Acta Botanica Brasilica, 2022, 36: e20220205
doi: 10.1590/1677-941X-ABB-2022-0205

Original article

Pollen profile of bee pollen from semiarid Northeastern Brazil

Viviane Miranda Karam[1], Tania Maria Sarmento Silva[2] and Francisco de Assis Ribeiro dos Santos[1*]

Received: August 10, 2022
Accepted: October 11, 2022

ABSTRACT

The Northeastern Brazil has xerical vegetation with different biomes. Its botanical heterogeneity represents shelter for diverse fauna. The region is rich in bees, which demand the resources offered by the plants, and provide pollination services. Bee pollen has been used as a beneficial food source for humans due to its high nutritional content and being a natural antioxidant. Pollen analysis can determine the plant species visited by bees, using them as the source of pollen supply. This study aimed to identify the main pollen types present in the pollen collected by *Apis mellifera* in the Northeastern Brazil and to define its botanical affinity. Commercial bee pollen samples produced in the region were treated by acetolysis method, mounted on slides, and the frequency of occurrence was estimated for each type of pollen. It was possible to distinguish 113 pollen types belonging to 35 botanical families, distributed in 92 genera. Fabaceae and Asteraceae were the families that most contributed to pollen types. Pollen types of *Cocos nucifera* and *Myrcia* were found in more than 50% of the samples. The families Arecaceae and Fabaceae showed high beekeeping potential. There is a striking similarity between the pollen samples from the states of Pernambuco and Rio Grande Norte.

Keywords: Melittopalynology, Bee product, Bee plants.

Introduction

The Northeastern Brazil has a territorial area that corresponds to 18.2% of the national territory and includes the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará, Piauí, and Maranhão. It's different geographic and climatic characteristics allow this region to encompass four biomes: Amazonia, Caatinga, Cerrado, and Atlantic Forest (IBGE 2019), showing high botanical variation, with approximately 11,740 plant species belonging to 2,056 genera and 212 families (Flora do Brasil 2020).

This high flora diversity reported for the Northeastern region, along with favorable climatic conditions, makes this region highly suitable for beekeeping, with the sustainability of bees helping forest conservation. Therefore, beekeeping is an economic and ecological alternative for the conservation of natural resources (Souza 2007).

In this context, *Apis mellifera* L. is a species that stands out because of its ability to adapt to different environments, and one of the factors that may contribute to this ability is its generalist behavior. *A. mellifera* has a broad foraging habit and does not prefer any specific group of plants as food, foraging all the flowering species available in the landscape

1 Programa de Pós-graduação em Botânica, Universidade Estadual de Feira de Santana, 44036-900, Feira de Santana, BA, Brazil
2 Laboratório de Bioprospecção Fitoquímica, Universidade Federal Rural de Pernambuco, 52171-900, Recife, PE, Brazil

* Corresponding author: f.a.r.santos@gmail.com

(Oliveira & Santos 2014), covering a wide foraging area in search of pollen and nectar, and encompassing a variety of plant groups (Proctor *et al*. 1996; Santos *et al*. 2006; Köppler *et al*. 2007; Muniz & Brito 2007). However, the source of pollen directly influences the nutritional value of resources (Andrada & Tellería 2005).

During the collection of pollen grains, honey bees agglutinate and mix them with nectar and salivary enzymes, thus forming bee pollen (Brasil 2001), which is stored in the cells of the honeycombs (Camazine 1993; Brasil 2001; Almeida-Muradian *et al*. 2005). In the hive, pollen is essential because it is the primary source of proteins necessary for the survival of bees, in addition to having lipids, minerals, and vitamins needed for feeding the larvae and for the development of the bees that have recently emerged (Baldi *et al*. 2004).

Furthermore, bee pollen is an interesting nutritional source not only for bees but also for humans (Pascoal *et al*. 2014). It has even been called the "only perfectly complete food" because it contains all the essential amino acids necessary for the human body (Silva *et al*. 2006). Bee pollen also has bioactive compounds, which positively affect human health; is considered a "functional food" (Mărgăoan *et al*. 2019), including about 200 different substances; and is significantly rich in natural antioxidants (Komosinska-Vassev *et al*. 2015). This implies that an increasing number of studies have focused on the composition of bee pollen and its use as a nutritional supplement for the human diet leading to development of a favorable trade system for the consumption of this product and the beekeeping industry (Barreto *et al*. 2006).

Considering that bee pollen is an essential food for bees and an important nutritional source for man, the importance of studies that contribute to the knowledge of pollen flora throughout the Northeastern Brazil arises. Therefore, this research aimed to evaluate the botanical profile of bee pollen produced in this region, to provide information that contributes to beekeepers in the elaboration of management plans, and to help them in the indication of the most productive sources for the hives.

Material and methods

Study area

The Northeast region of Brazil (Fig. 1) is the third-largest region in the country (1,552,175,412 km^2) and incorporates the largest number of states (nine). It is divided into four subregions based on its edaphological characteristics:

Figure 1. Northeastern Brazil (in grey) from where the bee pollen samples were obtained. The states: BA=Bahia, SE=Sergipe, AL=Alagoas, PE=Pernambuco, PB=Paraíba; RN=Rio Grande do Norte, CE=Ceará, and PI=Piauí.

Meio-Norte, Agreste, Sertão, and Zona da Mata. Furthermore, its vegetation encompasses four biomes: Amazonia, Caatinga, Cerrado, and Atlantic Forest, which allows the region to have a high richness of varied botanical species.

Bee pollen samples

The samples of bee pollen used in this research were produced in several areas of the Northeastern Brazil. For this reason, beekeepers' associations and/or cooperatives established throughout the region and municipal agricultural departments were contacted. In addition, samples were acquired by participating in congresses and meetings focused on beekeeping held in the northeastern states of Brazil, and from markets and natural product stores. A total of 28 samples of dehydrated bee pollen from different Northeastern states were used, distributed in the following way: Alagoas (2), Bahia (12), Ceará (2), Paraíba (2), Pernambuco (3), Piauí (2), Rio Grande do Norte (3), and Sergipe (2). Samples from the state of Maranhão were not included in this study.

Pollen analysis

Bee pollen analysis was performed following the method proposed by Alvarado & Delgado-Rueda (1985), with some modifications Novais & Absy (2013) using the acetolysis method (Erdtman 1960). The sediment was mounted on slides in glycerin jelly and sealed with paraffin wax. To perform qualitative and quantitative analyses of the pollen spectrum, five permanent slides were prepared for each sample.

Our study was based on the morphological characteristics of each pollen type to identify specific taxon (e.g., a species, a group of species, a genus, or a family) to which the bee pollen samples belonged. Thus, pollen type identification was carried out using a light microscope by referring to scientific articles, specialized palynological catalogs (Roubik & Moreno 1991; Carreira *et al*. 1996; Melhem *et al*. 2003; Lima *et al*. 2008; Bauermann *et al*. 2013; Silva *et al*. 2016), and the pollen library of the Laboratory of Plant Micromorphology, Department of Biological Sciences, State University of Feira de Santana (LAMIV/DCBio/UEFS), as proposed by Santos (2011).

To estimate the percentage of occurrence of each pollen type in the sample set, the frequency of occurrence (FO) was calculated. For this, a minimum of 500 pollen grains were counted in each sample (Bucher *et al*. 2004). Based on FO values, pollen types were classified according to the following classes: very frequent (>50%), frequent (21-50%), low frequent (10-20%), and rare (<10%) (Jones & Bryant Jr. 1996).

Through quantitative analysis, only pollen types with an FO value greater than 10% per sample were considered as "important sources" of pollen (Imperatriz-Fonseca *et al*. 1994), while those with FO value between 1%-10% were regarded as "secondary sources." Furthermore, samples in which the predominance of a particular pollen type exceeded 80% were deemed to be monofloral products (Campos *et al*. 2008).

Statistical analysis

The similarity between the samples was analyzed using the Jaccard coefficient, as it does not consider the shared absences as evidence of similarity. Analysis was performed using the PAST software - Paleontological Statistics, version 3.15 - (Hammer *et al*. 2001).

Results

According to the analyzed pollen spectra, 113 pollen types were distinguished in *A. mellifera* bee pollen produced in the Northeastern Brazil. Pollen types were associated with 35 botanical families, and Fabaceae contributed the highest number of pollen types (29), followed by Asteraceae (14), Rubiaceae (6), Anacardiaceae (5), Arecaceae (5), Euphorbiaceae (5), Myrtaceae (4), Malvaceae (3), Convolvulaceae (2), Malpighiaceae (2), and Salicaceae (2). The remaining families registered one pollen type.

Four pollen types were present in more than 50% of the samples and were classified as very frequent (VF): *Cocos nucifera* (Arecaceae), *Mimosa pudica/sensitiva* (Fabaceae), *Myrcia* (Myrtaceae), and Poaceae type (Poaceae) (Fig. 2). By analyzing the samples individually, it was possible to perceive that 25 of these pollen types are considered as important sources (FO>10%): *Amaranthus spinosus* and *Alternanthera* (Amaranthaceae), *Spondias* and *Tapirira guianensis* (Anacardiaceae), *Cocos* and *Elaeis* (Arecaceae), *Baccharis*, *Eupatorium*, *Mikania*, and *Vernonanthura* (Asteraceae), *Brassica* (Brassicaceae), *Aeschynomene*, *Chamaecrista*, *Copaifera*, Fabaceae 1, *Mimosa caesalpiniifolia*, *Mimosa candollei*, *M. pudica/sensitiva*, and *M. ulbrichiana* (Fabaceae), *Eucalyptus* and *Myrcia* (Myrtaceae), *Borreria verticillata* and *Guettarda* (Rubiaceae), *Banara* (Salicaceae), and *Cecropia* (Urticaceae) (Tab. 1, Fig. 3).

Cocos nucifera pollen type was registered in 23 analyzed samples (88.5%), classified as an important source in 17 samples, and stood out in one sample from Bahia and one from Piauí since it registered representativeness higher than 50% in both samples (65% and 86%, respectively). Furthermore, *Myrcia* pollen type was present in 21 analyzed samples, representing 80.8% of the total samples, was important in 10 of them, stood out in two samples from Alagoas (54% and 73%), and exhibited the highest participation as a secondary source (11 samples). *M. pudica/sensitiva* pollen type was observed in 20 samples (76.9%), and it was classified as an important source in 13 of them. In addition, it registered more than 80% of the representativeness of two samples from Bahia. Finally, although the Poaceae pollen type showed an FO value of

57.7%, it was classified as a secondary source in all samples in which it was present (<10% per sample) (Fig. 3).

Some pollen types did not exceed 50% of representativeness when considering the total sample set; however, they stood out by showing a percentage value higher than 50% in some specific samples: *M. candollei* (71%), *Baccharis* type (59%), and *M. caesalpiniifolia* (54,6%) were predominant in one sample from Paraíba, Bahia, and Rio Grande do Norte, respectively.

The pollen type richness showed an average value of 16 pollen types for samples from Ceará, 15 from Bahia, 13 for Sergipe and Pernambuco, 12 for Rio Grande do Norte, and 6 for Piauí (Table 1). On the other hand, three samples were considered monofloral, namely, PI1, which was represented by *C. nucifera* (86.1%), and BA7 and BA10, both represented by *M. pudica/sensitiva* pollen type (84.8% and 87.6%, respectively). Although some beekeepers affirmed that samples from Sergipe were monofloral with a predominance of Arecaceae, our results did not corroborate this information.

The statistical analysis showed a higher similarity index value between the Pernambuco 1 and Rio Grande do Norte 3 samples (approximately 62%). The presence of *C. nucifera*, *M. caesalpiniifolia*, *M. pudica/sensitiva*, *Commelina*, and *B. verticillata* contributed to the similarity between these samples.

Discussion

The pollen richness recorded in this study evidenced the vegetal diversity of the Northeastern Brazil; however, some pollen types indicated that certain plant species are more visited for the collection of pollen grains by honey bees in this region.

The presence of pollen grains belonging to *C. nucifera* (Arecaceae) is an important characteristic of bee pollens produced in the Northeastern Brazil. Consequently, it is considered a geographical indicator and it is also essential to produce bee pollen in Rio Grande do Norte, Bahia, and Sergipe (Freitas *et al*. 2013; Alves & Santos 2016; 2018). This species is critical in the study area, even in the beekeeping industry. Although it is regarded as an anemophilous species (Alves & Santos 2016), it is highly polliniferous and desirable to honey bees (Conceição *et al*. 2004). According to Leite & Conceição (2002), *C. nucifera* flowers all year long, strengthening this species' utilization by honey bees. This fact is of interest from the commercial point of view since, according to Bauermann *et al*. (2010), Arecaceae pollen grains contribute to texture and taste that please the consumer.

The Fabaceae family also stood out in this study, and it has been highlighted in several studies focused on bee pollen produced in the Northeastern region (Muniz & Brito 2007; Novais *et al*. 2010; Poderoso *et al*. 2012; Costa *et al*. 2015; and Alves & Santos 2018). Carvalho & Marchini (1999) emphasized that within Fabaceae, the Mimosoideae clade includes several species with an important polliniferous potential that are constantly visited by honey bees. In addition to their pollen production, these species bloom almost year-round (Carvalho *et al*. 2001; Santos Júnior & Santos 2003; Silva *et al*. 2004). The *M. pudica/sensitiva* pollen type, which was present in most of the analyzed samples, presented high beekeeping potential (Alves & Santos 2016) owing to the invasive nature and rapid spreading of these species in anthropogenic environments (Queiroz 2009; Dutra *et al*. 2020).

Myrtaceae family was also highlighted in this work, mainly due to the presence of *Myrcia* pollen type. According to Queiroz *et al*. (2006), Myrtaceae is one of the best-

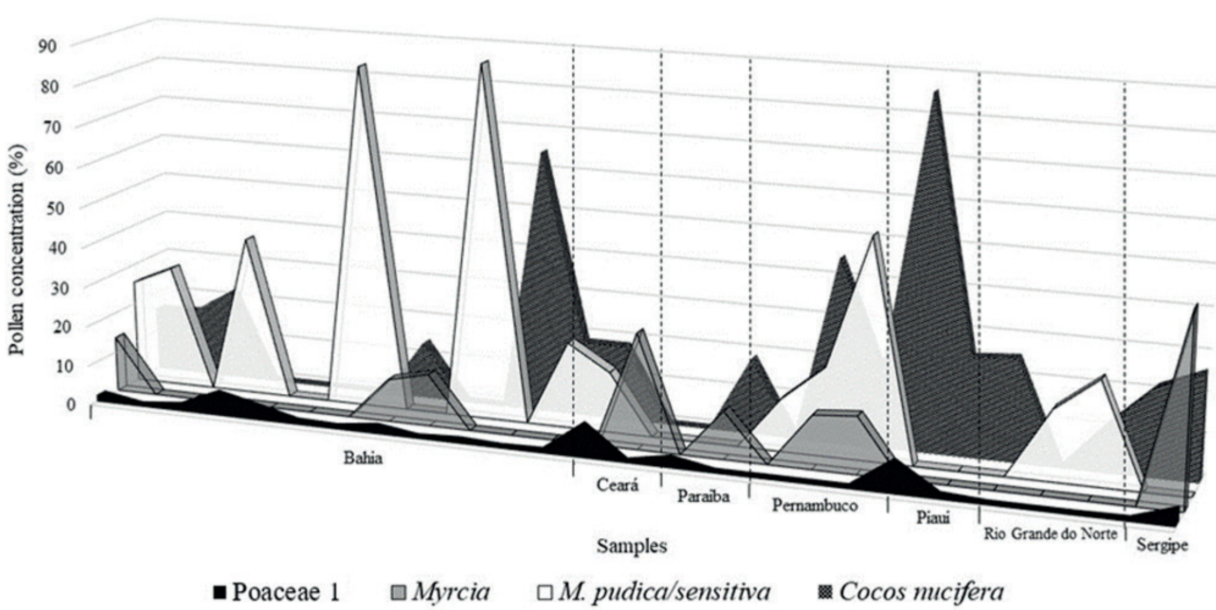

Figure 2. Pollen type representativeness (%) in commercialized bee pollen samples from states of the Northeastern Brazil.

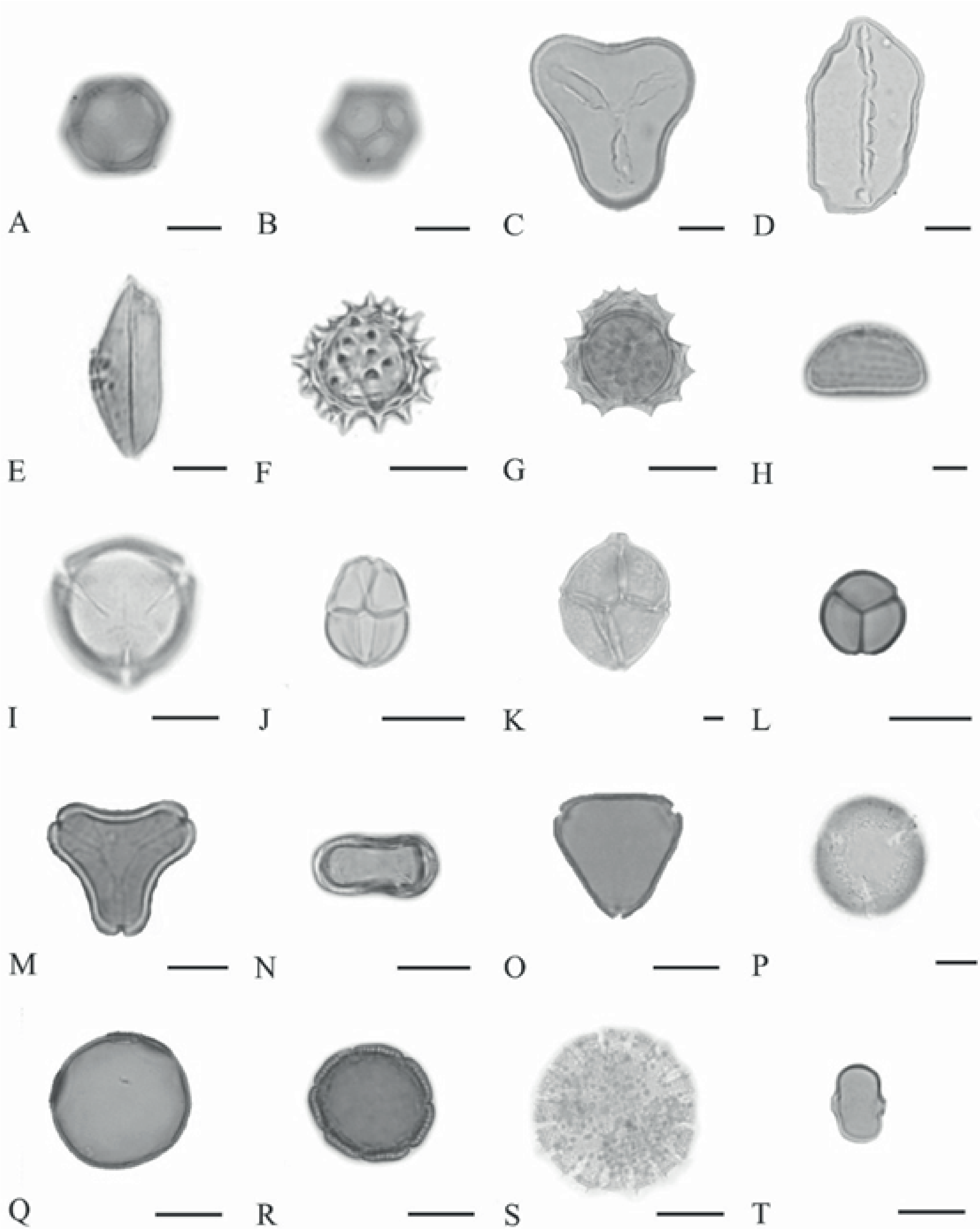

Figure 3. Predominant pollen types in commercialized bee pollen from the Northeastern Brazil: **A-B.** Amaranthaceae: *Alternanthera*; **C-E.** Arecaceae: **C-D.** *Cocos nucifera*, **E.** *Syagrus*; **F-G.** Asteraceae: **F.** *Baccharis*, G. *Mikania*; **H.** Commelinaceae: *Commelina*; **I.** Euphorbiaceae: *Ricinus*; **J-L.** Fabaceae: **J.** *Mimosa caesalpinifolia*, **K.** *M. candolei*, **L.** *M. pudica/sensitiva*; **M-O.** Myrtaceae: **M-N.** *Eucalyptus*, **O.** *Myrcia*; **P.** Nyctaginaceae: *Guapira*; **Q.** Poaceae: Poaceae; **R-S.** Rubiaceae: **R.** *Borreria verticillata*; **S.** *Richardia*; **T.** Urticaceae: *Cecropia*. Scale = 10 μm.

Table 1. Relative frequency (%) and frequency of occurrence (FO) classes of pollen types in commercialized bee pollen samples produced in the Northeastern Brazil. VF: Very frequent (>50%); F: Frequent (20- 50%); LF: Low frequent (10-20%); R: Rare (<10%).

Pollen types	Samples																												FO
	AL1	AL2	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10	BA11	BA12	CE1	CE2	PE1	PE2	PE3	PB1	PB2	PI1	PI2	RN1	RN2	RN3	SE1	SE2	
Amaranthaceae																													
Amaranthus hibridus							0,1																						R
A. spinosus							26																						R
A. viridis							0,7			0,2																			R
Alternanthera	0,2			15								0,4					2,2			1,8									LF
Anacardiaceae																													
Schinus			0,6		1,9	1,3																					43		LF
Spondias	0,9	0,5	1			0,1									4,3			1,4	0,4										LF
Tapirira guianensis					20	0,01		0,2																					LF
Anacardiaceae 1																												0,2	R
Thyrsodium										1,3																			R
Apiaceae																													
Apiaceae 1							1,1																						R
Aquifoliaceae																													
Ilex					0,5			2,5					9,2	0,2															LF
Arecaceae																													
Attalea								6,8											2,6									4,6	LF
Cocos nucifera	8,5	17	16	16	22					14	5,9	0,2	64,9	18,5	19	7,7	6,7	45	19		19	86	25	25	4,2	12	22	26	VF
Bactris										0,4	0,1																		R
Elaeis								2,9			15				0,2				0,1										LF
Syagrus		1	6,3		1,1			4,3		0,2	1			4,8					1,4		0,8			0,01					F
Asteraceae																													
Aspilia									1,1		0,1										0,2			0,7					LF
Baccharis				16				5			59	0,7		42,5														3,2	F
Bidens					0,9																								R
Conocliniopsis									0,7							0,1							1,1						LF
Elephantopus				0,3																									R
Emilia							1,2																			0,2			R
Eupatorium					11																								R
Lepidaploa					2,4			0,9					1,7		0,5												0,3		LF
Mikania	0,3	1,7	16									5,7		2,5	2,7												27		F
Pluchea					2,8									0,5															R
Senecio							0,4																						R
Taraxacum							1,5																						R
Vernonanthura 1				4	1,8		14					3,5	3	0,8					1,2									0,3	F
Vernonanthura 2					0,7			2																					R
Bignoniaceae																													
Tabebuia														0,4															R

Table 1. Cont.

Pollen types	Samples																												FO
	AL1	AL2	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10	BA11	BA12	CE1	CE2	PE1	PE2	PE3	PB1	PB2	PI1	PI2	RN1	RN2	RN3	SE1	SE2	
Brassicaceae																													
Brassica							22			0,4																			R
Cactaceae																													
Pilosocereus			0,2																				0,2				0,1		LF
Cyperaceae																													
Cyperaceae 1					2				0,5					1,8													0,1		LF
Combretaceae																													
Combretaceae 1		0,5																											R
Commelinaceae																													
Commelina			0,2												0,5		1,1				1,4			6,3	3	0,8	0,3		F
Convolvulaceae																													
Evolvulus									0,2						0,2					0,7				0,4					LF
Merremia																								0,5					R
Cucurbitaceae																													
Momordica							0,9			0,4																			R
Euphorbiaceae																													
Croton										0,2	0,1											3,6						0,2	LF
Jatropha																						2,6							R
Manihot						0,4																							R
Riccinus							0,1							0,4	0,5		2,5		0,5		1,1					0,6			F
Tragia					6,3																								R
Fabaceae																													
Acacia					0,1																								R
Aeschynomene	0,6			10	1,3																							0,2	LF
Andira														0,5															R
Apuleia																2,2													R
Cajanus																				0,4									R
Chamaecrista								29																					R
Copaifera										36																			R
Desmodium															2,1														R
Dioclea		0,5																			0,2								R
Hymenaeae							5,3																						R
Inga										0,4																			R
Fabaceae 1								21																					R
Fabaceae 2											0,1																		R
Fabaceae 3							0,2																						R
Fabaceae 4																								0,4					R
Mimosa 1																				0,2				0,2					R
M. caesalpiniifolia					0,4	9,2			11						3,2		17			21				4,5	55	34			F

Table 1. Cont.

Pollen types	Samples																												FO
	AL1	AL2	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10	BA11	BA12	CE1	CE2	PE1	PE2	PE3	PB1	PB2	PI1	PI2	RN1	RN2	RN3	SE1	SE2	
M. eliptica																												1,8	R
M. misera																5,2											0,3		R
M. candollei	2,8		1,3		0,1										10		20	1,4	0,2	71	8,8			19	0,3	0,2			F
M. tenuiflora																									0,1				R
M. ulbrichiana		0,5			3,6	9,9				1,7								1,9	2,9		49								F
M. pudica/sensitiva	32	4,4	26	30	0,6	39		2,5	85			87,6	0,8	21,2	15	0,1	13	22	54		0,3			1,3	17	26			VF
Piptadenia											5																		R
Pithecellobium			1,9																										R
Pseudopiptadenia					0,1																								R
Schyzolobium								2																				1,1	R
Senegalia											0,1																		R
Caesalpiniia														1,5															R
Lamiaceae																													
Hyptis							0,5		0,2												0,5				0,4				LF
Marsypianthes																				1,2									R
Raphiodon											0,1																		R
Salvia									1																			0,5	R
Lythraceae																													
Cuphea		0,2			0,1																								R
Malpighiaceae																													
Byrsonima															6,3			1,9	1,3									0,9	LF
Malpighiaceae 1										0,2																			R
Malvaceae																													
Eriotheca														2,3															R
Melocchia																				0,4									R
Waltheria				0,3															0,2										R
Melastomataceae																													
Miconia																												0,9	R
Moraceae																													
Brosium					1,2																								R
Myrtaceae																													
Eucalyptus			7,6			20					0,3	0,4					6,2	1,9	2,3		3,5		68	35	18				F
Eugenia																1,3													R
Myrcia	54	73	14	0,2	7,5	1,4	0,4	2,5		11	13	0,2			7,9	29	0,2	13	14		12		0,3		0,4		3,5	47	VF
Psidium										8,7											0,3								R
Nictaginaceae																													
Guapira		1,3	8		0,7										0,2										0,1		1,7		F

Table 1. Cont.

Pollen types	Samples																												FO
	AL1	AL2	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10	BA11	BA12	CE1	CE2	PE1	PE2	PE3	PB1	PB2	PI1	PI2	RN1	RN2	RN3	SE1	SE2	
Piperaceae																													
Piper								1,4																					R
Plantaginaceae																													
Angelonia																											1,2		R
Poaceae																													
Poaceae 1			1,7		1	5,3	3	0,5	0,2	1,5		0,5		0,2	7,8					2		7,4	0,7				0,2	3,7	VF
Polygonaceae																													
Ccoccoloba															0,5														R
Ramnaceae																													
Ziziphus												0,4																	R
Rubiaceae																													
Borreria											0,1				0,6	4,9			0,1		0,3								LF
Borreria verticilata	0,3		0,2	0,2	0,2										19	49	21			1,6	2			5,8	1,3	27		0,6	F
Diodela																0,7													R
Guettarda							21																						R
Mitracarpus									0,5																				R
Richardia				0,3											0,2		0,4	0,5			0,6			0,4	0,4	0,2			F
Rutaceae																													
Citrus				6,4																			4,7						R
Salicaceae																													
Banara										24																			R
Casearia																												0,6	R
Sapotaceae																													
Sapotaceae 1							0,4																						R
Solanaceae																													
Solanum											0,6																		R
Turneraceae																													
Piriqueta																						0,3							R
Urticaceae																													
Cecropia			0,2	1	8,3			16					15,3	2	0,2		9,6	9,4	0,2									7,1	F
Indeterminate																													
Indeterminate 1													5,1																R
Indeterminate 2							1																						R
Indeterminate 3					0,6																								R
Indeterminate 4																												0,6	R
Indeterminate 5												0,5																	R
Indeterminate 6																												0,8	R
Richness	9	11	16	13	28	10	19	16	10	16	15	11	7	16	21	10	12	10	16	10	16	5	7	14	12	9	12	19	

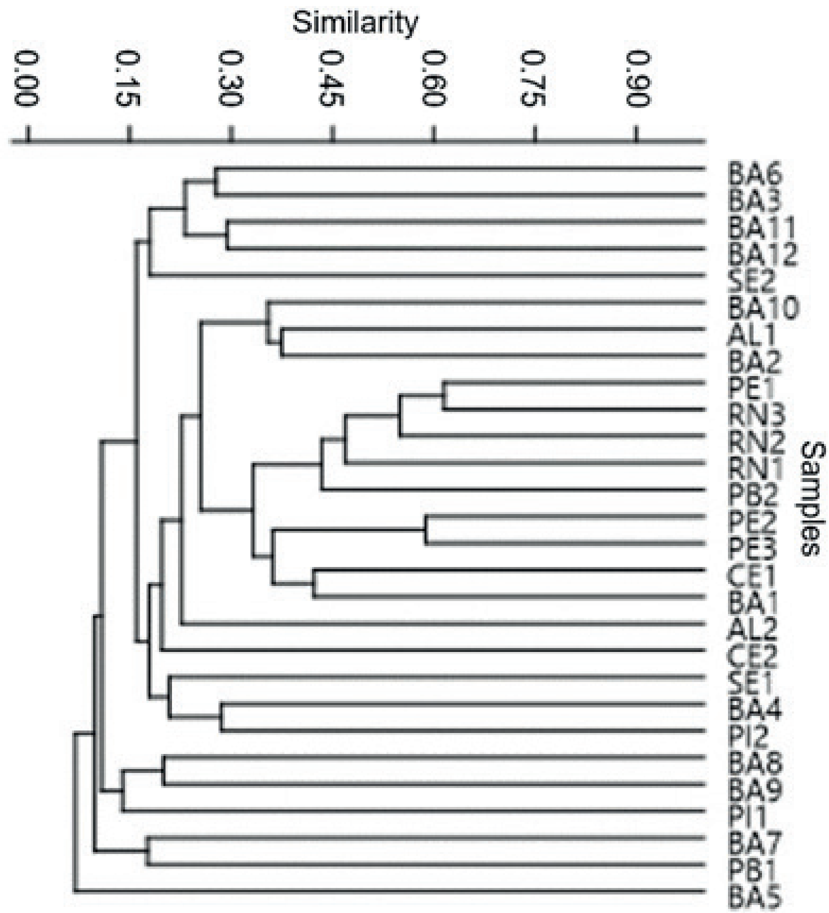

Figure 4. Dendrogram of similarity (Jaccard index) for samples of bee pollen produced and commercialized in the Northeastern Brazil. See Table 1 for sample codes.

represented families in the Brazilian semiarid region and is one of the most diverse families in the Caatinga. Furthermore, *Myrcia* is the second most represented pollen type in melissopalynological studies throughout Brazil and the seventh in the Northeastern (Souza *et al*. 2018). According to Freitas *et al*. (2013) and Alves & Santos (2016; 2018), this pollen type stood out in bee pollen samples from Bahia, Sergipe, and Rio Grande do Norte as it was classified as very frequent, which was corroborated in this research.

The Poaceae pollen type analyzed in the bee pollen samples in this study is an important representative of an anemophilous taxon. This pollen type represents plant species that are highly polliniferous and that contribute significantly to bee pollen composition (Alves & Santos 2014). Souza *et al*. (2018) corroborated this information by reporting that Poaceae is the sixth most represented pollen type in melissopalynological studies in Brazil. Alves & Santos (2016; 2018) also identified this pollen type in bee pollen samples from Bahia and Sergipe. Dórea *et al*. (2010) pointed out that despite the high frequency of the Poaceae pollen type when considering the entire sample set, it was present in low percentages per sample, which indicates its importance as a secondary source, as confirmed by our results.

Although a total of 113 pollen types were registered in the analyzed samples, which reinforces the generalist behavior of *A. mellifera* (Köppler *et al*. 2007), some samples were classified as monofloral (PI1, BA7, and BA10). This corroborates the results obtained by Suwannapong *et al*. (2012), who reported honey bees preference for plants that provide resources in greater quantity, taking advantage of the pollen source until its exhaustion.

Other samples from the state of Sergipe were indicated as monofloral because of the content of *C. nucifera* pollen grains present at the time of its sale. Nonetheless, this information was not confirmed in this study. In addition to the insufficient presentation of more precise information on the label of commercialized products, beekeepers lack a better understanding of the polliniferous sources of their apiaries and knowledge for developing a management plan for beehives and cultivation of plant species of beekeeping importance.

Conclusion

Based on the analyzed data, the richness of pollen types found in this study provides essential information about the flora visited by *A. mellifera* in the Northeastern Brazil, highlighting the contribution of some botanical groups to the protein diet.

Fabaceae and Asteraceae were the primary polliniferous sources used by *A. mellifera* in this region. In contrast, pollen types of *C. nucifera*, M. *pudica/sensitiva*, *Myrcia*, and Poaceae were very frequent in the samples. The first two sources contributed to samples that were considered monofloral bee pollen. This result is excellent for beekeepers because these species are widely distributed in the Northeast region. *Cocos nucifera*, in addition to contribute significantly to the composition of bee pollen samples in the region, also adds appreciable flavor and texture for human consumption.

The knowledge about the botanical sources that support the pollen (protein) diet of *A. mellifera* in Northeastern of Brazil contributes to the preservation of plant species of beekeeping importance in the region, as well as favoring the commercialization of pollen from these bees by beekeepers.

Acknowledgements

The authors express special thanks to CNPq for the scholarship for the first author and a scientific grant to FARS and TMSS; and FACEPE for grant to TMSS. Thanks to the Postgraduate Program in Botany and Plant Micromorphology Laboratory of State University of Feira de Santana for allowing the use of their facilities for this research.

Conflict of interest

The authors declare no conflict of interest.

References

Almeida-Muradian LB, Pamplona LC, Coimbra S, Barth OM. 2005. Chemical composition and botanical evaluation of dried bee pollen pellets. Journal of Food Composition and Analysis 18: 105-111.

Alvarado JL, Delgado-Rueda MD. 1985. Flora apicola em Uxpanapa, Veracruz, Mexico. Biotica 10: 257-275.

Alves RF, Santos FAR. 2014. Plant sources for bee pollen load production in Sergipe, northeast Brazil. Palynology 38: 90-100.

Alves RF, Santos FAR. 2016. Arecaceae potential for production of monofloral bee pollen. Grana 57: 1-10.

Alves RF, Santos FAR. 2018. Pollen foraged by bees (*Apis mellifera* L.) on the Atlantic Forest of Bahia, Brazil. Palynology 43: 523-529.

Andrada AC, Tellería MC. 2005. Pollen collected by honey bees (*Apis mellifera* L.) from south of Caldén district (Argentina): botanical origin and protein content. Grana 44: 115-122.

Baldi CB, Grasso D, Pereira SC, Fernández G. 2004. Caracterización bromatológica del pólen apícola argentino. Ciencia Docencia Tecnologia 29: 145-181.

Barreto LMRC, Funari RC, Orsi RO, Dib APS. 2006. Produção de pólen no Brasil. Taubaté, Editora Cabral e Livraria Universitária.

Bauermann SG, Evaldt ACP, Zanchin JR, Bordignon SAL. 2010. Diferenciação polínica de *Butia*, *Euterpe*, *Geonoma*, *Syagrus* e *Thritinax* e implicações paleoecológicas de Arecaceae para o Rio Grande do Sul. Iheringia 65: 35-46.

Bauermann SG, Radaeski JN, Evaldt ACP, Queiroz EP, Mourelle D, Prieto AR, Silva CI. 2013. Polen nas angiospermas: diversidade e evolução. Canoas, Editora Ulbra.

Brasil - Ministério de Agricultura e do Abastecimento. 2001. Instrução Normativa n. 3, de 19 de janeiro de 2001. Regulamento Técnico de Identidade e Qualidade do Pólen Apícola. Diário Oficial da União da República Federativa do Brasil. Brasília, 23 de janeiro de 2001, Seção 16-I, 18–23. http://www.prodapys.com.br/navega.php?idioma=fr&item=qualidade&sub=aV.

Bucher E, Kofler V, Vorwohl G, Zieger E. 2004. Lo spettro pollinico dei mieli dell'Alto Adige. Laives, Agenzia Provinciale per la Protezione dell'Ambiente e la Tutela del Lavoro.

Camazine S. 1993. The regulation of pollen foraging by honey bees: How foragers assess the colony's need for pollen. Behavioral Ecology and Sociobiology 32: 265-272.

Campos MGR, Bogdanov S, Almeida-Murdian LB, Szczesna T, Mancebo Y, Frigerio C, Ferreira F. 2008. Pollen composition and standardization of analytical methods. Journal of Apicultural Research 47: 156-163.

Carreira LMM, Silva MF, Lopes JRC, Nascimento LA. 1996. Catálogo de Pólen das Leguminosas da Amazônia Brasileira. Belém, Museu Paraense Emílio Goeldi.

Carvalho CAL, Marchini LC. 1999. Plantas visitadas por *Apis mellifera* L. no vale do rio Paraguaçu, município de Castro Alves, Bahia. Revista Brasileira de Botânica 22: 333-338.

Carvalho CAL, Moreti ACCC, Marchini LC, Alves RM, De Oliveira PCF. 2001. Pollen spectrum of honey of "uruçu" bee (*Melipona scutellaris* Latreille, 1811). Brazilian Journal of Biology 61: 63-67.

Conceição ES, Delabie JHC, Neto AOC. 2004. A entomofilia do coqueiro em questão: avaliação do transporte de pólen por formigas e abelhas nas inflorescências. Neotropical Entomology 33: 679-683.

Costa SN, Alves RMO, Carvalho CAL, Conceição PJ. 2015. Fontes de pólen utilizadas por *Apis mellifera* Latreille na Região Semiárida. Ciência Animal Brasileira (Online) 16: 491-497.

Dórea MC, Novais JS, Santos FAR. 2010. Botanical profile of bee pollen from the southern coastal region of Bahia, Brazil. Acta Botanica Brasilica 24: 862-867.

Dutra VF, Morales M, Jordão LSB, Borges LM, Silveira FS, Simon MF, Santos-Silva J, Nascimento JGA, Ribas ODS. 2020. Mimosa. In: Flora do Brasil 2020. Rio de Janeiro, Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/fb83463

Erdtman G. 1960. The acetolysis method. A revised description. Svensk Botanisk Tidskrift 39: 561-564.

Flora do Brasil. 2020. Rio de Janeiro, Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/

Freitas AS, Arruda VAS, Almeida-Muradian LBD, Barth OM. 2013. The botanical profiles of dried bee pollen loads collected by *Apis mellifera* (Linnæus) in Brazil. Sociobiology 60: 56-64.

Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4: 4.

IBGE - Instituto Brasileiro de Geografia e Estatística. 2019. http://www.ibge.gov.br

Imperatriz-Fonseca VL, Ramalho M, Kleinert-Giovannini A. 1994. Abelhas sociais e flores: Análise polínica como método de estudo. In: Pirani JR, Cortopassi-Laurino M (eds.), Flores e abelhas em São Paulo. São Paulo, EDUSP, FAPESP. p. 17-30.

Jones GD, Bryant Jr VM. 1996. Melissopalynology. In: Jansonius J, McGregor DC (eds.) Palynology: Principles and applications. Dallas, American Association of Stratigraphic Palynologists Foundation. p. 933-938.

Komosinska-Vassev K, Olczyk P, Kaźmierczak J, Mencner L, Olczyk K. 2015. Bee pollen: chemical composition and therapeutic application. Evidence Based Complementary and Alternative Medicine 2015: 297425

Köppler K, Vorwohl G, Koeniger N. 2007. Comparison of pollen spectra collected by four different subspecies of the honey bee *Apis mellifera*. Apidologie 38: 341-353.

Leite IRM, Conceição CRF. 2002. Fenologia de coqueiro na zona costeira de Pernambuco. Revista Brasileira de Agropecuária Sustentável 37: 745-752.

Lima LCL, Silva FHM, Santos FAR. 2008. Palinologia de espécies de *Mimosa* L. (Leguminosae-Mimosoideae) do semiárido brasileiro. Acta Botanica Brasilica 22: 794-805.

Mărgăoan R, Strant M, Varadi A, Topal E, Yücel B, Cornea-Cipcigan M, Campos MG, Vodnar DC. 2019. Bee collected pollen and bee bread: bioactive constituents and health benefits. Antioxidants 8: 568.

Melhem TS, Cruz-Barros MAV, Corrêa AMS, Makino-Watanabe H, Silvestre-Capelato MS F, Esteves VLG. 2003. Variabilidade polínica em plantas de Campos de Jordão (São Paulo, Brasil). Boletim do Instituto de Botânica (São Paulo) 16: 1-104.

Muniz FH, Brito ER. 2007. Levantamento da flora apícola do município de Itapicuru-Mirim, Maranhão. Revista Brasileira de Biociência 5: 111-113.

Novais JS, Lima LCL, Santos FAR. 2010. Bee pollen loads and their use in indicating flowering in the Caatinga region of Brazil. Journal of Arid Environments 74: 1355-1358.

Novais JS, Absy ML. 2013. Palynological examination of the pollen pots of native stingless bees from the Lower Amazon region in Pará, Brazil. Palynology 37: 218-230.

Oliveira PP, Santos FAR. 2014. Prospecção palinológica em méis da Bahia. Feira de Santana, Print Mídia.

Pascoal A, Rodrigues S, Teixeira A, Feás X, Estevinho LM. 2014. Biological activities of commercial bee pollens: Antimicrobial, antimutagenic, antioxidant and anti-inflammatory. Food and Chemical Toxicology 63: 233-239.

Poderoso JCM, Correia-Oliveira ME, Paz LC, Souza TMS, Vilca FZ, Dantas PC, Ribeiro GT. 2012. Botanical preferences of Africanized Bees (*Apis mellifera*) on the Coast and in the Atlantic Forest of Sergipe, Brazil. Sociobiology 59: 97–105.

Proctor M, Yeo P, Lack A. 1996. The natural history of pollination. Portland, Timber Press.

Queiroz LP, Conceição AA, Giulietti AM. 2006. Nordeste semi-árido: caracterização geral e lista das fanerógamas. In: Giulietti AM, Conceição AA, Queiroz LP (eds.) Diversidade e caracterização das fanerogamas do semi-árido brasileiro. Recife, APNE. p. 15-360.

Queiroz LP. 2009. Leguminosas da Caatinga. Feira de Santana, UEFS/Kew, Royal Botanic Gardens.

Roubik DW, Moreno JE. 1991. Pollen and spores of Barro Colorado Island. Monographs in Systematic Botany. St. Louis, Missouri Botanical Garden.

Santos FAR, Oliveira JM, Oliveira PP, Leite KRB, Carneiro CE. 2006. Plantas do semiárido importantes para as abelhas. In: Santos FAR. (ed.) Apium plantae. Recife, IMSEAR. p. 61-86.

Santos FAR. 2011. Identificação botânica do pólen apícola. Magistra 23: 4-9.

Santos Júnior MC, Santos FAR. 2003. Espectro polınico de amostras de méis coletadas na microrregião do Paraguassu, Bahia. Magistra 15: 79–78.

Silva FHM, Santos FAR, Lima LCL. 2016. Flora polínica das caatingas: Estação Biológica de Canudos, Bahia, Brasil. Feira de Santana, Micron Bahia.

Silva JMC, Tabarelli M, Fonseca MT, Lins LV. 2004. Biodiversidade da caatinga: áreas e ações prioritárias para a conservação. Brasília, Ministério do Meio Ambiente/Universidade Federal de Pernambuco.

Silva TMS, Camara CA, Lins ACS, Barbosa-Filho JM, Silva EMS, Freitas BM, Santos, FAR. 2006. Chemical composition and free radical scavenging activity of pollen loads from stingless bee *Melipona subnitida* Ducke. Journal of Food Composition and Analysis 19: 507-511.

Souza DC. 2007. Importância socioeconômica. In: Souza DC (ed.). Apicultura: manual do agente de desenvolvimento rural. Brasília, SEBRAE. p. 29-36.

Souza RR, Abreu VHR, Novais JS. 2018. Melissopalynology in Brazil: a map of pollen types and published productions between 2005 and 2017. Palynology 43: 690-700.

Suwannapong G, Eiri DM, Benbow ME. 2012. Honeybee communication and pollination. In: Bandani AR (ed.). New Perspectives in Plant Protection. Rijeka, IntechOpen. p. 39-62.