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Research Article / Artículo de Investigación

Pollen niche of *Melipona crinita* Moure & Kerr, 1950 (Hymenoptera: Apidae) in a meliponary of Acre, Brazil: a study case

Nicho de polen de *Melipona crinita* Moure y Kerr, 1950 (Hymenoptera: Apidae) en un meliponario de Acre, Brasil: un estudio de caso

Francisco Cildomar da Silva Correia[1*] and Rui Carlos Peruquetti[1]

[1]*Postgraduate Program in Sanity and Sustainable Animal Production in the Western Amazon (PPGESPA/UFAC) Federal University of Acre, Highway 364 – Campus of the Federal University of Acre, Zip code 69920-900, Rio Branco/Acre, Brazil.* **cildomar12@hotmail.com, rcperuquetti@yahoo.com.br*

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Abstract. *Melipona crinita* is widely used in meliponiculture for the production of honey, in several places in the Amazon. Thus, the aim of this study was: (i) determine the seasonal characteristics of the pollen collected by *M. crinita*, regarding the botanical origin; (ii) the growth habit of plants visited by workers and (iii) the contribution of wild and agricultural species in providing pollen for this bee. Our hypotheses were: (i) *M. crinita* is a generalist species in the use of its pollen sources; (ii) *M. crinita* adjusts pollen foraging according to flowering variation and (iii) *M. crinita* visits mainly wild trees and shrubs to collect pollen. The research was carried out from April 2018 to March 2019 in a meliponary located in the rural area of Rio Branco, Acre, Brazil using a colony of *M. crinita*. The collected samples revealed 46 pollen types, distributed in 25 families and 41 genera of plants. Fabaceae (Mimosoideae) presented a higher frequency of occurrence, FO = 41.67%. The pollen types with the highest frequency of occurrence were: *Solanum*, FO = 19.72%; *Alchornea*, FO = 16.13% and *Senna*, FO = 11.93%, with the least seasonal being: *Solanum* and *Aparisthmium cordatum*. From the total plants visited by *M. crinita*, 71.74% were wild; 28.26% agricultural; 36.96% trees; 34.78% shrubs; 15.22% herbs; 6.52% lianas and 6.52% sub-bushes. Wild trees and shrubs represented 64.80% of all pollen collected by *M. crinita*. Thus, the conservation of these plants is essential for the successful management of *M. crinita* in meliponaries.

Key words: Family farming; meliponiculture; pollen analysis; resource collection; stingless bee.

Resumen. *Melipona crinita* es una abeja ampliamente utilizada en la meliponicultura para la producción de miel en varios lugares de la Amazonía. Así, el objetivo de esta investigación fue: (i) determinar las características estacionales del polen recolectado por *M. crinita*, en cuanto al origen botánico; (ii) el hábito de crecimiento de las plantas visitadas por las obreras y (iii) la contribución de las especies silvestres y agrícolas en el suministro de polen para esta abeja. Nuestras hipótesis fueron: (i) *M. crinita* es una especie generalista en el uso de sus fuentes de polen; (ii) *M. crinita* ajusta la búsqueda de polen de acuerdo con la variación de la floración y (iii) *M. crinita* visita principalmente árboles y arbustos silvestres para recolectar polen. La investigación se llevo a cabo entre abril de 2018 y marzo de 2019 en un meliponario ubicado en la zona rural de Rio Branco, Acre, Brasil utilizando una colonia de *M. crinita*. Las muestras recolectadas revelaron 46 tipos de polen, distribuidos en 25 familias y 41 géneros de plantas. Fabaceae (Mimosoideae) presentó la mayor frecuencia de ocurrencia,

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FO = 41, 67%. Los tipos de polen con mayor frecuencia de ocurrencia fueron: *Solanum*, FO = 19,72%; *Alchornea*, FO = 16,13% y *Senna*, FO = 11,93%, siendo las menos estacionales: *Solanum* y *Aparisthmium cordatum*. Del total de plantas visitadas por *M. crinita*, el 71,74% fueron silvestres; 28,26% agrícolas; 36,96% árboles; 34,78% arbustos; 15,22% hierbas; 6,52% lianas y 6,52% subarbustos. Los árboles y arbustos silvestres representaron el 64,80% de todo el polen recolectado por *M. crinita*. Por lo tanto, la conservación de estas plantas es fundamental para un manejo exitoso de *M. crinita* en meliponarios.

Palabras clave: Abeja sin aguijón; agricultura familiar; análisis de polen; colección de recursos; meliponicultura.

Introduction

Stingless bees are a very diverse group of eusocial insects of the order Hymenoptera (family Apidae, tribe Meliponini). Currently, in Brazil, 251 species are known (Oliveira and Nogueira 2023). *Melipona crinita* Moure and Kerr, 1950 can be found in Bolivia (Cochabamba); Brazil (Acre, Amazonas, Rondônia); Peru (Loreto, San Martín) and Venezuela (Amazonas) (Camargo *et al*. 2013).

Melipona crinita inhabits anthropogenic and natural environments, such as lowland forests, igapó and dryland (Brown and Albrecht 2001; Oliveira *et al*. 2013). It builds nests in tree hollows of Fabaceae, Lecythidaceae, Lythraceae and Myrtaceae (Oliveira *et al*. 2013; Correia *et al*. 2016). This species usually forages in the early hours of the morning, with temperatures ranging between 24 °C and 26 °C, with pollen being the most collected resource (Cortopassi-Laurino 2004).

Melipona crinita is widely used in meliponiculture for honey production, in various locations in the Amazon region (Oliveira *et al*. 2013). However, currently, only eight botanical families are known to supply flowers to this bee (Oliveira *et al*. 2013; Pimentel *et al*. 2021). Although we believe that *M. crinita* may be a generalist species and that it collects pollen mainly from wild trees and shrubs, since according to Roubik *et al*. (1986) and Malagodi-Braga and Kleinert (2009), wild trees are the plant species most visited by stingless bees.

In Acre, *M. crinita* (yellow uruçu) is widely creared in meliponaries by family farmers because it is considered a good honey producer, producing 3 to 6 liters per year per nest (Venturieri *et al*. 2003; Carvalho-Zilse *et al*. 2005; Kerr *et al*. 2005; Cortopassi-Laurino *et al*. 2006). However, until now, the pollen niche of this species is little known. Based on this, the currently study was aimed to determine: (i) the seasonal characteristics of the pollen collected by *M. crinita*, regarding the botanical origin; (ii) the growth habit of plants visited by workers and (iii) the contribution of wild and agricultural species in providing pollen for this bee. Our hypotheses were: (i) *M. crinita* is a generalist species in the use of its pollen sources; (ii) *M. crinita* adjusts pollen foraging according to flowering variation throughout the year and (iii) *M. crinita* visits mainly wild trees and shrubs to collect pollen. The answers to these hypotheses can help beekeepers in the formation of meliponicultural pastures.

Materials and Methods

The survey was conducted from April 2018 to March 2019 in a meliponary containing a colony of *M. crinita*; two from *Melipona grandis* Guérin, 1844; six from *Melipona subnitida* Ducke, 1911 and 22 from *Melipona eburnea* Friese, 1900, located in the rural area of the municipality of Rio Branco, Acre, Brazil (9°55′57″ S; 67°53′19″ W). The property consists of an area with an agroforestry system – SAF and family farming, surrounded by pastures and fragments of wild vegetation, being close to urbanized areas (Fig. 1).

To obtain the pollen samples, a colony of *M. crinita* was used, kept in a standard box, model INPA, at fortnightly breaks. In total, 24 samples were taken. Each sampled day, between 5 am and 9 am, the period of greatest intensity of foraging by *Melipona* Illiger, 1806 bees (Roubik 1989), 10 workers which returned to the colony with loads of pollen in their corbiculae were captured with entomological net. The captured bees were sacrificed with a pressure in the chest region and deposited in 10 ml tubes, containing 3 ml of 70% alcohol to remove the pollen grains adhered to their bodies.

To identify the pollen collected by *M. crinita*, a set of 78 microscopic slides was assembled, three for each sample, following the methodology described by Jones (2012). From each pollen sample, a 20 μl subsample of the sedimented pollen at the bottom of the tubes in which the bees were stored was taken with an automatic pipette. This material was placed in a 2 ml tube, then 0.5 ml of Calberlla solution was added for grain coloring (Correia and Peruquetti 2017). To assemble the slides, a 25 μl aliquot of the mixture was used.

The slides produced were photomicrographed under an optical microscope, equipped with a camera and an image capture system in magnifications of 1,000x for identification and 400x for counting, following the methodology described by Colinvaux *et al*. (1999). The classification of pollen grains was carried out according to the concept of De Klerk and Joosten (2007), who define "pollen type" as a morphological attribute, which includes one or more species, as taxonomic categories.

From the images obtained, a qualitative analysis of pollen types and their classification into family, genus or species was performed, using a reference collection, built with pollen grains collected from 139 species of flowering plants (wild and agricultural) existing on the property, where the study was carried out and, in its surroundings, and with pollen from 124 exsiccates deposited in duplicate in the herbarium of the Federal University of Acre, Acre, Brazil.

The criteria used in the classification of botanical species established at the study place (wild and agricultural plants) adopted the formulation proposed by Gliessman (2000). On what, agricultural: those managed in the practice of agriculture and wild: species present naturally in the place, whether or not originating in the region. The definition of species as tree, bush, herb, liana and subshrub followed the classification system described by Almeida and Almeida (2014).

The frequency of occurrence (FO) of pollen types in the samples followed the model proposed by Jones and Bryant (1996): rare (<10%); uncommon (10 to 20%); frequent (from 21 to 50%) and very frequent (> 50%), based on the percentage of occurrence of each type of pollen. The frequency of occurrence was calculated by dividing the number of samples in which a pollen type occurs by the number total samples.

The amplitude of the *M. crinita* pollen niche was calculated using the standardized Levins Index (B) (Krebs 1999):

$$B = \frac{1}{\sum_i \left(\frac{n_i}{n} \right)^2}$$

on what:
B = Levins Index
n_i = Number of pollen types of a given species
i = Total number of pollen types sampled

Standardization was expressed by the formula:

$$B'_A = \frac{B-1}{n-1}$$

on what:
B'_A = standardized Levins Index
B = Levins measure of diet width
n = Total number of plant species in the diet

The value of B′ ranges from (0 to 1), niche values close to "1" indicate that the bee has collected resources in a wide range of botanical species. Values close to "0" indicate a preference for few plants, and zero corresponds to the use of a single plant species.

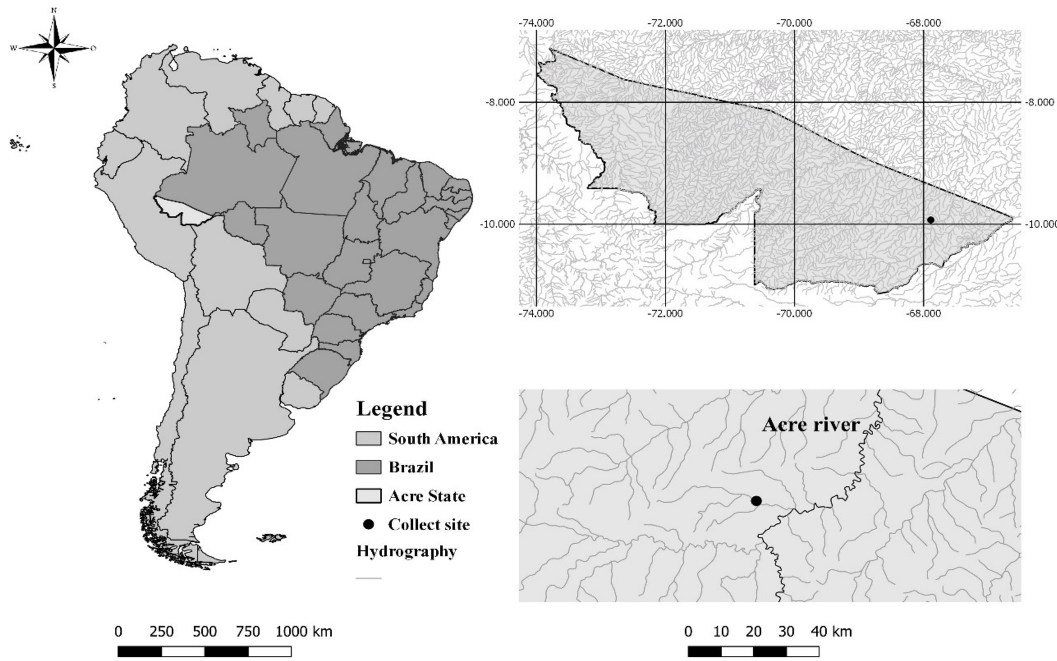

Figure 1. Location of the meliponary where the study was carried out (Google Earth ™). / Ubicación del meliponario donde se realizó el estudio (Google Earth ™).

Results

From the comparison between the pollen samples of *M. crinita* with the collection of reference, it was possible to identify 46 pollen types, distributed in 25 families and 41 genera. From this total, 24 were identified at the species level (Tab. 1, Figs. 2, 3).

In the sample set of months evaluated, pollen types belonging to Fabaceae showed the highest frequency of occurrence, FO = 26.09%. Within Fabaceae, the subfamily Mimosoideae was the most abundant, FO = 41.67%, followed by Caesalpinioideae, FO = 33.33% and Papilionoideae, FO = 25.00% (Fig. 4).

When analyzing the general quantity of pollen types collected by *M. crinita*, those that obtained the highest frequency of occurrence were: *Solanum* L., FO = 19.72%; *Alchornea* Sw., FO = 16.13% and *Senna* Mill., FO = 11.93%. The others had FO <10% (Fig. 5).

Solanum, besides being the pollen type with the highest frequency of occurrence, in the grand total of sampled months, in May it had FO = 77.38% and in July, FO = 49.38%, which demonstrates the importance of this botanical genera in pollen supply for *M. crinita*.

Other significant pollen types in the pollen diet of *M. crinita* were: *Alchornea*, in February had FO = 62.76%; *Mimosa caesalpiniifolia* Benth. in December, FO = 57.32% and *Schinus* L., in August, FO = 52.01% (Fig. 6).

Table 1. Pollen types found in the corbicles and attached to the body of *Melipona crinita* created in a meliponary located in Rio Branco, Acre, Brazil. / Tipos de polen encontrados en las corbicillas y adheridos al cuerpo de *Melipona crinita* criada en un meliponario ubicado en Rio Branco, Acre, Brasil.

Botanical families	Subfamilies	Pollen types
Anacardiaceae		*Schinus*
Apiaceae		*Eryngium foetidum*
Arecaceae		*Astrocaryum aculeatum*
Arecaceae		*Cocos nucifera*
Arecaceae		*Oenocarpus bacaba*
Asteraceae		*Vernonia*
Begoniaceae		*Begonia*
Bixaceae		*Bixa*
Cannabaceae		*Celtis*
Combretaceae		*Combretum*
Cucurbitaceae		*Citrullus*
Dilleniaceae		*Doliocarpus*
Dilleniaceae		*Doliocarpus dentatus*
Euphorbiaceae		*Alchornea*
Euphorbiaceae		*Aparisthmium cordatum*
Euphorbiaceae		*Croton lanjouwensis*
Fabaceae	Caesalpinioideae	*Copaifera multijuga*
Fabaceae	Caesalpinioideae	*Delonix*
Fabaceae	Caesalpinioideae	*Lonchocarpus*
Fabaceae	Caesalpinioideae	*Senna*
Fabaceae	Mimosoideae	*Inga edulis*
Fabaceae	Mimosoideae	*Inga marginata*
Fabaceae	Mimosoideae	*Mimosa adenophylla*
Fabaceae	Mimosoideae	*Mimosa caesalpiniifolia*
Fabaceae	Mimosoideae	*Samanea tubulosa*
Fabaceae	Papilionoideae	*Bowdichia virgilioides*
Fabaceae	Papilionoideae	*Crotalaria retusa*
Fabaceae	Papilionoideae	*Pterodon*
Lauraceae		*Persea americana*
Loranthaceae		*Struthanthus flexicaulis*
Lythraceae		*Cuphea*
Muntingiaceae		*Muntingia calabura*
Myrtaceae		*Psidium guajava*
Myrtaceae		*Syzygium malaccense*
Ochnaceae		*Cespedesia*
Oxalidaceae		*Averrhoa carambola*
Phyllanthaceae		*Hyeronima*
Rubiaceae		*Isertia*
Salicaceae		*Casearia*
Salicaceae		*Laetia*
Sapindaceae		*Allophylus*
Sapindaceae		*Cupania*
Solanaceae		*Solanum*
Solanaceae		*Solanum rugosum*
Solanaceae		*Solanum stramonifolium*
Verbenaceae		*Lantana camara*

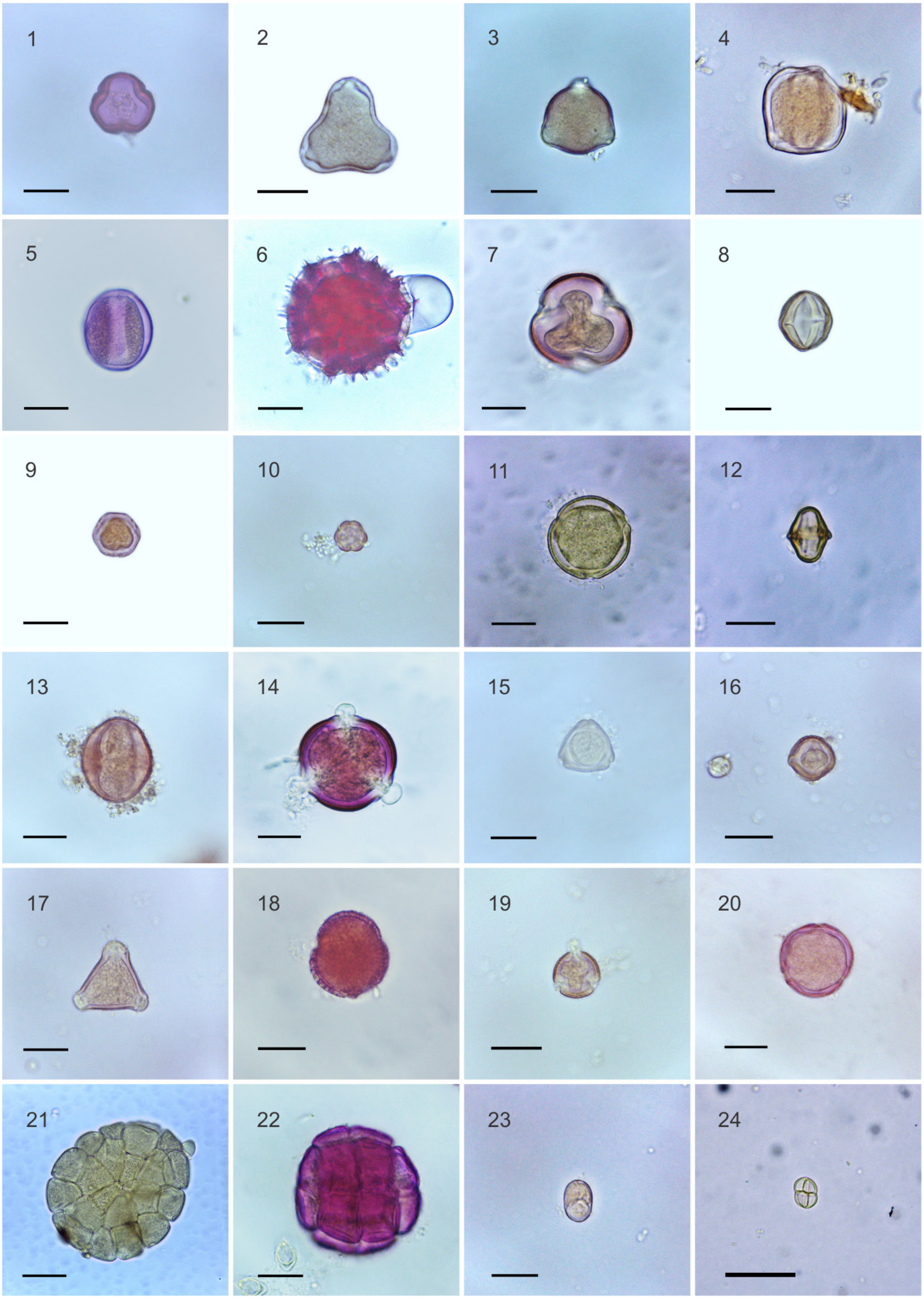

Figure 2. Optical photomicrographs of pollen types collected by *Melipona crinita*: / Fotomicrografías ópticas de tipos de polen recogidos por *Melipona crinita*: Anacardiaceae – *Schinus* (1); Apiaceae – *Eryngium foetidum* (2); Arecaceae – *Astrocaryum aculeatum* (3); *Cocos nucifera* (4); *Oenocarpus bacaba* (5); Asteraceae – *Vernonia* (6); Begoniaceae – *Begonia* (7); Bixaceae – *Bixa* (8); Cannabaceae – *Celtis* (9); Combretaceae – *Combretum* (10); Cucurbitaceae – *Citrullus* (11); Dilleniaceae – *Doliocarpus* (12); *Doliocarpus dentatus* (13); Euphorbiaceae – *Alchornea* (14); *Aparisthmium cordatum* (15); *Croton lanjouwensis* (16); Fabaceae (Caesalpinioideae) *Copaifera multijuga* (17); *Delonix* (18); *Lonchocarpus* (19); *Senna* (20); Fabaceae (Mimosoideae) *Inga edulis* (21); *Inga marginata* (22); *Mimosa adenophylla* (23); *Mimosa caesalpiniifolia* (24) (Bars = 20 μm).

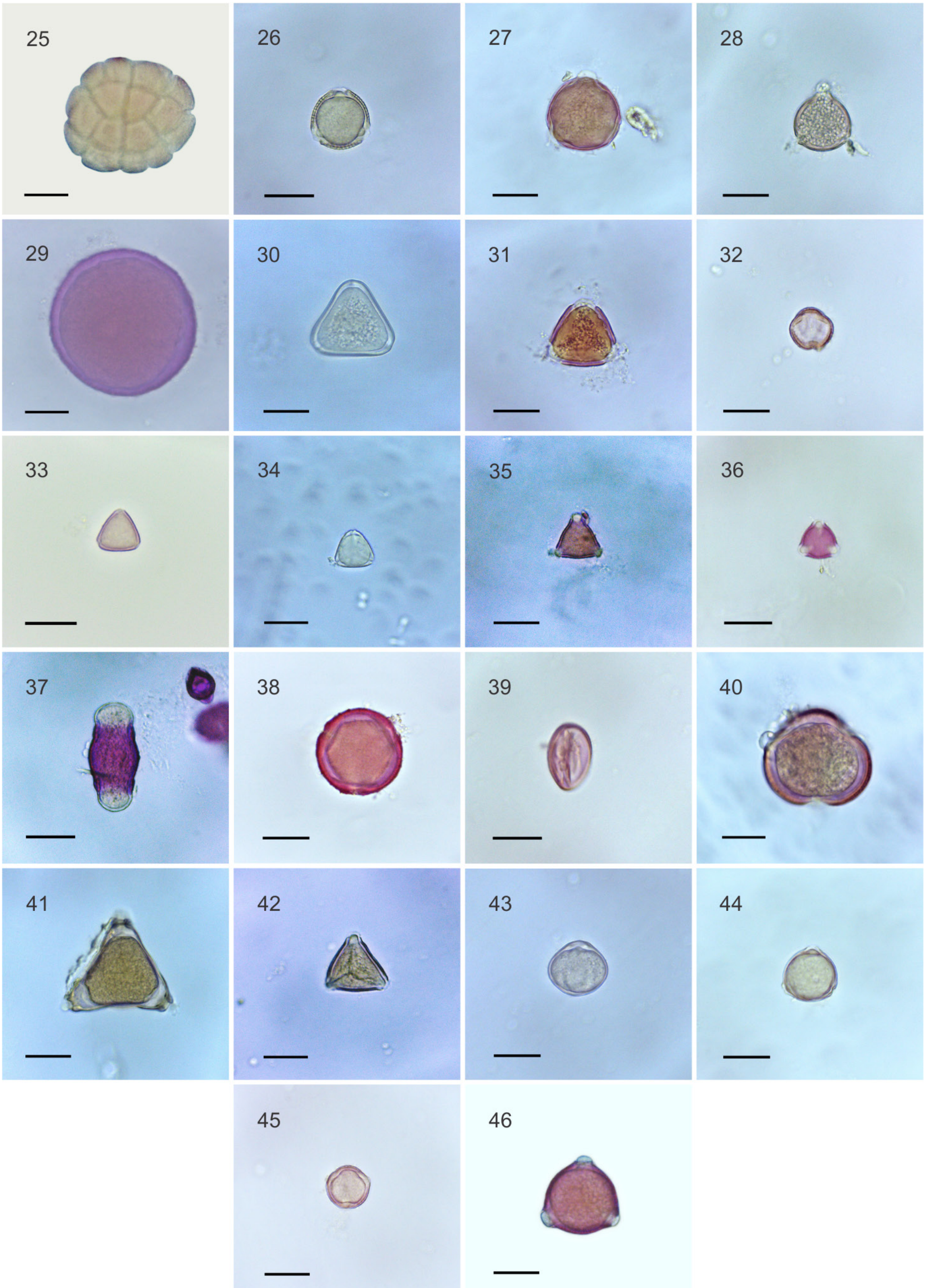

Figure 3. Optical photomicrographs of pollen types collected by *Melipona crinita*: / Fotomicrografías ópticas de tipos de polen recogidos por *Melipona crinita*: Fabaceae (Mimosoideae) *Samanea tubulosa* (25); Fabaceae (Papilionoideae) *Bowdichia virgilioides* (26); *Crotalaria retusa* (27); *Pterodon* (28); Lauraceae – *Persea americana* (29); Loranthaceae – *Struthanthus flexicaulis* (30); Lythraceae – *Cuphea* (31); Muntingiaceae – *Muntingia calabura* (32); Myrtaceae – *Psidium guajava* (33); *Syzygium malaccense* (34); Ochnaceae – *Cespedesia* (35); Oxalidaceae – *Averrhoa carambola* (36); Phyllanthaceae – *Hyeronima* (37); Rubiaceae – *Isertia* (38); Salicaceae – *Casearia* (39); Salicaceae – *Laetia* (40); Sapindaceae – *Allophylus* (41); *Cupania* (42); Solanaceae – *Solanum* (43); *Solanum rugosum* (44); *Solanum stramonifolium* (45); Verbenaceae - *Lantana camara* (46) (Bars = 20 μm).

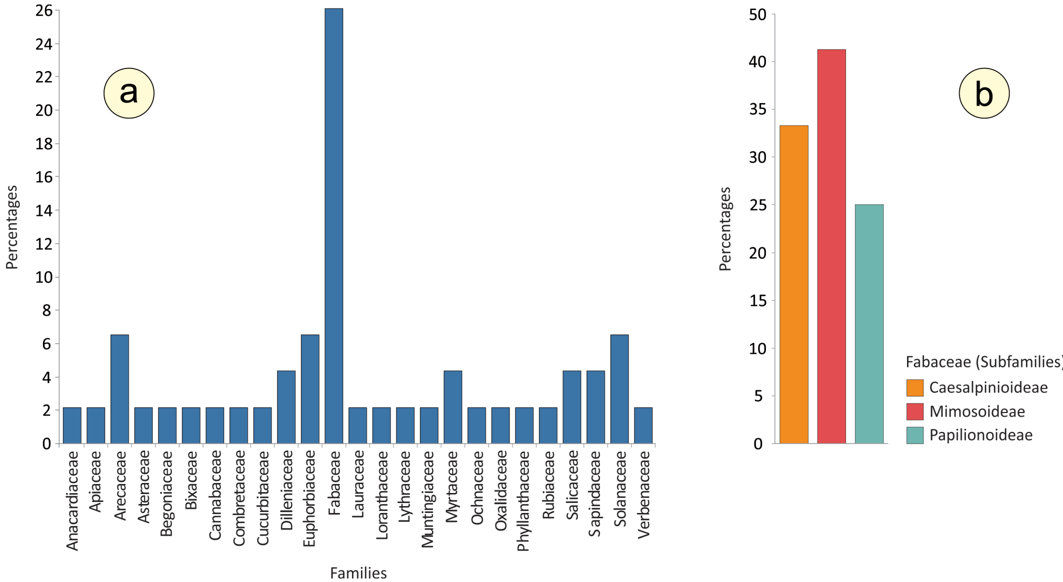

Figure 4. (a) Frequency of occurrence of botanical families visited by *Melipona crinita*, from April 2018 to March 2019. **(b)** Frequency of occurrence of the Mimosoideae, Caesalpinioideae and Papilionoideae subfamilies. / **(a)** Frecuencia de presencia de familias botánicas visitadas por *Melipona crinita*, de abril de 2018 a marzo de 2019. **(b)** Frecuencia de presencia de las subfamilias Mimosoideae, Caesalpinioideae y Papilionoideae.

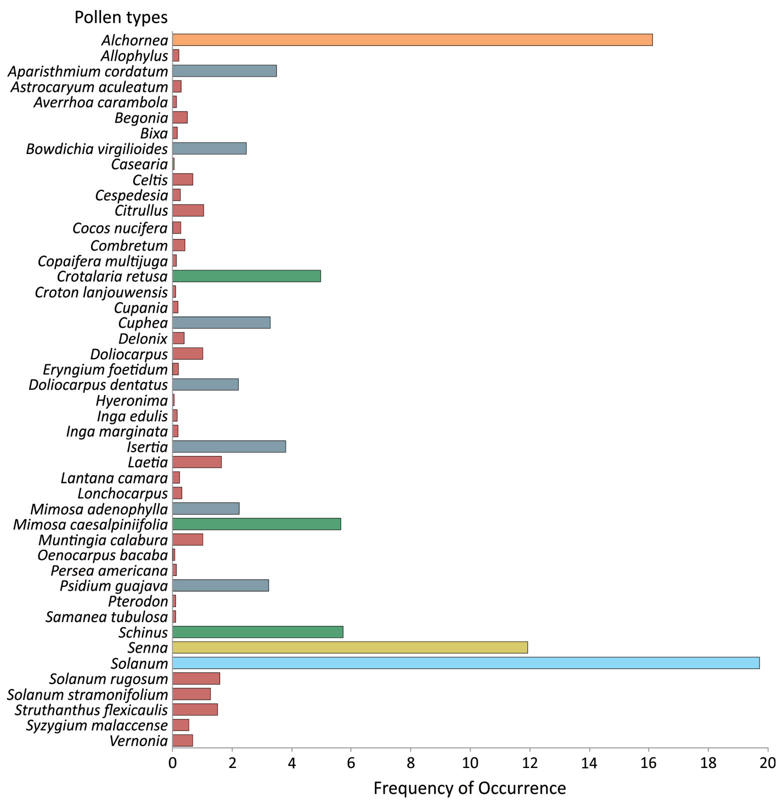

Figure 5. Frequency of occurrence of pollen types present in samples of *Melipona crinita*, from April 2018 to March 2019. / Frecuencia de presencia de tipos de polen presentes en muestras de *Melipona crinita*, de abril 2018 a marzo 2019.

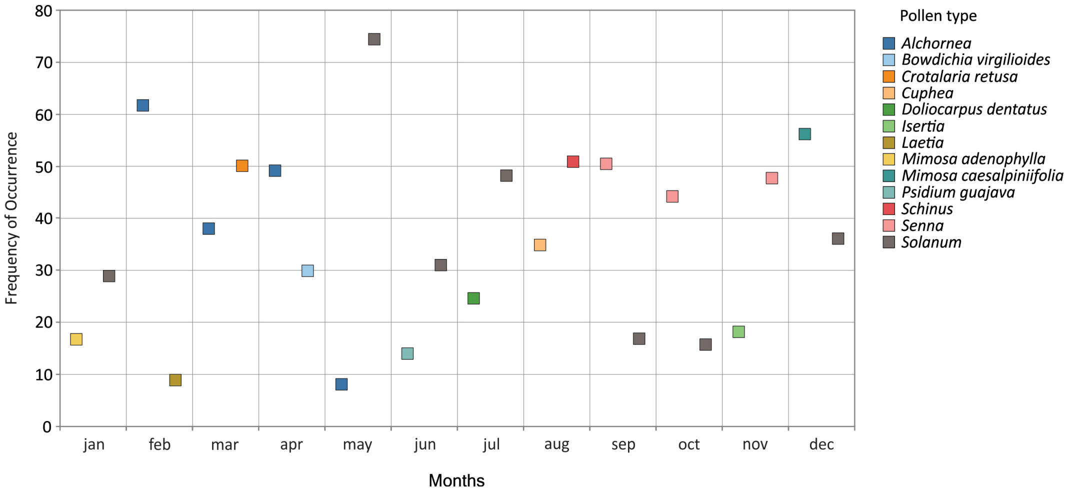

Figure 6. Frequency of occurrence of the most representative pollen types, within each sampled month. Only the two most abundant in each month are represented. / Frecuencia de presencia de los tipos de polen más representativos, dentro de cada mes muestreado. Sólo se representan los dos más abundantes de cada mes.

It was also verified that seasonality of the botanical species used by *M. crinita* for pollen collection showed wide variation during the study, with the pollen types being less seasonal, *Solanum*, which was observed in January, March, May, June, July, September, October, November and December; *Aparisthmium cordatum* (A.Juss.) Baill., in February, April, May, June, September, November and December. In addition, October, June and January were the months with the highest number of species offering pollen to *M. crinita* (Fig. 7).

From the total plants visited by *M. crinita*, 71.74% were wild, established in the forest fragments of the property and its surroundings and 28.26% agricultural in the agroforestry yard. In addition, 36.96% were trees; 34.78% shrubs; 15.22% herbs; 6.52% lianas and 6.52 sub-bushes (Fig. 8).

When the importance of these botanical groups was analyzed, about the amount of pollen offered, it was observed that wild trees and shrubs represented 64.80% of all pollen collected by *M. crinita*, during the studied period (Fig. 9).

Among the pollen types belonging to wild plants, the most frequent were *Solanum*, FO = 24.00%; *Alchornea*, FO = 19.63% and *Senna*, FO = 14.52%. The others had FO <10%. Among those related to cultivation species, *Schinus* was the main one, FO = 31.17%, followed by *M. caesalpiniifolia*, FO = 30.67% and *Psidium guajava* L., FO = 17.58%. The other taxons, as well as the pollen types of wild species, also presented FO <10%. What demonstrates the importance of these two botanical groups in the pollen diet of *M. crinita*.

Discussion

When individually evaluated each of the months sampled, it was observed that *M. crinita* collected resources from different species of agricultural and wild plants. Furthermore, this bee intensified its foraging activities on some plant species in certain periods (Fig. 6). Thus, the degree of specialization of *M. crinita* may be associated with the abundance of resources available throughout the year. Levins *B* index = 9.54; Levins *B'* standardized index = 0.10, which gives *M. crinita* the status of generalist floral visitor. We also identified that the pollen sources used by *M. crinita* represent 28.33% of the total plant species already recorded for *Melipona* throughout the Amazon region. In previous studies, a total of 60 botanical families visited by *Melipona* in the Amazon between 1977 and 2020 were recorded (Pimentel *et al.* 2021), of which 17 are used by *M. crinita* spoon floral resources (Fig. 10).

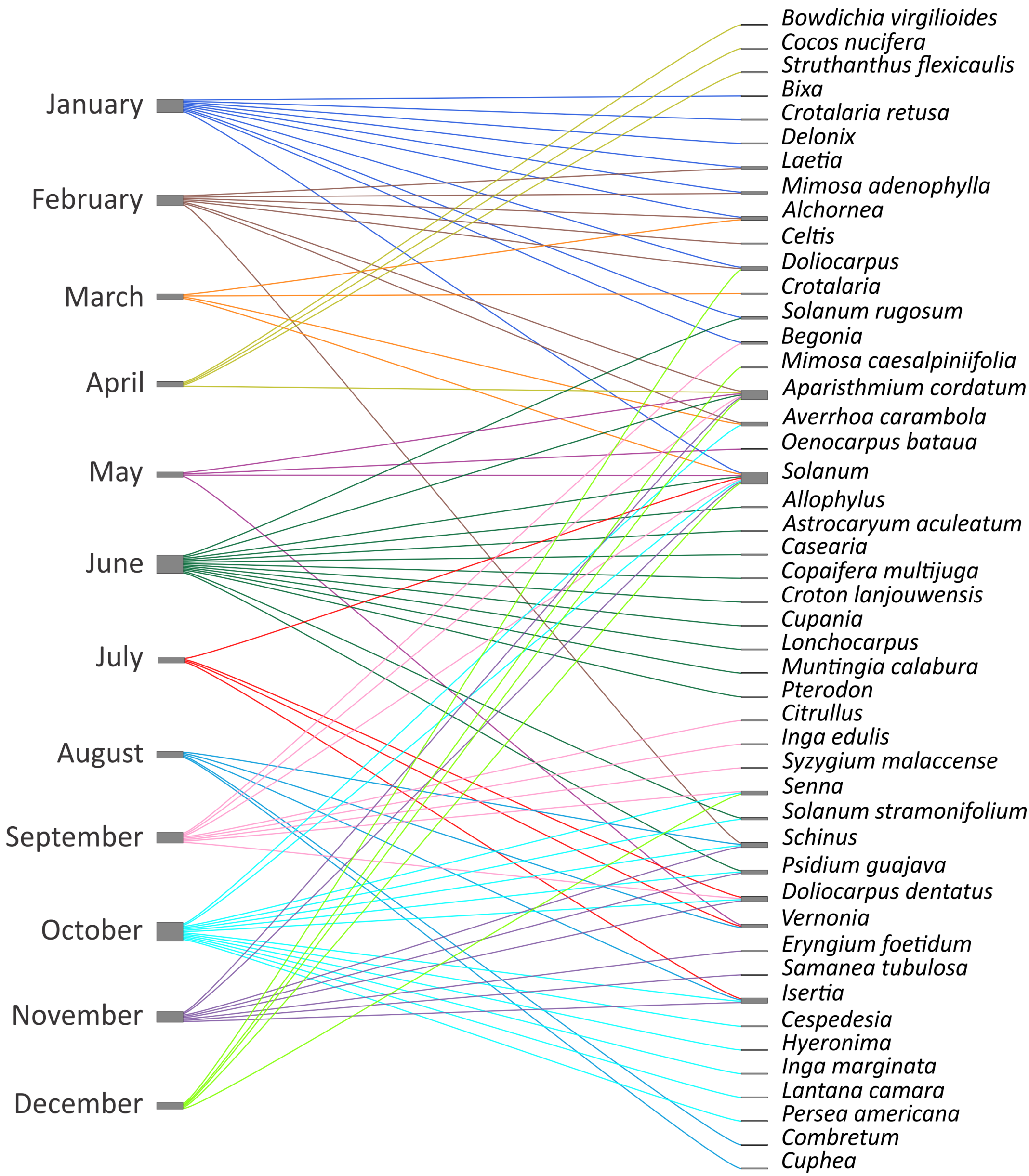

Figure 7. Distribution of the flowering period of the plants used by *Melipona crinita*, for pollen collection, from April 2018 to March 2019. / Distribución del periodo de floración de las plantas utilizadas por *Melipona crinita* para la recolección de polen, desde abril de 2018 hasta marzo de 2019.

Furthermore, we verified that Fabaceae (Mimosoideae) were the main suppliers of pollen resources for *M. crinita*, which has also been observed by several authors in palynological studies developed with other species of stingless bees and with *Apis mellifera* Linnaeus, 1758. As an example, Barros (1965); Absy and Kerr (1977); Absy *et al.* (1980); Ramalho *et al.* (1990); Marques-Souza (1996); Oliveira *et al.* (2009) and recently those by Costa *et al.* (2015); Correia *et al.* (2016); Correia and Peruquetti (2017); Absy *et al.* (2018); Nascimento *et al.* (2019); Correia *et al.* (2020); Pimentel *et al.* (2021) and Guimarães *et al.* (2021).

These records demonstrate that the pollen profile of *M. crinita* was strongly influenced by local conditions, as Fabaceae (Mimosoideae) is among the most exploited by stingless bees in number of species, due to their poliniferous potential (Ferreira *et al*. 2010; Freitas *et al*. 2013; Matos *et al*. 2014). Besides, in the Amazon, tree, herbaceous, shrub and lianescent leguminous represented 23% of the total species visited by bees (Oliveira *et al*. 2009). In the Acre forests, Fabaceae is the most abundant and diversified taxon, with long flowering periods (Araújo and Silva 2000; Daly and Silveira 2008; Medeiros *et al*. 2014). Thus, the high frequency of Fabaceae in the diet of *M. crinita*, may be related to the diversity of plants of this family in the studied area, showing that species of Fabaceae can be considered key plants for the meliponiculture of Acre.

The high presence of pollen types such as *Solanum* and *Alchornea* may be related to the fact that many plants of these genera occur in secondary formation forests, in the Amazon, and remain flowered several months a year, offering pollen in abundance (Absy and Kerr 1977; Absy *et al*. 1980; Lorenzi 2002; Silva *et al*. 2004; Webster 2004; Ferreira and Absy 2013). Other taxon with a high frequency of occurrence in pollen samples of *M. crinita*, such as *Schinus* and *M. caesalpiniifolia* are cited by many authors as important in the stingless bee diet, in different regions of Brazil (Moreti *et al*. 2002; Barth 2004; Martins *et al*. 2011; Novais *et al*. 2015; Correia *et al*. 2018; Haidamus *et al*. 2019).

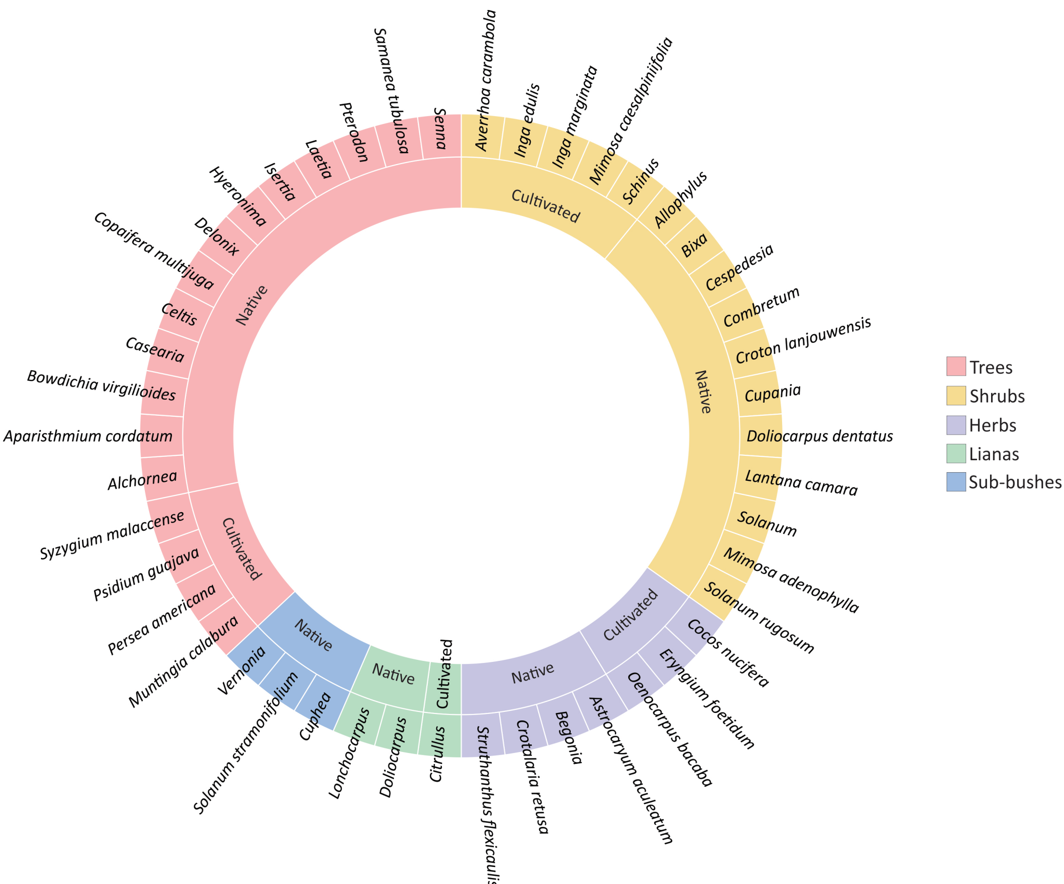

Figure 8. Frequency of growth habit and origin of plants visited by *Melipona crinita*, from April 2018 to March 2019. / Frecuencia de hábito de crecimiento y origen de las plantas visitadas por *Melipona crinita*, de abril de 2018 a marzo de 2019.

Although the results show that *M. crinita* prefers to collect pollen resources in some botanical species, Heinrich (1976), Ramalho *et al*. (1985), and Velthus (1992) pointed out that pollen types with (FO) inferior <10% can be considered secondary resources, especially when other plants are saturated by other pollinators or when flowering is reduced according to seasonal changes (Fig. 8). Furthermore, on some occasions, secondary sources move to a central position in the food supply (Novais and Absy 2013). Thus, it is possible that *M. crinita* adjusts its foraging activities to collect pollen according to the intensity of flowering, which may explain the difference in the number of plants visited by this bee, between the sampled months. However, the large number of species exploited by *M. crinita* for pollen collection may be related to the diversity of plants at the study place, which confirms the general behavior of this species of bee, as previously described by Pimentel *et al*. (2021).

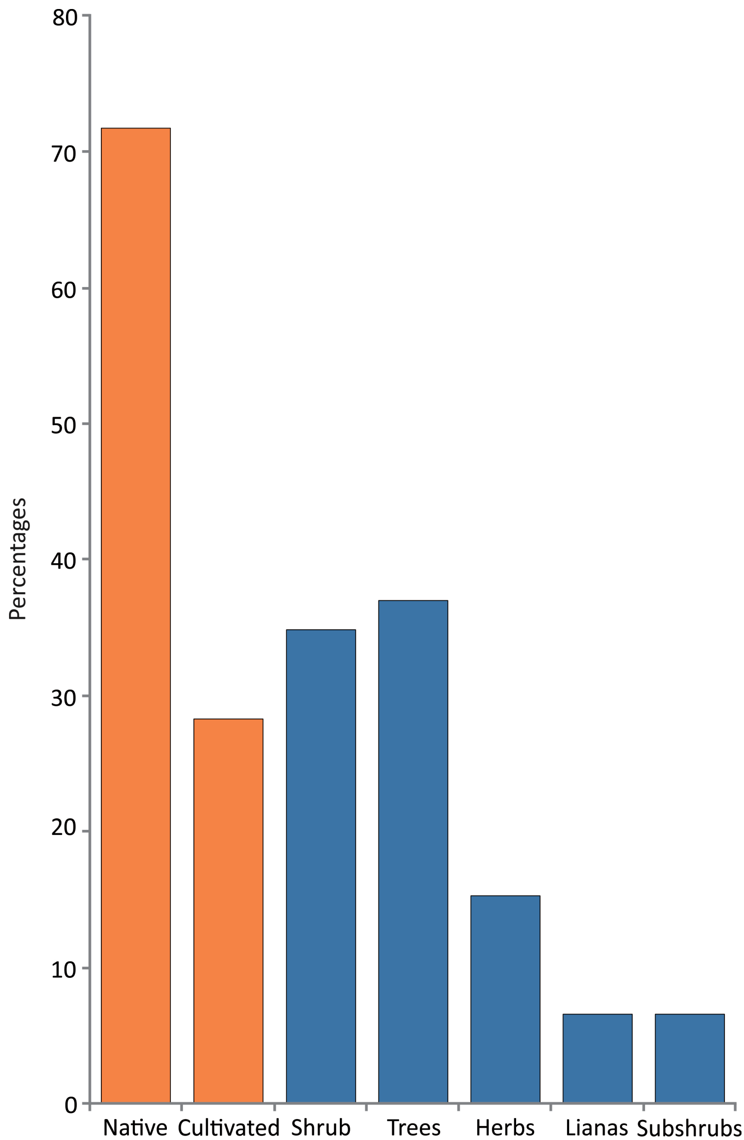

Figure 9. Frequency of pollen types collected by *Melipona crinita*, based on the origin and growth habit of each plant species. / Frecuencia de tipos de polen recolectados por *Melipona crinita*, según el origen y hábito de crecimiento de cada especie vegetal.

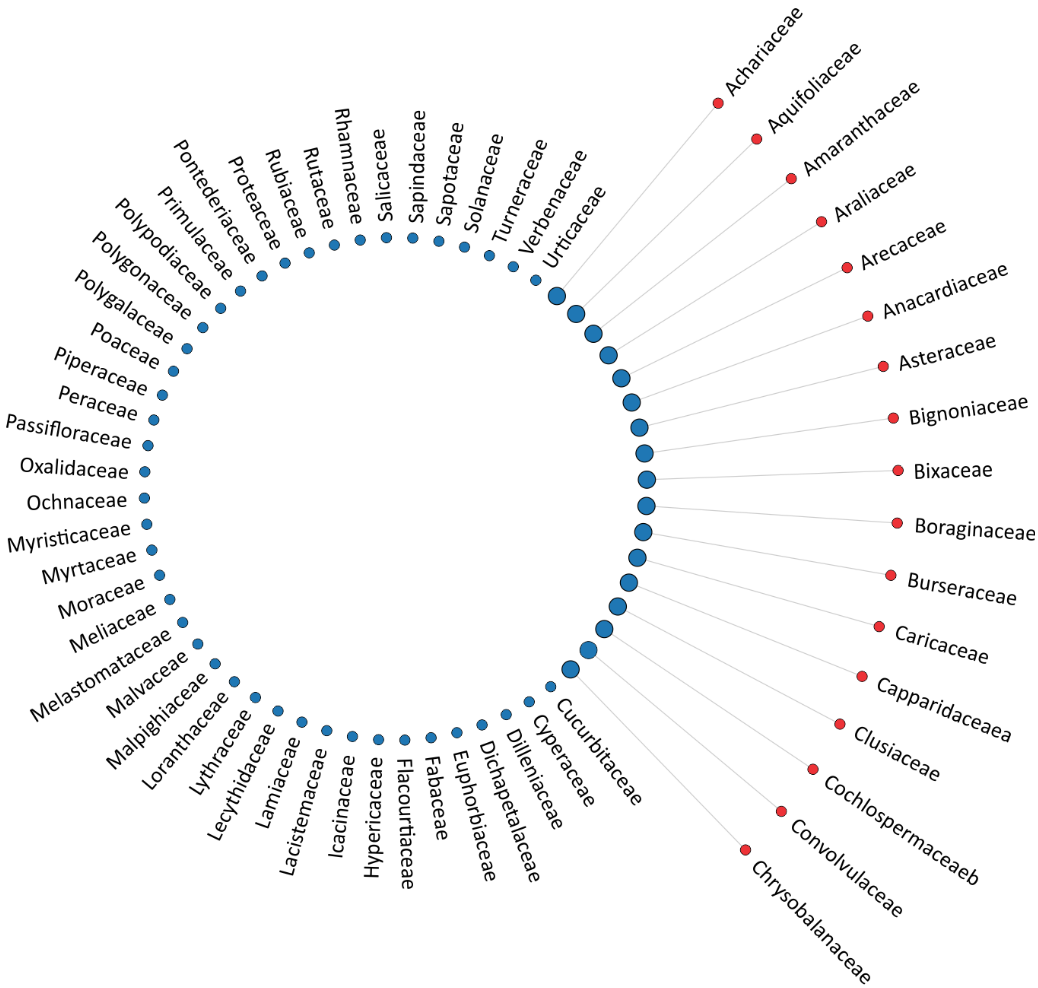

Figure 10. Blue dots - families visited by *Melipona* in the Amazon, between 1977 and 2020; red dots - families identified in this study as pollen sources for *Melipona crinita*; the lines between the red and blue dots indicate that the families identified in this study are part of those that are already known to provide floral resources for *Melipona* bees in the Amazon. The chart was built based on data from Pimentel *et al*. (2021). / Puntos azules - familias visitadas por *Melipona* en la Amazonía, entre 1977 y 2020; puntos rojos - familias identificadas en este estudio como fuentes de polen para *Melipona crinita*; las líneas entre los puntos rojo y azul indican que las familias identificadas en este estudio son parte de las que ya se sabe que proporcionan recursos florales para las abejas meliponas en la Amazonía. El gráfico fue construido con base en datos de Pimentel *et al*. (2021).

On the other hand, the low concentration of some pollen types may have occurred due to some plant species having a small production of pollen, due to the availability of this resource in the closeness of the meliponary, or due to the performance of foraging activities by the workers (Carvalho *et al*. 1999; Oliveira *et al*. 2009), or due the low attractiveness of some species, such as *Averrhoa carambola* L.; *Oenocarpus bacaba* Mart.; *Persea americana* Mill.; *Inga marginata* Willd.; *Inga edulis* Mart. and *Cocos nucifera* L. These plants are located a few meters from the meliponary and in large quantities, even though they had little relevance during the studied period, together they represented only 0.98% of all pollen sampled between April 2018 and March 2019. This fact corroborates the observations of Tasei (1973), that an unattractive and abundant species is always less visited than a very attractive and scarce flower.

As for the seasonality of plants used by *M. crinita* to collect resources, differences were observed between the results found in this study and the observed by Correia *et al*. (2018) with the species *M. eburnea* and Correia *et al*. (2020), with the *Melipona grandis* specie, both in the same area, in which the least seasonal pollen types were *Solanum*, *M. caesalpiniifolia*, *Eugenia jambolana* Lam. and *Manihot esculenta* Crantz; *Solanum*, *Cassia mimosoides* L., *M. caesalpiniifolia*, *Miconia* Ruiz & Pav. and *Mimosa pudica* L., respectively. This non-conformity probably reflects the annual variation in flowering of the species that occupy the study place, a phenomenon frequently observed in tropical forests (Wright and Cornejo 1990).

According to Moraes *et al*. (2020), pollen types present repeatedly in monthly samples are valuable food sources for bees. However, a diversified flowering over time, formed by species with mace flowering and species with multiple flowering, favors the formation of good beekeeping/meliponic pastures (Solomé and Orth 2003), what indicates that the meliponic species established in the study area have potential for the management of *M. crinita* for honey production.

Our hypothesis that *M. crinita* collects pollen resources mainly from wild trees and shrubs was also confirmed, as trees represented 41.18% of pollen collected by this bee during the study period and shrub, 23.62%. Correia *et al*. (2018) also verified that, similarly to what was observed in this study, of the plants visited by *M. eburnea*, 43.20% were trees and shrubs, established in the fragments of natural forest. Other surveys also point out that wild trees are the plant species most visited by stingless bees (Roubik *et al*. 1986; Martínez-Hernández *et al*. 1994; Ramalho 2004; Malagodi-Braga and Kleinert 2009; Obregon *et al*. 2013; Correia *et al*. 2020).

According to Ramalho (2004) and Absy *et al*. (2018), the predominance of trees as suppliers of floral resources to stingless bees occurs because these individuals collect pollen and nectar, preferably in large quantities, which is not generally observed in other botanical groups. Thus, the conservation of these plants is essential for the successful management of *M. crinita* in meliponaries.

Conclusion

Melipona crinita collected pollen mainly from Fabaceae – Mimosoideae, Arecaceae and Euphorbiaceae. This bee also visited 17 of the 60 botanical families in the Amazon known to provide pollen resources for *Melipona.* Among the identified pollen types, *Solanum* was the one that presented the highest frequency of occurrence in the studied period, being also the least seasonal. Among the plants used by *M. crinita* for pollen collection, most were wild trees and shrubs. Furthermore, we checked that *M. crinita* possibly adjusts pollen foraging according to the supply of this resource throughout the year.

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Literature Cited

Absy, M.L. and Kerr, W.E. (1977) Algumas plantas visitadas para obtenção de pólen por operárias de *Melipona seminigra merrilae* em Manaus. *Acta Amazonica*, *7*(3): 309-315. https://doi.org/10.1590/1809-43921977073309

Absy, M., Bezerra, E.B. and Kerr, W.E. (1980) Plantas nectaríferas utilizadas por duas espécies de *Melipona* da Amazônia. *Acta Amazonica*, *10*(2): 271-281. https://doi.org/10.1590/1809-43921980102271

Absy, M.L., Rech, A.R. and Ferreira, M.G. (2018) Pollen Collected by Stingless Bees: A Contribution to Understanding Amazonian Biodiversity. *In*: P. Vit., S. R. M., Pedro, and D. W. Roubik (Eds.), *Pot-Pollen in Stingless Bee Melittology* (pp. 29-46). Berlim: Springer International Publishing.

Almeida, M. and Almeida, C.V. (2014) *Morfologia do caule de plantas com sementes*. Piracicaba: USALQ/USP, 155 pp.

Araújo, H.J.B. and Silva, I.G. (2000) *Lista de espécies florestais do Acre (ocorrência com base em inventários florestais)*. Rio Branco: Embrapa-CPAF/AC, 77 pp.

Barros, M.B. (1965) *Apicultura*. Rio de Janeiro: Edições Serviço de informação agrícola, 257 pp.

Barth, O.M. (2004) Melissopalynology in Brazil: a review of pollen analysis of honeys, propolis and pollen loads of bees. *Scientia Agricola*, *61*(3): 342-350. https://doi.org/10.1590/S0103-90162004000300018

Brown, J.C. and Albrecht, C. (2001) The effect of tropical deforestation on stingless bees of the genus *Melipona* (Insecta: Hymenoptera: Apidae: Meliponini) in central Rondonia, Brazil. *Journal of Biogeography*, *28*(5): 623-634. https://doi.org/10.1046/j.13652699.2001.00583.x

Camargo, J.M.F., Pedro S.R.M. and Melo, G.A.R. (2013) Meliponini Lepeletier, 1836. *In*: Moure, J. S., Urban, D. and Melo, G. A. R. (Orgs). *Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region*. *online version*. Retrived from: http://www.moure.cria.org.br/catalogue. Accessed date: 20 December, 2022.

Carvalho, C.A.L., Marchini, L.C. and Ros, P.B. (1999) Fontes de pólen utilizados por *Apis mellifera* L. e algumas espécies de Trigonini (Apidae) em Piracicaba (SP). *Bragantia*, *58*(1): 49-56. https://doi.org/10.1590/S0006-87051999000100007

Carvalho-Zilse, G.A., Silva, C.G. N., Zilse, N., Vilas-Boas, H.C., Silva, A.C., Laray, J.P., Freire, D.C.B. and Kerr, W.E. (2005) *Criação de abelhas sem ferrão*. Manaus: ProVárzea/IBAMA, 27 pp.

Colinvaux, P.A., Oliveira, P.E. and Moreno, J.E. (1999) *Amazon Pollen Manual and Atlas*. New York: Harwood Academic Press, 344 pp.

Correia, F.C.S. and Peruquetti, R.C. (2017) *Nicho polínico da abelha uruçu beiço*. Saarbrücken: Novas Edições Acadêmicas, 65 pp.

Correia, F.C.S., Ferreira, M.G., Peruquetti, R.C. and Gomes, F.A. (2020) Trophic resources collected by *Melipona grandis* Guérin, 1844 (Apidae: Meliponina) in rural area of Rio Branco, Acre – Brazil. *Oecologia Australis*, *24*(3): 676-687. https://doi.org/10.4257/oeco.2020.2403.11

Correia, F.C.S., Peruquetti, R.C. and Ferreira, M.G. (2018) Análise do nicho trófico e da influência das precipitações no forrageamento de *Melipona eburnea* Friese (Apidae: Meliponina) criadas no Acre, Brasil. *Entomobrasilis*, *11*(1): 13-19. https://doi.org/10.12741/ebrasilis.v11i1.711

Correia, F.C.S., Peruquetti, R.C., Ferreira, M.G. and Carvalho, Y.K. (2016) Abundância, distribuição espacial de ninhos de abelhas sem ferrão (Apidae: Meliponini) e espécies vegetais utilizadas para nidificação em um fragmento de floresta secundária em Rio Branco, Acre. *EntomoBrasilis*, *9*(3): 163-168. https://doi.org/10.12741/ebrasilis.v9i3.613

Cortopassi-Laurino, M. (2004) Seasonal strategies of harvesting by *Melipona* sp. in the Amazon region. *In*: Proceedings of the 8th IBRA International Conference on Tropical Bees and VI Encontro Sobre Abelhas (pp. 258-263). Ribeirão Preto, Brazil.

Cortopassi-Laurino, M., Imperatriz-Fonseca, V.L., Roubik, D.W., Dollin, A., Heard, T., Aguilar, I. B., Venturieri, G.C., Eardley, C. and Nogueira-Neto, P. (2006) Global meliponiculture: challenges and opportunities. *Apidologie*, *37*(2): 275-292. https://doi.org/10.1051/apido:2006027

Costa, S.N., Alves, R.M.O., Carvalho, C.A.L. and Conceição, P.J. (2015) Fontes de pólen utilizadas por *Apis mellifera* Latreille na Região Semiárida. *Ciência Animal Brasileira*, *16*(4): 491-497. https://doi.org/10.1590/1089-6891v16i425538

Daly, D.C. and Silveira, M. (2008) *Primeiro catálogo da flora do Acre, Brasil/First catalogue of the flora of Acre, Brazil*. Rio Branco: EDUFAC, 555 pp.

De Klerk, P. and Joosten, H. (2007) The difference between pollen types and plant taxa: a plea for clarity and scientific freedom. *Eiszeitalter und Gegenwart Quaternary Science Journal*, *56*(3): 162-171. https://doi.org/10.3285/eg.56.3.02

Ferreira, M.G. and Absy, M.L. (2013) Pollen analysis of the post-emergence residue of *Melipona* (*Melikerria*) *interrupta* Latreille (Hymenoptera: Apidae) bred in the central Amazon region. *Acta Botanica Brasilica*, *27*(4): 709-713. https://doi.org/10.1590/S0102-33062013000400009

Ferreira, M.G., Manente-Balestieri, F.C.D. and Balestieri, J.B.P. (2010) Pólen coletado por *Scaptotrigona depilis* (Moure) (Hymenoptera, Meliponini), na região de Dourados, Mato Grosso do Sul, Brasil. *Revista Brasileira de Entomologia*, *54*(2): 258-262. https://doi.org/10.1590/S0085-56262010000200008

Freitas, A.S., Arruda, V.A.S., Almeida-Muradian, L.B. and Barth, O.M. (2013) The botanical profiles of dried bee pollen loads collected by *Apis mellifera* (Linnaeus) in Brazil. *Sociobiology*, *60*(1): 56-64. https://doi.org/10.13102/sociobiology.v60i1.56-64

Gliessman, S.R. (2000) *Agroecologia: processos ecológicos em agricultura sustentável*. Porto Alegre: UFRGS, 653 pp.

Guimarães, J.T.F., Costa, L., Zappi, D.C., Batista Junior, W.F., Lopes, K.F., Alves, R.C.O., Romeiro, L.A., Silva, E.F., Carreira, L.M.M., Rodrigues, T.M., Giannini, T.C., Imperatriz-Fonseca, V.L. and Barth, O.M. (2021) Foraging preferences of the native stingless bee *Melipona seminigra pernigra* (Apidae: Meliponini) in campo rupestre on canga of Serra dos Carajás, southeastern Amazonia. *Biota Neotropica*, *21*(1): e20201004. https://doi.org/10.1590/1676-0611-BN-2020-1004

Haidamus, S.L., Lorenzon, M.C.A., Koshiyama, A.S. and Tassinari, W.S. (2019) Floral diversity in different types of honey. *Brazilian Archives of Biology and Technology*, *62*: e19180241. https://doi.org/10.1590/1678-4324-2019180241

Heinrich, B. (1976) The foraging specializations of individual bumblebees. *Ecological Monographs*, *46*(2): 105-128. https://doi.org/10.2307/1942246

Jones, G.D. (2012) Pollen extraction from insects. *Palynology*, *36*(1): 86-109. https://doi.org/10.1080 / 01916122.2011.629523

Jones, G.D. and Bryant, V.M. (1996) Melissopalynology. *In*: J. Jansonius, & D. C. McGregor (Eds.), *Palynology, principles and applications* (pp. 933–938). Salt Lake City: AASP Found.

Kerr, W.E., Carvalho, G.A., Silva, A.C. and Assis, M.G.P. (2005) Aspectos pouco mencionados da biodiversidade amazônica. *Mensagem Doce*, *80*: 46-60.

Krebs, C.J. (1999) *Ecological Methodology*. Menlo Park: Addison Wesley Educational Publishers, 620 pp.

Lorenzi, H. (2002) *Árvores brasileiras: Manual de identificação e cultivo de plantas arbóreas do Brasil*. Nova Odessa: Instituto Plantarum, 384 pp.

Marques-Souza, A.C. (1996) Fontes de pólen exploradas por *Melipona compressipes manaosensis* (Apidae: Meliponinae), abelha da Amazônia Central. *Acta Amazonica*, *26*(1-2): 77-86. https://doi.org/10.1590/1809-43921996261086

Malagodi-Braga, K.S. and Kleinert, A.M.P. (2009) Comparative analysis of two sampling techniques for pollen gathered by *Nannotrigona testaceicornis* Lepeletier (Apidae, Meliponini). *Genetics and Molecular Research*, *8*(2): 596-606. https://doi.org/10.4238/vol8-2kerr014

Martínez-Hernández, E., Cuadriello-Aguilar, J.I., Ramírez-Arriaga, E., Medina-Camacho, M., Sosa-Nájera, M.S. and Melchor-Sánchez, J.E. (1994) Foraging of *Nannotrigona testaceiconis, Trigona* (*Tetragonisca*) *angustula, Scaptotrigona mexicana* and *Plebeia* sp. in the Tacaná region, Chiapas, Mexico. *Grana*, *33*(4-5): 205-217. https://doi.org/10.1080/00173139409429001

Martins, A.C.L., Rêgo, M.M.C., Carreira, L.M.M. and Albuquerque, P.M.C. (2011) Espectro polínico de mel de tiúba (*Melipona fasciculata* Smith, 1854, Hymenoptera, Apidae). *Acta Amazonica*, *41*(2): 183-190. https://doi.org/10.1590/S0044-59672011000200001

Matos, V.R., Alencar, S.M. and Santos, F.A.R. (2014) Pollen types and levels of total phenolic compounds in propolis produced by *Apis mellifera* L. (Apidae) in an area of the semiarid region of Bahia, Brazil. *Anais da Academia Brasileira de Ciências*, *86*(1): 407-418. https://doi.org/10.1590/0001-376520142013-0109

Medeiros, H., Obermüller, F.A., Daly, D.C., Silveira, M., Castro, W. and Forzza, R.C. (2014) Botanical advances in Southwestern Amazonia: The flora of Acre (Brazil) five years after the first catalogue. *Phytotaxa*, *177*(2): 101-117. https://doi.org/10.11646/phytotaxa.177.2.2

Moraes, J.I.S., Lopes, M.T.R., Ferreira-Gomes, R.L., Lopes, A.C.A., Pereira, F.M., Souza, B.A. and Pereira, L.A. (2020) Bee flora and use of resources by africanized bees. *Floresta e Ambiente*, *27*(3): e20170083. https://doi.org/10.1590/2179-8087.008317

Moreti, A.C.C., Marchini, C., Souza, V.C. and Rodrigues, R.R. (2002) *Pollen atlas of melliferous plants*. Rio de Janeiro: Papel e Virtual, 44 pp.

Nascimento, A.C.S., Martins, M.I.F.P.O., Gomes, M.C.R.L., Ferreira-Ferreira, J., Sousa, I.S., Franco, C.L.B. and Souza, M.J.S. (2019) *Sociobiodiversidade da reserva de desenvolvimento sustentável Amanã (1998–2018): 20 anos de pesquisas*. Tefé: Instituto de Desenvolvimento Sustentável Mamirauá, 352 pp.

Novais, J.S. and Absy, M.L. (2013) Palynological examination of the pollen pots of native stingless bees from the Lower Amazon region in Pará, Brazil. *Palynology*, *37*(2): 218-230. https://doi.org/10.1080/01916122.2013.787127

Novais, J.S., Garcêz, A.C.A., Absy, M.L. and Santos, F.A.R. (2015) Comparative pollen spectra of *Tetragonisca angustula* (Apidae, Meliponini) from the lower Amazon (N Brazil) and caatinga (NE Brazil). *Apidologie*, *46*(4): 417-431. https://doi.org/10.1007/s13592-014-0332-z

Obregon, D., Rodríguez, C.A., Fermín, J. and Nates-Parra, C.G. (2013) Botanical Origin of Pot-Honey from *Tetragonisca angustula* Latreille in Colombia. *In*: P. Vit., S. R. M. Pedro, & D. W. Roubik (Eds.), *Pot-Honey: um legacy of stingless bees* (pp. 337–348). New York: Springer International Publishing.

Oliveira, M.L. and Nogueira, D.S. (2023) *Apidae in Catálogo Taxonômico da Fauna do Brasil*. PNUD. Retrived from: http://fauna.jbrj.gov.br/fauna/faunadobrasil/5076. Accessed date: 10 Jan. 2023.

Oliveira, F.F., Richers, B.T.T., Silva, J.R., Farias, R.C. and Matos, T.A.L. (2013) *Guia Ilustrado das abelhas sem ferrão das Reservas Amanã e Mamirauá, Brasil (Hymenoptera, Apidae, Meliponini).* Tefé: IDSM, 267 pp.

Oliveira, F.P.M., Absy, M.L. and Miranda, I.S. (2009) Recurso polínico coletado por abelhas sem ferrão (Apidae, Meliponinae) em um fragmento de floresta na região de Manaus-Amazonas. *Acta Amazonica*, *39*(3): 505-518. https://doi.org/10.1590/S0044-59672009000300004

Pimentel, A.D.A., Absy, M.L., Rech, A.R. and Abreu, V.H.R. (2021) Polliniferous flora foraged by *Melipona* bees along the Rio Negro in the Brazilian Amazon. *Grana*, *60*(5): 1-13. https://doi.org/10.1080/00173134.2021.1882555

Ramalho, M. (2004) Stingless bees and mass flowering trees in the canopy of Atlantic Forest: a tight relationship. *Acta Botanica Brasilica*, *18*(1): 37-47. https://doi.org/10.1590/S0102-33062004000100005

Ramalho, M., Imperatriz-Fonseca, V.L., Kleinert-Giovannni, A. and Cortopassi-Laurino, M. (1985) Exploitation of floral resources by *Plebeia remota* Holmberg (Apidae, Meliponinae). *Apidologie*, *16*(3): 305-330. https://doi.org/10.1051/apido:19850306

Ramalho, M., Kleinert-Giovannini, A. and Imperatriz-Fonseca, V.L. (1990) Important bee plants for stingless bees (*Melipona* and *Trigonini*) and africanized honey bees (*Apis mellifera*) in neotropical habitats: a review. *Apidologie*, *21*(5): 469-488. https://doi.org/10.1051/apido:19900508

Roubik, D.W. (1989) *Ecology and natural history of tropical bees*. Cambridge: Cambridge University Press, 514 pp.

Roubik, D.W., Moreno, J.E., Vergara, C. and Wittmann, D. (1986) Sporadic food competition with the African honey bee: projected impact on Neotropical social bees. *Journal of Tropical Ecology*, *2*(2): 97-111. https://doi.org/10.1017/S0266467400000699

Silva, A.C., Kinupp, V.F., Absy, M.L. and Kerr, W.E. (2004) Pollen morphology and study of the visitors (Hymenoptera, Apidae) of *Solanum stramoniifolium* Jacq. (Solanaceae) in Central Amazon. *Acta Botânica Brasilica*, *18*(3): 653-657. https://doi.org/10.1590/S0102-33062004000300022

Solomé, J.A. and Orth, A.I. (2003) Flora apícola catarinense e sua ação sobre as colmeias. *Mensagem Doce*, 71. Retrived from: https://www.apacame.org.br/mensagemdoce/71/artigo3.htm. Accessed date: 22 December, 2022.

Tasei, J.N. (1973) Le comportement de nidification chez *Osmia* (*Osmia*) *cornuta* Latr. et *Osmia* (*Osmia*) *rufa* L. (Hymenoptera, Megachilidae). *Apidologie*, *4*(3): 195-225. https://doi.org/10.1051/apido:19730301

Velthus, H.H.W. (1992) Pollen digestion and the evolution of sociality in bees. *Bee World*, *73*(2): 77-89. https://doi.org/10.1080/0005772X.1992.11099119

Venturieri, G.C., Raiol, V.F.O. and Pereira, C.A.B. (2003) Avaliação da introdução da criação racional de *Melipona fasciculata* (Apidae: Meliponina), entre os agricultores familiares de Bragança - PA, Brasil. *Biota Neotrópica*, *3*(2): 1-7. https://doi.org/10.1590/S1676-06032003000200003

Webster, G. (2004) Euphorbiaceae. *In*: N. Smith., S.A. Mori., A. Henderson., D.W. Stevenson, & S.V. Heald. (Eds.), *Flowering plants of the Neotropics* (pp. 146-150). Princeton: University Press.

Wright, S.J. and Cornejo, F.H. (1990) Seasonal drought and leaf fall in a tropical forest. *Ecology*, *71* (3): 1165-1175. https://doi.org/10.2307/1937384