonian Research (INPA) was consulted.

To define the frequency classes, the pollen types were grouped according to Louveaux et al. (1978): predominant pollen (PD = >45%), secondary pollen (PA = 16 to 45%), important pollen (PIi= 3 to 15%), and important minor pollen (PIo = <3%). The amplitude of the trophic niche in the honey samples was calculated using the diversity index (H') of Shannon-Weaver (1949), which is based on the proportion of pollen types found in the monthly samples, according to the formula $H' = -\Sigma$ (pi x ln pi), where *H'* is the diversity index, *pi* is the proportion of each pollen type found in the monthly samples, and *ln* is the natural logarithm. The equitability index (J') of Pielou (1977) allows estimating the degree of uniformity of the plant species visited by the bees in a given month. It is calculated according to the formula $J' = H'/H'max$, where *H'* is the diversity index and *H' max* is the natural logarithm of the total number of pollen types present in the sample. The uniformity index can vary from 0 to 1, indicating an interval between completely heterogeneous use and completely homogeneous use of resources, respectively. Precipitation data for the sampling period was obtained from the National Institute of Meteorology, Pará meteorological station (INMET, 2018). The botanical nomenclature for the Fabaceae family follows the new classification based on phylogenetic analyses (LPWG, 2017).

Results

One hundred and three pollen types collected by *M. seminigra pernigra* and *M. interrupta* bees were identified, distributed across 22 families, with eight indeterminate pollen types. Of this total, 59 pollen types were collected exclusively by *M. seminigra pernigra*, 29 were exclusive to *M. interrupta* and 15 were shared by both species (Table 1). The pollen types found at rates above 50% in the honey samples and shared by both bee species were *Bellucia* (Melastomataceae), *Eugenia* (Myrtaceae), *Miconia* (Melastomataceae), *Myrcia* (Myrtaceae), *Protium heptaphyllum* (Burseraceae), and *Spondias mombin* (Anacardiaceae).

Pollen spectrum of M. seminigra pernigra

The number of pollen types found per month in *M. seminigra* honeys ranged from five in October to 21 in February. *Mimosa pudica* (Fabaceae/Caesalpinioideae), was the most representative pollen type found in honey from this species (August, 65.20%), being classified as a predominant pollen. Secondary pollen types were identified as: Indeterminate (type 3), in July (39.60%); *Miconia* (Melastomataceae), December (38.00%), March (37.60%), September (35.00%), and June (30.00%); *Mouriri* (Melastomataceae), in October (33.60%); *Myrcia* (Myrtaceae), in January (30.00%); *Tapirira guianensis* (Anacardiaceae), in October (28.20%); *Protium heptaphyllum* (Burseraceae), in November (28.20%); *Spondias mombin* (Anacardiaceae), in November (27.20%); and *Mimosa pigra* (Fabaceae/ Caesalpinioideae), in November (17.40%) (Fig 1).

A total of 30 pollen types were classified as important pollen, distributed across nine families, with emphasis on *Bellucia* (Melastomataceae), in January (12.80%); *Eugenia* (Myrtaceae), in September (10.00%); and *Talisia* (Sapindaceae), in March (10.00%), as they occurred at a percentage of 10.00% or more. Another 34 pollen types collected by *M. seminigra* were classified as important minor pollen, distributed across 15 families, with emphasis on Fabaceae (eight types). Considering the pollen types with a percentage greater than 10.00%, *Bellucia*, *Eugenia*, *Miconia*, *Mimosa pigra*, *Mouriri*, *Myrcia*, *Protium heptaphyllum*, *Spondias mombin, Talisia, and Tapirira guianensis* were considered attractive to *M. seminigra*.

Pollen spectrum of M. interrupta

Melipona interrupta honey samples contained fewer than 10 pollen types in nine of the 12 honey samples analyzed, with the highest number of pollen types found in May (13)

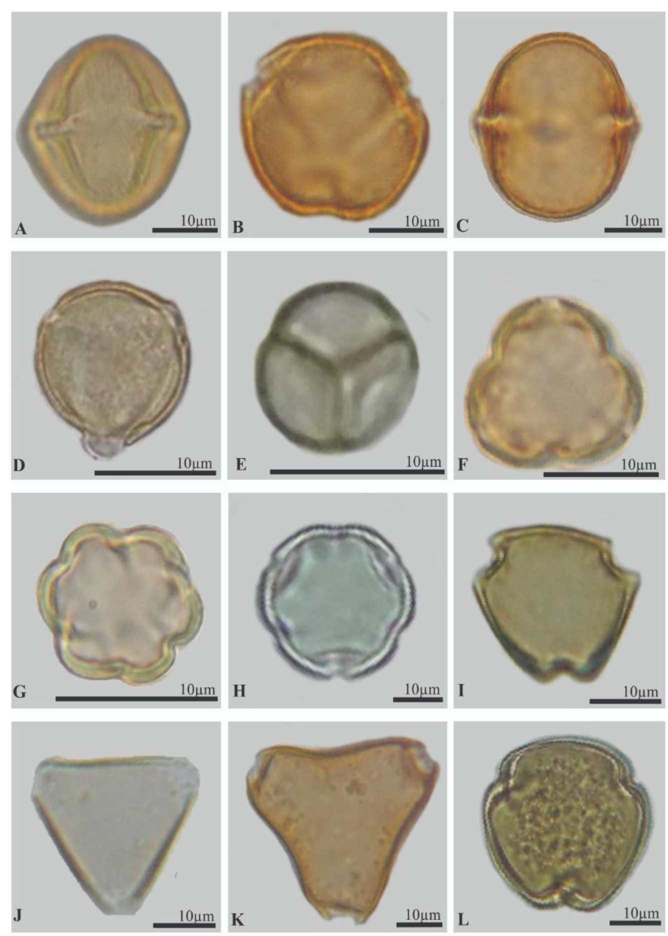

Fig 1. Photomicrographs of the most frequent pollen types found in honey samples of *Melipona seminigra pernigra.* Anacardiaceae, *Spondias mombin* (A) and *Tapirira guianensis* (B); Burseraceae, *Protium heptaphyllum* (C); Fabaceae, *Dialium* (D) and *Mimosa pudica* (E); Melastomataceae, *Bellucia* (F), *Miconia* (G) and *Mouriri* (H); Myrtaceae, *Eugenia* (I) and *Myrcia* (J); Sapindaceae, *Talisia* (K); Solanaceae, *Solanum* (L).

and the lowest number of pollen types in July, September, and November (5). The following pollen types were considered predominant: *Protium heptaphyllum* (Burseraceae), in February (76.20%), January (74.20%), March (61.00%), and August (59.60%); *Miconia* (Melastomataceae), in November (76.00%), April (70.00%), and September (64.00%); and *Spondias mombin* (Anacardiaceae), in January (56.40%). The pollen types grouped into the secondary pollen class were: *Bellucia* (Melastomataceae), in September (35.00%); *Mouriri* (Melastomataceae), in May (28.40%); *Eugenia* (Myrtaceae), in July (18.80%) and August (18.20%); and *Cassia* (Fabaceae/Caesalpinioideae), in August (18.60%) (Table 2, Fig 2).

For the important pollen frequency class, 18 types were found, distributed across eight families, with emphasis on Myrtaceae, having five types (Table 2). The *Bellucia*, *Cassia*, and *Eugenia* pollen types were represented at over 10.00% in at least one sample, and were therefore considered attractive for *M. interrupta.* Nineteen pollen types were found as important minor pollen, distributed across 11 botanical families.

Ecological indexes

The diversity obtained for the pollen spectrum of the *M. seminigra pernigra* honeys exhibited the highest values in February (H' = 2.635), April (H'= 2.344) and March (H' = 2.273), while the lowest values were found in July (H' = 1.621), October (H' = 1.311) and August (H' = 1.301). With regard to equitability, the collections were most uniform in October (J' = 0.945), November (J' = 0.891) and February (J' = 0.866). In contrast, the lowest uniformity values were recorded in March (J' = 0.757), December (J' = 0.712) and August (J' = 0.592) (Table 1).

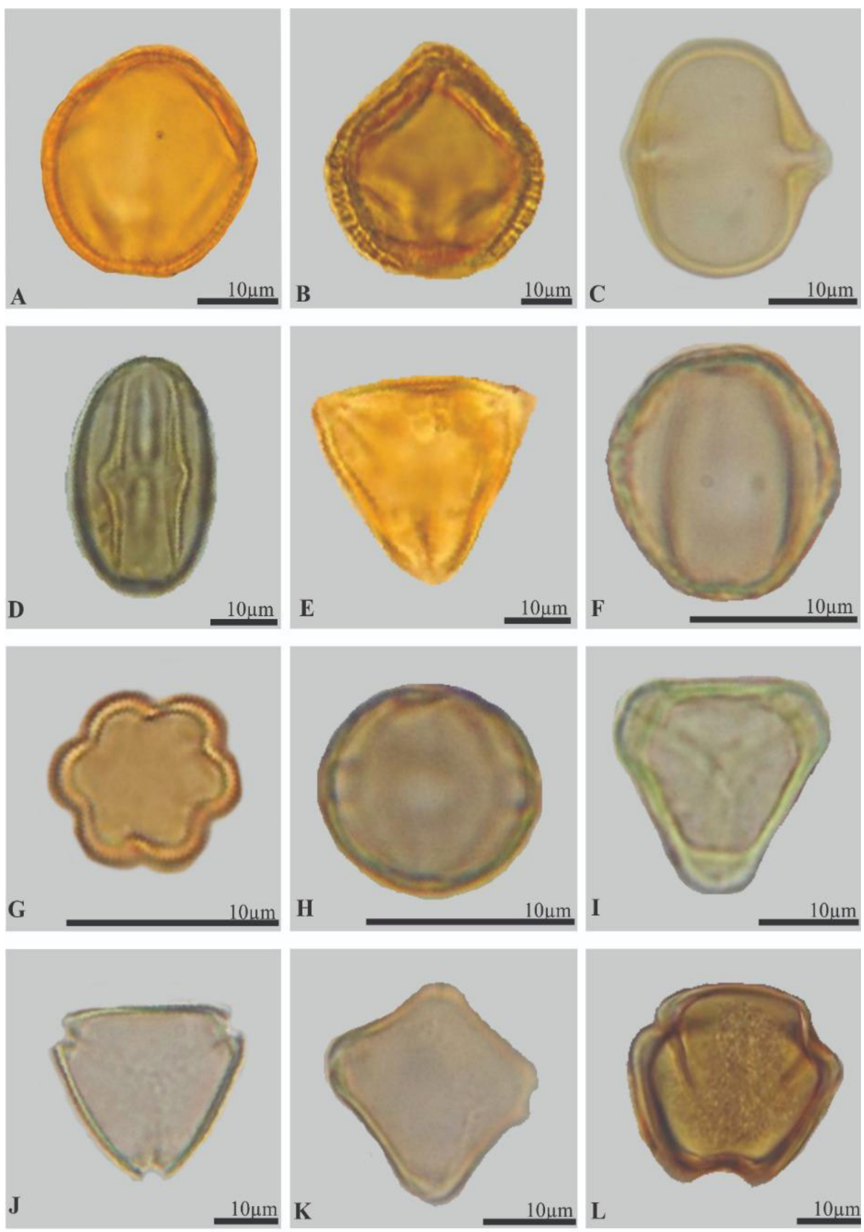

Fig 2. Photomicrographs of the most frequent pollen types found in honey samples of *Melipona seminigra.* Anacardiaceae, *Spondias mombin* (A); Araliaceae, *Schefflera morototoni* (B); Burseraceae, *Protium heptaphyllum* (C); Fabaceae, *Cassia* and *Copaifera* (D, E); Melastomataceae, *Bellucia* (F), *Miconia* (G) and *Mouriri* (H); Myrtaceae, *Eugenia* (I), *Myrcia* (J) and *Psidium* (K); Solanaceae, *Solanum* (L).

The diversity index registered for *M. interrupta* had its highest values in June (H' = 2.128), May (H' = 1.879), and August (H' = 1.548), and its lowest values in July (H' = 1.34), February (H' = 0.952), and November (H' = 0.929). The uniformity index for this bee species was highest in June (J' = 0.856), and September (J' = 0.806) and May (J' = 0.733), with the lowest values being obtained in January (J' = 0.505), December 2016 (J' = 0.443), and February (J' = 0.433) (Table 2).

Climatic data

The environmental variables recorded during the sampling period showed a high variation in rainfall volume, with the highest values measured in January (247 mm) and March (256 mm). In contrast, the lowest values were recorded in August/October (10 mm) and November (zero). For relative humidity, the highest values were recorded in January (91%) and February/March (92%), and the lowest values were measured in October (80%) and November (79%). With regard to temperature, the highest values were obtained in September/October (28 °C) and November (29 °C), while the lowest values were recorded in January, February and March (26 °C), followed by April and June (25 °C) (INMET, 2018) (Fig 3).

The month of February was when the greatest number of pollen types were found in the samples from *M. seminigra pernigra*. For *M. interrupta*, the month with the greatest number of types was May.

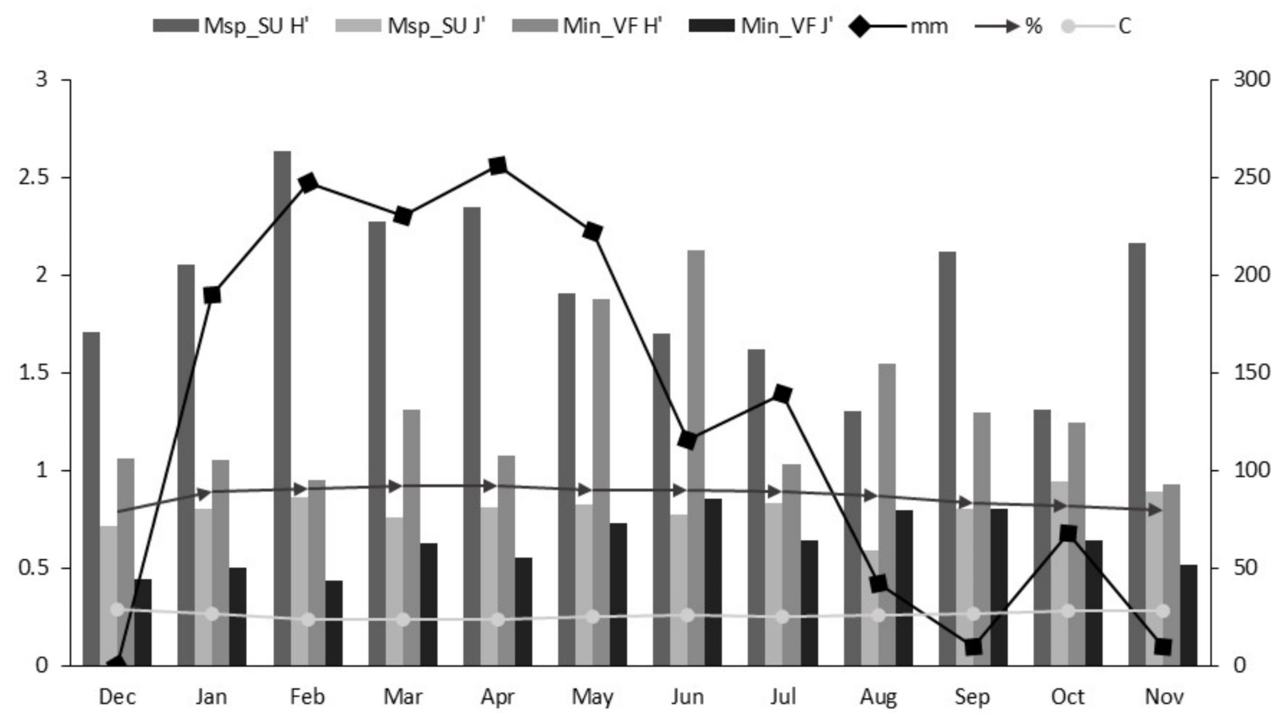

Fig 3. Diversity (H') and uniformity (J') records for pollen types found in samples of honey from *Melipona seminigra pernigra* (Msp) and *Melipona interrupta* (Min), as well as temperature (°C), relative humidity (%), and precipitation (mm) data for the communities of Suruacá (SU) and Vila Franca (VF), Resex Tapajós-Arapiuns, Pará, Brazil, between December 2016 and November 2017.

Discussion

Among the stingless bees reared in apiaries in the Amazon, the genus *Melipona* stands out. A number of melissopalynological studies have been carried out in this region with this genus (Absy & Kerr, 1977; Absy et al., 1984; Oliveira et al., 2009; Ferreira & Absy, 2013; Ueira-Vieira et al., 2013; Rezende et al., 2019). These studies emphasize the importance of polliniferous plants related to the *Miconia* and *Bellucia* (Melastomataceae) pollen types as key species for the feeding of these pollinating insects (Ferreira & Absy, 2017a; Rezende et al. 2019). These plant species have low seasonality, guaranteeing the availability of the resource for long periods in the year. These were also classified in this study as predominant pollen types for *M. interrupta* and secondary pollen grains for *M. seminigra pernigra*. This is due to the fact that some species of bees pollinate by vibration, grabbing the anthers (predominantly with poricidal dehiscence) and vibrating their thorax, shaking the anthers and releasing the pollen. This is common for some families, such as Fabaceae/Caesalpinioideae, Melastomataceae, and Solanaceae (Buchmann, 1983; Pinheiro & Sazima, 2007; Nunes-Silva et al., 2010).

In our study, the pollen types *Miconia* (Melastomataceae) and *M. pudica* (Fabaceae/Caesalpinioideae) refer to plant species that produce a lot of pollen and little or no nectar. Similarly, Barth (1989) noticed a high percentage of pollen grains from polliniferous plants in Brazilian honey samples. On the other hand, we identified several pollen types botanically related to plants that are probably good sources of nectar and produce little pollen: *Talisia* (Sapindaceae), *Tapirira guianensis* (Anacardiaceae), *Syzygium* (Myrtaceae), *Protium heptaphyllum* (Burseraceae) and *Eugenia* (Myrtaceae).

The frequent occurrence of *Miconia* (Melastomataceae) and *Mimosa pudica* (Fabaceae/Caesalpinioideae) in *M. seminigra* and *M. interrupta* honey samples in this study may be related to the size of pollen grains, which vary from small to very small and are always released in large quantities by plants (Absy et al., 1980; Ferreira & Absy, 2017b; Rezende et al., 2019). Some pollen types from polliniferous plants, when found in the pollen spectrum of honeys, may indicate the geographical origin of the samples, as well as, suggest potential pollen sources for bees. According to Roubik and Moreno (2013), predominant pollen in honey is often no indication of nectar source, if flowers are nectarless.

The principal pollen types responsible for high pollen frequencies in the samples were: for *M. seminigra*, *Mimosa pudica* (65.20%), and for *M. interrupta*, *Protium heptaphyllum* (76.20%), *Miconia* (76.00%), and *Spondias mombin* (56.40%). Ferreira and Absy (2017a), studying the honey pollen spectrum and trophic interactions between the colonies of *Melipona* (*Michmelia*) *seminigra merrillae* Cockerell and *M. interrupta*, found a strong relation between the nutrition of these species and the *Mimosa pudica* (Fabaceae/Caesalpinioideae) pollen type, aligning with the results of this study for the community of Suruacá.

Meanwhile, Oliveira et al. (2009) observed pollen resources collected by stingless bees in a forest fragment in the Manaus region and highlighted the importance of the Burseraceae family, with pollen type *Protium heptaphyllum*. This pollen type was used by all bees and was an important source for *M. seminigra merrillae*. In the same study, the family Anacardiaceae was represented by the types *T. guianensis* and *Spondias mombin*, collected by the foragers of *M. seminigra merrillae* and *M. fulva*. The reward gained by the bees, from most species of Anacardiaceae, is its nectar. In these species, the flowers have ripe anthers and their pollen is fully exposed, favoring opportunistic collection. The flowers of this family are usually not very showy, being hermaphrodite or unisexual (Ribeiro et al., 1999).

In the current study, some pollen type families were found to be well represented, such as Fabaceae, with *Mimosa pudica* for *M. seminigra*; Burseraceae, with *Protium heptaphyllum* and Melastomataceae, with *Miconia*, for *M. interrupta*. According to Judd et al. (2010), the Melastomataceae, Fabaceae, and Myrtaceae families are predominantly pollinated by bees.

Pollen types with less than 10.00% representativity can act as complementary resources and become important in the maintenance of colonies for limited periods, when the supply of the principal resources is subject to seasonal variations (Ramalho et al., 1985). The *M. seminigra pernigra* species had greater pollen richness (n = 74) in its honey samples. In contrast, *M. interrupta* had lower richness (n = 44). Results similar to these were found in the study by Ferreira and Absy (2017b), who analyzed pollen types in honey and trophic relationships between colonies of *M. seminigra merrillae* and *M. interrupta* raised in meliponaries in the city of Manaus, Amazonas. This approach can show the general tendency of these bees, as discussed by Ramalho et al. (2007).

The diversity (H') values for *M. seminigra pernigra* in the community of Suruacá were found to be higher throughout the year in comparison to *M. interrupta*. The equitability analysis (J') showed that *M. seminigra pernigra* utilized a larger pollen spectrum and that its use of different pollen types was more homogeneous, indicating that this species can be considered more generalist in its use of resources. Meanwhile, *M. interrupta* presented a very similar pollen spectrum, with differences in the abundance of the pollen types utilized, being less generalist and showing greater preference for a few pollen types. The lowest diversity for *M. seminigra*, recorded in August, and for *M. interrupta*, in November, suggest the use of few sources that could have been more attractive due to a greater abundance of types, whereas, in the rainy season, pollen was collected from a greater number of sources at lower frequency levels.

These results are those similar to those found by Oliveira et al. (2009). They verified that rainfall is the most important factor influencing the extension of the pollen spectrum, promoting greater diversity in collection due to the low level of flowering.

Rainfall was verified to be an important factor that influences the extension of the pollen spectrum, as verified in the month of February for *M. seminigra*, and in the month of May for *M. interrupta*, when the greatest number of pollen types were obtained. The bees collected a total of 147 pollen types during the rainy season and 98 during the driest period, in the two communities. This can be explained by the supply of resources during certain periods. During the dry period, the most intense flowering of certain species, such as *T. guianensis*, occurs. The similarity between diversity indexes shows that these bees exhibit a similar collection potential, which may compromise the maintenance of more sensitive systems or populous species, depending on the diversity of flowers and the behavior of the bees with regard to these flowers (Ferreira & Absy, 2017a).

In this study, pollen from the families Anacardiaceae, Melastomataceae, Fabaceae/Caesalpinioideae - mimosoid clade, and Myrtaceae was associated with both species of bees and these pollen types were found in abundance in the honey samples. Although there have been several studies on the pollen types collected by stingless bees in the Amazon region and the importance of these studies for the development of meliponiculture in local communities, few studies have prioritized pollen analyses of honey samples from these species, even though this is the most valuable resource for beekeepers (Novais et al., 2015; Ferreira & Absy, 2017b; Rezende et al., 2019).

Conclusion

Of the 103 pollen types found to be present in honey samples from *M. seminigra pernigra* and *M. interrupta*, 15 pollen types were shared by both species. Considering the proportion of pollen types found in the samples, the botanical families being explored by both bee species were, in descending order, Melastomataceae, Fabaceae/Caesalpinioideae, Burseraceae, Myrtaceae, and Anacardiaceae.

The species *M. seminigra pernigra* collected different pollen types more homogeneously, indicating that this species can be considered more generalist in its use of resources. Meanwhile, *M. interrupta* honeys had a pollen spectrum similar to *M. seminigra*, with differences regarding the abundance of pollen types used and being less generalist, with greater preference for a few pollen types. The predominant pollen types were *Mimosa pudica* (Fabaceae/Caesalpinioideae) for *M. seminigra* honeys, and *Miconia* (Melastomataceae), *Protium heptaphyllum* (Burseraceae) and *Spondias mombin* (Anacardiaceae) for *M. interrupta*. Some of these pollen types are related to polliniferous plants, such as *M. pudica* and *Miconia*. However, even though they do not contribute to the nectariferous composition of honey, they may indicate polliniferous preferences to be investigated in further studies.

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Authors' Contributions

RRS, JSN and VHRA conceived the main idea of the research; RRS, ADAP and LLN collected, processed and analyzed the samples; RRS wrote the text; RRS, ADAP, LLN, JSN and VHRA revised the text.

Table 1. Frequency of pollen types found in honey samples of *Melipona seminigra pernigra* (Apidae: Meliponini) collected from December 2016 (Dec 16) to November 2017 (Nov 17) in the community of Suruacá, Tapajós-Arapiuns Extractive Reserve, Santarém (PA), Brazil.

Plant Family/Pollen Type	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17
ANACARDIACEAE												
Anacardium										5.00		
Spondias mombin	11.20	2.80	2.60			7.00	8.80			6.00		27.20
Tapirira guianensis		5.80	3.60						8.20	10.00	28.20	10.40
Type 1			6.00									
Type 2			1.00									
ARALIACEAE												
Schefflera morototoni					5.00							
Type 1						1.60						
Type 2								6.20				
Type 3												9.60
ARECACEAE												
Elaeis				1.00	2.00							
Maximiliana maripa				1.20								
ASTERACEAE												
Ambrosia		1.00	1.00	0.60								
Bactris			3.40									
BURSERACEAE												
Protium heptaphyllum	16.00	12.20	20.20	4.60	24.00	17.00	13.20	23.40	6.20	13.00	28.20	
CYPERACEAE												
Scleria										1.20		
EUPHORBIACEAE												
Alchornea			2.00	1.20					5.40			
Type 1				1.20								

Table 1. Frequency of pollen types found in honey samples of *Melipona seminigra pernigra* (Apidae: Meliponini) collected from December 2016 (Dec 16) to November 2017 (Nov 17) in the community of Suruacá, Tapajós-Arapiuns Extractive Reserve, Santarém (PA), Brazil. (Continuation)

Plant Family/Pollen Type	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17
FABACEAE/ CAESALPINIOIDEAE												
Cassia mimosoides				3.40								
Delonix regia		1.00										
Inga					1.20							
Leucaena					4.00							
Mimosa												17.40
Mimosa pigra					3.00							
Mimosa pudica	2.80	4.00	6.60	10.80	4.60	21.00	29.20		65.20			
Mimosa sensitiva					2,00							
Stryphnodendron	1.00									2.00		
Stryphnodendron guianense			2.00	2.00								
Type 1			3.40									
Type 2				3.60								
Type 3												2.20
FABACEAE/ DETARIOIDEAE												
Copaifera langsdorffii				1.60								
Hymenaea	1.00						1.00	8.20				
Hymenaea parvifolia		1.00	1.00	1.40								
FABACEAE/ DIALIOIDEAE												
Dialium												7.40
FABACEAE/ PAPILIONOIDEAE												
Swartzia					1.60							
LORANTHACEAE												
Phthirusa					1.00							
MALPIGHIACEAE												
Byrsonima					3.00					2.00		
Type 1	0.60											
Type 2				0.80								
MALVACEAE												
Rhodognaphalopsis minor			1.20									
Malvaceae type			2.00									
MELASTOMATACEAE												
Bellucia	5.60	12.80	10.40	4.00		9.00				11.00		
Miconia	38.00	18.00		37.60	27.00	30.00	2.20	13.40		35.20		
Mouriri						6.00	34.40				33.60	
Type 1								7.20				
Type 2									2.60			

Table 1. Frequency of pollen types found in honey samples of *Melipona seminigra pernigra* (Apidae: Meliponini) collected from December 2016 (Dec 16) to November 2017 (Nov 17) in the community of Suruacá, Tapajós-Arapiuns Extractive Reserve, Santarém (PA), Brazil. (Continuation)

Plant Family/Pollen Type	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17
MYRTACEAE												
Eugenia		1.40	6.00		3.20	6.00	5.00				10.00	7.60
Eugenia stipitata												
Myrcia	22.00	30.00	15.80		7.00							
Psidium	1.00								1.20			2.00
Psidium guajava		1.60										
Syzygium			1.60		4.40					3.00		
Type 1			4.00									
Type 2				6.80								
Type 3							3.00					
Type 4							3.20					
Type 5												3.00
PASSIFLORACEAE												
Passifloraceae type			1.20					2.00				
POLYGONACEAE												
Triplaris										1.00		
RUBIACEAE												
Rubiaceae type												1.00
RUTACEAE												
Zanthoxylum				1.00								
SAPINDACEAE												
Serjania						1.00						
Talisia	0.80	8.40		10.00					1.00	1.00		
SAPOTACEAE												
Pouteria					2.00							
Sapotaceae type			5.00									
SOLANACEAE												
Solanum					2.00	1.40			7.40	5.00		
URTICACEAE												
Cecropia					3.00					4.60		
INDETERMINATE												
Type 1				6.00								
Type 2				1.20								
Type 3								39.60				
Type 4									2.80			
Type 5												7.00
Type 6												5.20
Total %	100	100	100	100	100	100	100	100	100	100	100	100
Number of pollen types	11	13	21	20	17	10	9	7	9	14	5	12
Diversity (H’)	1.708	2.056	2.635	2.273	2.344	1.903	1.703	1.621	1.301	2.123	1.311	2.161
Equitability (J’)	0.712	0.802	0.866	0.757	0.811	0.826	0.775	0.833	0.592	0.804	0.945	0.891

Table 2. Frequency of pollen types found in honey samples of *Melipona interrupta* (Apidae: Meliponini) collected from December 2016 (Dec 16) to November 2017 (Nov 17) in the community of Vila Franca, Tapajós-Arapiuns Extractive Reserve, Santarém (PA), Brazil.

Plant Family/Pollen Type	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17
ANACARDIACEAE												
Spondias mombin	2.00	56.40	0.80	2.00								
ARALIACEAE												
Schefflera morototoni	5.00			5.60	1.60	1.20	3.00					
Araliaceae type		2.30	1.80									
ARECACEAE												
Arecaceae type											3.00	
ASTERACEAE												
Ambrozia								1.00				
BURSERACEAE												
Protium heptaphyllum	74.00	34.80	76.20	61.00	3.20	2.80	2.60	59.60	44.40	10.00	3.00	3.40
CUNONIACEAE												
Cunoniaceae type					1.00							
CYPERACEAE												
Cyperus						3.40						
FABACEAE/ CAESALPINIOIDEAE												
Cassia type 1							4.00		18.60			
Cassia type 2									3.00			
Inga							3.00					
Type 1	2.00											
Type 2	1.00											
Type 3			1.60									
Type 4			1.20									
Type 5	1.00											
FABACEAE/ DETARIOIDEAE												
Copaifera		1.00	1.20		9.20		7.40					
FABACEAE/ PAPILIONOIDEAE												
Aldina						1.00						
Diplotropis						1.00						
LORANTHACEAE												
Phthirusa	1.00											
MALPIGHIACEAE												
Byrsonima						2.60						
Malpighiaceae type	1.00	1.00										
MALVACEAE												
Malvaceae type				0.80								
MELASTOMATACEAE												
Bellucia	3.00					2.40	5.00		7.20	35.00		7.00
Miconia	10.00	2.40	10.60	8.60	70.00	33.4	35.4	19.60		43.00	64.00	76.00
Mouriri						28.4						
Type 1					10.00		8.00					
Type 2						8.00	7.00					

Table 2. Frequency of pollen types found in honey samples of *Melipona interrupta* (Apidae: Meliponini) collected from December 2016 (Dec 16) to November 2017 (Nov 17) in the community of Vila Franca, Tapajós-Arapiuns Extractive Reserve, Santarém (PA), Brazil. (Continuation)

Plant Family/Pollen Type	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17
MYRTACEAE												
Eugenia					5.00	11.40	13.00	18.80	18.20	5.00	11.00	5.00
Eugenia stipitata						1.00						
Myrcia		1.20	4.00	9.60								
Psidium							6.00					3.60
Psidium guajava							5.60					
Type 1			2.60									
Type 2				11.40								
Type 3									3.80			
Type 4											8.00	
POLYGONACEAE												
Polygonum				1.00								
RUBIACEAE												
Borreria											3.00	
SAPINDACEAE												
Sapindaceae type		0.60										
SOLANACEAE												
Solanum										7.00	8.00	5.00
Type 1								1.00				
INDETERMINATE												
Type 1						3.40						
Type 2									4.80			
Total %	100	100	100	100	100	100	100	100	100	100	100	100
Number of pollen types	11	8	9	8	7	13	12	5	7	5	7	5
Diversity (H')	1.063	1.051	0.952	1.309	1.072	1.879	2.128	1.034	1.548	1.297	1.248	0.929
Equitability (J')	0.443	0.505	0.433	0.63	0.551	0.733	0.856	0.643	0.796	0.806	0.641	0.518

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