The Pollen Spectrum of *Apis mellifera* Honey from Reconcavo of Bahia, Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ASN, CALC and GSS designed the study and interpreted the data. Author CALC performed statistical analysis. Authors ASN, CALC and GSS participated in study conduction and data interpretation. Author ASN drafted the manuscript. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Background: The use of pollen grains to establish the geographical and botanical origin of honey samples, and for supplying information concerning to the floral class of a honey produced in a region, has been employed since 1895. Pollen analysis has relevant significance for the quality control of a honey that may include numerous pollen grains and elements of honeydew. The objective of this work was to determine the botanical origin of pollen from plants contributing in the composition of honey from the region of Reconcavo of Bahia, Brazil.

Methodology: Form each honey sample, a 10 g subsample was diluted in 20 mL of distilled warm water (40ºC) and centrifuged before the supernatant was drawn out. After centrifugation the pollen sediment was acetolysed following for better observation of the pollen grains. Subsequently, this sediment was mounted in microscopy slides with glycerin jelly for latter pollen grains counting and identification. The identification of the pollen grains found in the samples was determined by comparison with a reference collection from the Palynotheca of the Nucleus of Insect Studies from the Federal University of Reconcavo da Bahia and with descriptions obtained from specialized literature. A total of 70 honey samples of *Apis mellifera* L. were obtained from beekeepers of 17

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counties in the Reconcavo of Bahia region, from March 2009 to February 2010, and palynologically analysed. Acetolyzed pollen were count and identified.
Results: One hundred and twelve pollen types were identified, distributed within 35 families. Among these pollen types, 67.00% occurred with low frequency (rare) within the samples analyzed. Inside abundance class, 63.00% occurred as minor pollen. Mimosaceae was the richest accounting for 13.00% of the pollen types. There was similarity among the sources of trophic resources used by *A. mellifera* in the counties studied, with the highest similarity index of trophic resources found between the counties of Cabaceiras do Paraguaçu and São Felipe (Cs = 0.68).
Conclusion: Pollen analysis demonstrated that honey produced by *A. mellifera* in the region of Reconcavo of Bahia, Brazil, is predominantly multifloral, with emphasis the Mimosaceae.

1. INTRODUCTION

Pollen grains are spontaneously collected by bees while they collect nectar from flowers. As a consequence, pollen is present in honey composition and for this reason it becomes an important marker of the botanical and geographical origin of honey. Those grains also help to determine honey variety [1,2]. A quantitative and qualitative palynological survey of a honey sample constitutes its pollen spectrum. This spectrum identifies the nectar producing plant species, the non producer species, the contaminants, and when compared to known base line data can be used to detect mixtures of honey and falsification in labeling [3]. Trough the quantitative analysis of pollen grains is possible to establish the proportion in which each nectariferous plant contributes in honey composition, thus determining the botanical species that gave origin to such honey [4]. This information is important as it identifies those species that should be conserved or restored into the landscape in order to assist in the establishment of a sustainable beekeeping industry [5,6].

While pollen grains from nectar supplying plants, known as nectariferous plants, are honey components, a percentage of honey pollen may also originate from anemophilous plants. There is also a third category of plants, the polliniferous plants, that in addition to supplying small nectar quantities, supply significant quantities of pollen [7].

Nectariferous plants are usually under represented in pollen spectra as they supply a lot of nectar but little pollen. Thus, the presence of a small number of grains may indicate a great quantity of nectar. In pure honey samples from this category, few pollen grains and sediment are present. On the other hand, polliniferous plants

are over represented in pollen spectra, supplying few nectar quantities but great quantities of pollen. The presence of vast amounts of pollen may indicate less nectar percentages. When a honey sample contains more than 98% of pollen from a polliniferous plant, it must be considered a monofloral honey [3,7].

The pollen analysis is a method used to describe floral origin of honey and is useful to estimate the diversity of local flora. The knowledge of honey origin allows to map the regions suitable for apiculture. The decline in floral resources used by bees is considered one of the main causes involved in loss of pollinators, therefore, the pollen analysis has become an important tool to identify apicultural flora that can be propagated to increase food resources for honeybees. Thus, considering the "global collapse of honeybees" and "pollination crisis", studies on the identification of apicultural flora are important. [8].

In the Reconcavo of Bahia region, beekeeping is based on a familiar agricultural system, lacking enough information about floral diversity to sustain efficiently such activity. In this context, the objective of the present study was to determine the botanical origin of pollen contained in honey samples of *Apis mellifera* L. (Hymenoptera: Apidae), contributing to the knowledge of the regional honey flora.

2. MATERIALS AND METHODS

The Reconcavo Baiano is a region located in the state of Bahia, northeastern Brazil, in the surroundings of Baía de Todos os Santos. In this region, there are vegetation typologies varying according to altitude and proximity to depressions of Caatinga in some municipalities, namely Castro Alves and Santa Terezinha. The predominant vegetation is the Atlantic Forest formed by a mosaic between dense

ombrophilous forest, semideciduous forest, and shrubby vegetation. Toward the north-northeastern border, the vegetation features deciduous sharper characteristics, due to the proximity to the "Caatinga edge". Because of these characteristics, some municipalities such as Dom Macedo Costa, Elísio Medrado, Itatim and Santa Teresinha, constitute an important transition area between the Atlantic Forest and Caatinga biomes. The families Asteraceae, Caesalpiniaceae, Fabaceae, Mimosaceae, Myrtaceae, Solanaceae, and Malvaceae have several species visited by *Apis mellifera* in the Reconcavo Baiano [9].

A total of 70 honey samples of *A. mellifera* were obtained in 17 counties from the Reconcavo of Bahia region, Brazil: Amargosa (n=2), Cabaceiras do Paraguaçu (n=4), Cachoeira (n=7), Castro Alves (n=4), Conceição do Almeida (n=2), Cruz das Almas (n=6), Dom Macedo Costa (n=3), Elísio Medrado (n=2), Governador

Mangabeira (n=6), Itatim (n=4), Jaguaripe (n=4), Maragogipe (n=4), Muritiba (n=2), Santa Teresinha (n=6), Santo Antonio de Jesus (n=3), São Felipe (n=4) and Sapeaçu (n=4) (Fig. 1). Honey samples were obtained directly from beekeepers from the main honey producing counties within the Reconcavo of Bahia region, from March 2009 to February 2010.

Samples were prepared according to Louveaux et al. [10] following the guidelines of the International Commission of Bee Botany and the International Honey Commission (von der Ohe et al., 2004). Form each honey sample, a 10 g subsample was diluted in 20 mL of distilled water and centrifuged before the supernatant was drawn out. After centrifugation the pollen sediment was acetolysed following Erdtman [11] for better observation of the pollen grains. Subsequently, this sediment was mounted in microscopy slides with glycerin jelly for latter pollen grains counting and identification.

Fig. 1. Map of the Reconcavo of Bahia region (Brazil) with location of the apiaries, from where the honey samples were obtained
Geographic coordinates 01 – Amargosa (13°01'38"S; 39°36'22"W), 02 – Cabaceiras do Paraguaçu (12°31'32"S; 39°10'44"W), 03 – Cachoeira (12°35'20"S; 38°58'08"W), 04 – Castro Alves (12°44'51"S; 39°25'52"W), 05 – Conceição do Almeida (12°48'30"S; 39°11'57"W), 06 – Cruz das Almas (12°39'10"S; 39°07'19"W), 07 – Dom Macedo Costa (12°58'35"S; 39°08'56"W), 08 – Elísio Medrado (12°55'58"S; 39°30'44"W), 09 – Governador Mangabeira (12°35'56"S; 39°01'15"W), 10 – Itatim (12°42'49"S; 39°41'36"W), 11 – Jaguaripe (13°06'28"S; 38°53'20"W), 12 – Maragogipe (12°46'42"S; 38°55'10"W), 13 – Muritiba (12°38'12"S; 39°05'45"W), 14 – São Felipe (14°49'05"S; 41°23'04"W), 15 – Santo Antonio de Jesus (12°57'11"S; 39°16'28"W), 16 – Sapeaçu (12°43'34"S; 39°10'45"W) and 17 – Santa Teresinha (12°44'59"S; 39°31'06"W)

The identification of the pollen grains found in the samples was determined by comparison with a reference collection from the Palynotheca of the Nucleus of Insect Studies from the Federal University of Reconcavo da Bahia and with descriptions obtained from specialized literature as Barth [3,12], Barth et al.[13], Moreti et al. [14].

After the determination of botanical origin of pollen samples, at least 1000 pollen grains/sample were counted consecutively [15]. The relative frequency of each pollen type was established trough the formula: $f = (n_i/N)$ x100, where f = relative frequency of the pollen type i within the sample; n_i = number of pollen grains of the i type within the sample; N = total number of pollen grains within sample [16].

Subsequently, values of the mean and the confidence interval were calculated for each pollen type (i), with its respective Superior Limit (LS) and Inferior Limit (LI) at 1% and 5% significance level, and the frequency (rare = $n_i \leq LI_{5\%}$; Frequent = $LI_{5\%} < n_i < LS_{5\%}$; and Very Frequent = $n_i \geq LS_{5\%}$) and abundance classes (predominant pollen = $n_i \geq LS_{1\%}$; secondary pollen = $LI_{5\%} \leq n_i < LS_{1\%}$; Important minor pollen = $LI_{1\%} \leq n_i < LI_{5\%}$; minor pollen = $n_i < LI_{1\%}$) acquired [17].

The pollen similarity among honey samples of *A. mellifera* by county from the Reconcavo of Bahia region was obtained by the use of the similarity coefficient of Sörensen, expressed as the formula: *Cs = 2c / (s1 + s2)*, where: *s1* is the number of pollen types within the county *1* samples, *s2* is the number of pollen types within the county *2* samples and *c* is the number of common pollen types for both counties.

3. RESULTS

By means of pollen analysis of the samples, the botanical origin of 112 pollen types was determined, distributed in 35 families (Table 1). Among families found in the present study, Mimosaceae had the largest number of pollen types, with 13.00% of the total, followed by Asteraceae and Fabaceae, both with 9.00% and Myrtaceae, Caesalpiniaceae and Rubiaceae with 8.00%, 7.00% and 5.00%, respectively.

The pollen types *Alternanthera brasiliana*, *Borreria verticillata*, *Centratherum punctatum*, *Chamaecrista rotundifolia*, *Eugenia uniflora*, *Eupatorium* II, *Mimosa arenosa*, *M. caesalpiniaefolia*, *M. pudica*, *M. tenuiflora*, *Psidium guajava*, *Spondias* and *Syagrus coronata* were classified as very frequent (VF) and as predominant pollen (PP), concerning abundance classification. Pollen of *Acacia t*ype, *Anadenanthera colubrina*, *Baccharis*, *Byrsonima*, *Cardiospermum corindum*, *Cecropia*, *Centrosema*, *Croton* I, *Croton* III, *Desmodium*, *Heliotropium angiospermum*, *Hyptis*, *Mitracarpus*, *Myrcia*, *Psidium*, *Schinus terebinthifolius*, *Senna obtusifolia*, *Serjania pernambucensis*, *Syzygium* and *Vernonia* I were classified as secondary pollen (SP) and frequent (F) (Table 1 and Figs. 2, 3).

Regarding the frequency classes, 67.00% of the pollen types from the analyzed honey samples were rare, 21.00% were frequent and 13.00% very frequent. Concerning the abundance classes, 63.00% were classified as minor pollen, 23.00% as secondary pollen, 13.00% as predominant pollen and 4.00% as important minor pollen.

Pollen types with major occurrence among all 70 honey samples were *Syagrus coronata* (94.12% of the samples), *Mimosa arenosa* (88.24%), *M. pudica* (88.24%) and *Centratherum punctatum* (82.35%).

Samples from the counties of Cabaceiras do Paraguaçu, Cruz das Almas, Governador Mangabeira, São Felipe and Santa Teresinha had the greatest richness of pollen types. The mean number of pollen types was 26 per county, with Governador Mangabeira having the greatest number of types (40) and Amargosa the lowest, with only 11 types.

Pollen analysis of the honey samples from the Reconcavo of Bahia region, had a contribution of diverse plant species in its composition, with two samples having a high occurrence percentage of pollen types. One in Amargosa, with 96.12% of predominance of the *M. arenosa* type and one in Santa Teresinha, with 95.20% predominance of *Spondias* type.

The presence of pollen types of anemphilous species (*Cecropia*, Poaceae I and Poaceae II) was also observed, with the *Cecropia* type being considered as secondary pollen and the others considered as minor pollen (Table 1). The *Citrus* pollen type occurred as secondary in two samples from Cruz das Almas county, representing 19.50% and 15.05% of the total types in the sample.

The higher similarity levels were found between honeys from the following counties: Cabaceiras do Paraguaçu/São Felipe (Cs = 0.68), Cabaceiras do Paraguaçu/Governador Mangabeira (Cs = 0.62), Conceição do Almeida/São Felipe (Cs = 0.61) and Conceição do Almeida/Sapeaçu (Cs = 0.60) (Table 2). The county of Castro Alves, when compared with the other localities, showed low similarity index, varying from Cs = 0.05 to 0.26. The geographical location of this county comprehends a transitional zone between Atlantic Forest and Caatinga.
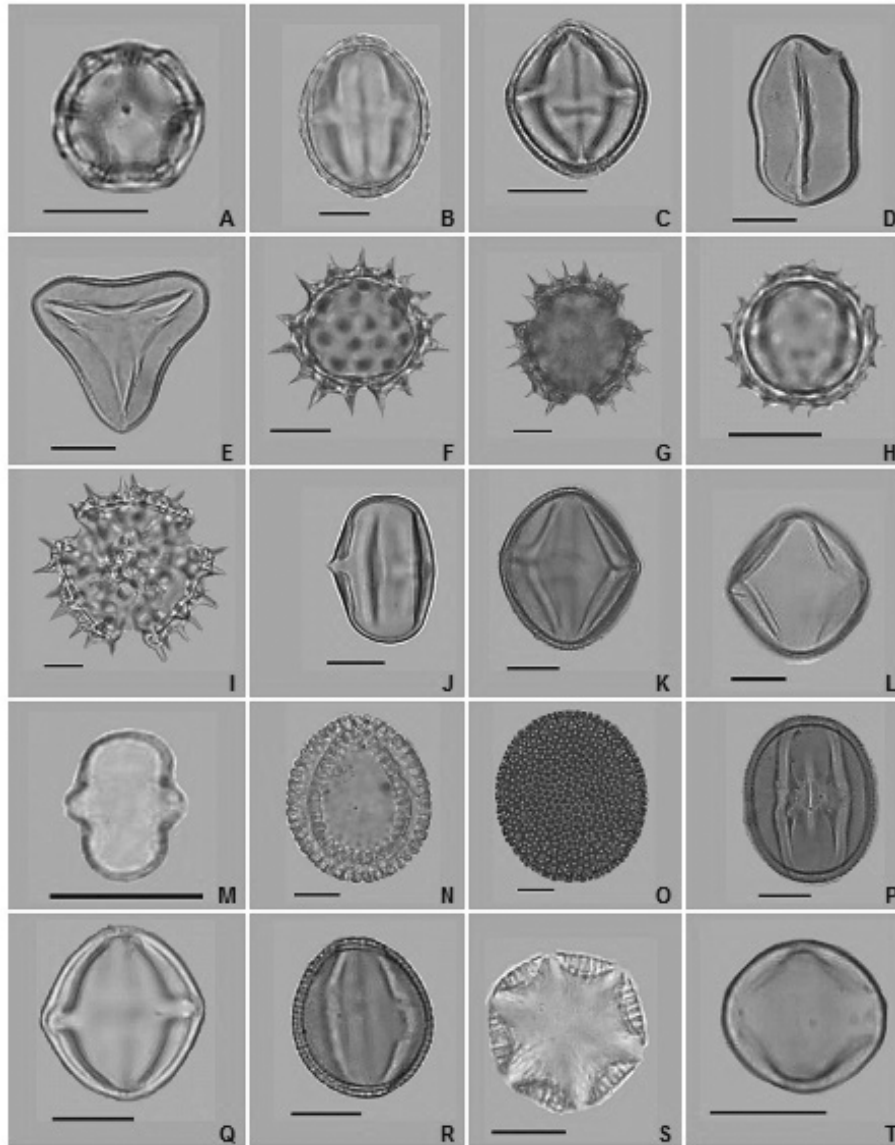

Fig. 2. Photomicrography of the predominant and secondary pollen types in *Apis mellifera* L. (Hymenoptera: Apidae) honey samples from the Reconcavo of Bahia, Brazil
Where: EV (Equatorial View) and PV (Polar View). Amaranthaceae A. *(PV) Alternanthera brasiliana.* Anacardiaceae B. *(EV) Spondias, C. (EV) Schinus terebinthifolius.* Arecaceae D. *(monosulcate) Syagrus coronata, E. (trichotomosuclate) Syagrus coronata.* Asteraceae F. *(PV) Baccharis, G. (PV) Centratherum punctatum, H. (PV) Eupatorium II, I. (PV) Vernonia I. Boraginaceae J. (EV) Heliotropium angiospermum.* Caesalpiniaceae K, *L. (EV) Senna obtusifolia.* Cecropiaceae M. *(EV) Cecropia).* Euphorbiaceae N. *(PV) Croton I, O. (PV) Croton III.* Fabaceae P. *(EV) Centrosema, Q. (EV) Chamaecrista rotundifolia, R. (EV) Desmodium.* Lamiaceae S. *(PV) Hyptis.* Malpighiaceae T. *(EV) Byrsonima. Scale: 10 µm*
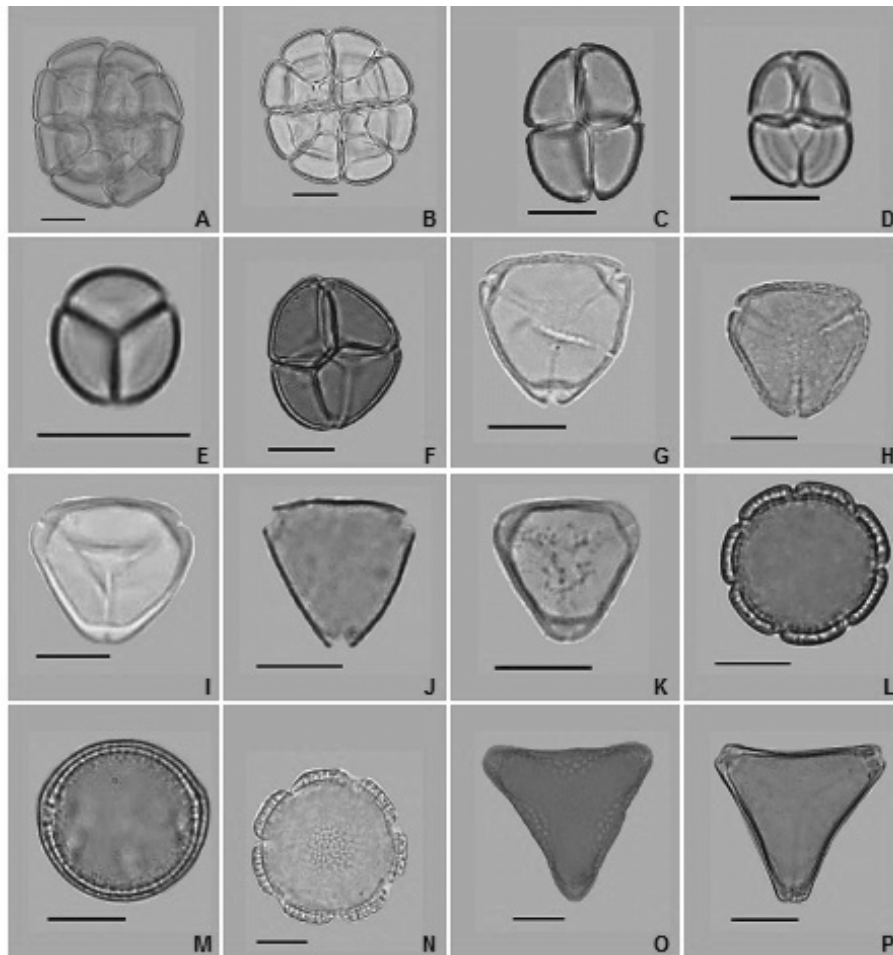
Fig. 3. Photomicrography of the predominant and secondary pollen types in *Apis mellifera* L. (Hymenoptera: Apidae) honey samples from the Reconcavo of Bahia, Brazil
Where: EV (Equatorial View) and PV (Polar View). Mimosaceae A. (polyad) Acacia, B. (polyad) Anadenanthera colubrina, C. (ditetrad) Mimosa arenosa, D. (ditetrad) M. caesalpiniaefolia, E. (tetrahedral tetrad) M. pudica, F. (tetrad) M. tenuiflora. Myrtaceae G. (PV) Eugenia uniflora, H. (PV) Myrcia, I. (PV) Psidium guajava, J. (PV) Psidium, K. (PV) Syzygium. Rubiaceae L. (PV), M. (EV) Borreria verticillata, N. (PV) Mitracarpus. Sapindaceae O. (PV) Cardiospermum corindum, P. (PV) Serjania pernambucensis. Scale: 10 µm

4. DISCUSSION

According to various authors, the Mimosaceae has significant potential for beekeeping due to its abundant distribution in the distinct regions in Brazil and as a source of trophic resources (pollen and nectar) for bees [16,18-20]. Moreti et al. [21] showed the importance of the participation of various species of Mimosaceae in the constitution of honey within the State of Bahia, Brazil.

The Asteraceae is considered one of the richest in number of species visited by social bees in different regions of Brazil [22]. In the present study this family was one of the most diverse in

pollen types and some of these types were classified as predominant and secondary (Table 1). Locatelli and Machado [23] suggest that this is probably due to the fact this family is one of the largest and greater geographical distribution among angiosperms.

Novais et al. [24] identified 46 pollen types from 22 botanical families in honey samples of *A. mellifera* from the semi-arid region in Bahia, Brazil, with the Fabaceae having an exceptional number of pollen types, followed by Malvaceae, Asteraceae, Euphorbiaceae, Rubiaceae and Lamiaceae. This is similar to the results found in this study.

Table 1. Relative frequency (RF), frequency class (FC) and abundance class (AC) of the pollen types observed in honey samples (n = 70) of *Apis mellifera* L. (Hymenoptera: Apidae) in the region of Reconcavo of Bahia. ($IC_{5\%}$= 403.03±211.70; $IC_{1\%}$ = 403.03±278.22)

Family	Pollen types	RF (%)	FC^A	AC^A	Family	Pollen types	RF (%)	FC^A	AC^A
Amaranthaceae	*Alternanthera brasiliana*	2.297	VF	PP	Caesalpiniaceae	*Senna macranthera*	0.044	R	MP
	Alternanthera tenella	0.219	R	MP		*Senna obtusifolia*	0.649	F	SP
	Gomphrena	0.029	R	MP		*Senna occidentalis*	0.058	R	MP
Anacardiaceae	*Astronium*	1.212	F	SP	Cecropiaceae	*Cecropia*	0.709	F	SP
	Schinus terebinthifolius	0.631	F	SP	Combretaceae	*Terminalia catappa*	0.011	R	MP
	Spondias	3.819	VF	PP	Commelinaceae	*Commelina benghalensis*	0.213	R	MP
Apocynaceae	Apocynaceae	0.002	R	MP	Euphorbiaceae	*Croton* I	0.432	F	SP
Arecaceae	Arecaceae I	0.009	R	MP		*Croton* II	0.146	R	MP
	Arecaceae II	0.031	R	MP		*Croton* III	0.727	F	SP
	Arecaceae III	0.253	R	MP	Fabaceae	*Centrosema arenarium*	0.004	R	MP
	Syagrus coronata	3.970	VF	PP		*Centrosema*	0.919	F	SP
Asteraceae	*Baccharis*	0.656	F	SP		*Chamaecrista rotundifolia*	9.951	VF	PP
	Centratherum punctatum	4.298	VF	PP		*Crotalaria incana*	0.002	R	MP
	Eclipta Alba	0.215	R	MP		*Desmodium*	0.498	F	SP
	Elephantopus	0.004	R	MP		Fabaceae	0.035	R	MP
	Eupatorium I	0.202	R	MP		*Galactia*	0.131	R	MP
	Eupatorium II	1.728	VF	PP		*Macroptilium*	0.084	R	MP
	Mikania	0.102	R	MP		*Myrocarpus fastigiatus*	0.352	R	IMP
	Vernonia I	0.450	F	SP		*Stylosanthes*	0.004	R	MP
	Vernonia II	0.270	R	MP	Lamiaceae	*Hyptis*	1.112	F	SP
	Vernonia III	0.379	R	IMP		*Salvia*	0.055	R	MP
Boraginaceae	*Cordia superba*	0.179	R	MP	Loranthaceae	*Struthanthus*	0.027	R	MP
	Heliotropium angiospermum	0.623	F	SP	Lythraceae	*Cuphea racemosa*	0.022	R	MP
Caesalpiniaceae	*Bauhinia forficata*	0.002	R	MP	Malpighiaceae	*Byrsonima*	1.134	F	SP
	Copaifera langsdorffii	0.241	R	MP		*Malpighia*	0.002	R	MP
	Senna I	0.117	R	MP	Malvaceae	*Sida* I	0.004	R	MP
	Senna II	0.002	R	MP		*Sida* II	0.002	R	MP
	Senna III	0.020	R	MP		*Sida linifolia*	0.031	R	MP

[A] *IC5% = confidence interval at 5% level; IC1% = confidence interval at 1% level; n = number of pollen grains; PP = predominant pollen ($n \geq LS_{1\%}$); SP = secondary pollen ($LI_{1\%} \leq n < LS_{1\%}$); MP = minor pollen ($n < LI_{1\%}$); IMP = important minor pollen ($LI_{1\%} \leq n LI_{5\%}$) and (R = rare ($ni \leq LI5\%$;); F = frequent ($LI5\% < ni < LS5\%$); VF = Very frequent ($ni \geq LS5\%$)*

Table 1 (Continued). Relative frequency (RF), frequency class (FC) and abundance class (AC) of the pollen types observed in honey samples (n = 70) of *Apis mellifera* L. (Hymenoptera: Apidae) in the region of Reconcavo of Bahia. (IC$_{5\%}$= 403.03±211.70; IC$_{1\%}$ = 403.03±278.22)

Family	Pollen types	RF (%)	FC[A]	AC[A]	Family	Pollen types	RF (%)	FC[A]	AC[A]
Melastomataceae	*Tibouchina*	0.004	R	MP	Passifloraceae	*Passiflora*	0.002	R	MP
Mimosaceae	*Acacia*	0.521	F	SP	Poaceae	Poaceae I	0.071	R	MP
	Acacia bahiensis	0.246	R	MP		Poaceae II	0.009	R	MP
	Acacia langsdorfii	0.206	R	MP	Polygonaceae	*Antigonon leptopus*	0.009	R	MP
	Anadenanthera colubrina	1.216	F	SP	Portulacaceae	*Portulaca oleracea*	0.029	R	MP
	Inga bahiensis	0.066	R	MP	Rhamnaceae	*Ziziphus joazeiro*	0.392	R	IMP
	Leucaena leucocephala	0.173	R	MP	Rubiaceae	*Borreria* I	0.115	R	MP
	Mimosa arenosa	18.711	VF	PP		*Borreria* II	0.013	R	MP
	Mimosa caesalpiniaefolia	2.490	VF	PP		*Borreria verticillata*	1.540	VF	PP
	Mimosa I	0.126	R	MP		*Mitracarpus hirtus*	0.058	R	MP
	Mimosa II	0.024	R	MP		*Mitracarpus*	0.510	F	SP
	Mimosa pudica	15.494	R	PP		*Richardia grandiflora*	0.058	R	MP
	Mimosa quadrivalvis	0.164	R	MP	Rutaceae	*Citrus*	0.246	R	MP
	Mimosa tenuiflora	1.568	VF	PP		Rutaceae	0.009	R	MP
	Piptadenia	0.197	R	MP	Sapindaceae	*Cardiospermum*	0.080	R	MP
	Prosopis juliflora	1.046	F	SP		*Cardiospermum corindum*	1.121	F	SP
Molluginaceae	*Mollugo verticillata*	0.086	R	MP		*Serjania pernambucensis*	0.574	F	SP
Moraceae	Moraceae	0.244	R	MP	Solanaceae	*Solanum americanum*	0.066	R	MP
Myrtaceae	*Eucalyptus* I	0.018	R	MP		*Solanum erianthum*	0.182	R	MP
	Eucalyptus II	0.031	R	MP		*Solanum* I	0.326	R	IMP
	Eucalyptus III	0.004	R	MP		*Solanum* II	3.990	VF	PP
	Eucalyptus IV	0.020	R	MP	Sterculiaceae	*Melochia tomentosa*	0.611	F	SP
	Eugenia uniflora	2.253	VF	PP		*Waltheria indica*	0.357	R	IMP
	Myrcia	1.203	F	SP	Tiliaceae	*Corchorus*	0.002	R	MP
	Psidium guajava	2.384	VF	PP	Verbenaceae	*Aloysia*	0.055	R	MP
	Psidium	0.716	F	SP		*Gmelina*	0.002	R	MP
	Syzygium	0.547	F	SP		*Lantana camara*	0.168	R	MP
Nyctaginaceae	Nyctaginaceae	0.071	R	MP		*Lippia*	0.253	R	MP

[A] IC5% = confidence interval at 5% level; IC1% = confidence interval at 1% level; n = number of pollen grains; PP = predominant pollen (n $\geq$ LS$_{1\%}$); SP = secondary pollen (LI$_{5\%}$ $\leq$ n < LS$_{1\%}$); MP = minor pollen (n < LI$_{1\%}$); IMP = important minor pollen (LI$_{1\%}$ $\leq$ n LI$_{5\%}$) and (R = rare (ni $\leq$ LI5%;); F = Frequent (LI5% < ni < LS5%); VF = very frequent (ni $\geq$ LS5%)

Table 2. Sorensen similarity coefficient for pollen types found in *Apis mellifera* L. (Hymenoptera: Apidae) honey samples from 17 counties from Reconcavo da Bahia, Brazil: March 2009 to February 2010

	AMG	CAP	CAC	COA	CAT	CRU	DMC	EMD	GMA	ITA	JAG	MAR	MUR	SAF	SAT	SAJ	SAP
AMG	-	0.24	0.41	0.26	0.12	0.31	0.29	0.52	0.32	0.46	0.21	0.31	0.14	0.30	0.40	0.31	0.27
CAP		-	0.52	0.24	0.19	0.33	0.38	0.40	0.62	0.42	0.43	0.45	0.46	0.68	0.52	0.43	0.49
CAC			-	0.52	0.17	0.32	0.17	0.46	0.39	0.31	0.40	0.51	0.35	0.55	0.42	0.41	0.37
COA				-	0.16	0.46	0.35	0.51	0.55	0.36	0.41	0.58	0.27	0.61	0.33	0.50	0.60
CAT					-	0.14	0.17	0.26	0.16	0.20	0.05	0.16	0.15	0.24	0.25	0.14	0.24
CRU						-	0.24	0.32	0.52	0.29	0.20	0.13	0.35	0.35	0.41	0.36	0.40
DMC							-	0.35	0.51	0.31	0.34	0.35	0.24	0.47	0.31	0.44	0.32
EMD								-	0.36	0.45	0.30	0.45	0.30	0.47	0.44	0.27	0.43
GMA									-	0.27	0.39	0.45	0.36	0.51	0.44	0.43	0.52
ITA										-	0.27	0.36	0.27	0.41	0.45	0.33	0.22
JAG											-	0.49	0.09	0.46	0.24	0.37	0.37
MAR												-	0.22	0.57	0.35	0.29	0.37
MUR													-	0.27	0.31	0.32	0.37
SAF														-	0.58	0.39	0.46
SAT															-	0.40	0.40
SAJ																-	0.43
SAP																	-

AMG = Amargosa, CAC = Cachoeira, CAP = Cabaceiras do Paraguaçu, CAT = Castro Alves, COA = Conceição do Almeida, CRU = Cruz das Almas, DMC = Dom Macedo Costa, EDM = Elísio Medrado, GMA = Governador Mangabeira, ITA = Itatim, JAG = Jaguaripe, MAR = Maragogipe, MUR = Muritiba, SAF = São Felipe, SAJ = Santo Antonio de Jesus, SAP = Sapeaçu and SAT = SantaTeresinha

According to Melo [25], pollen type of *M. pudica* was the most frequent in honey samples of Africanized bees in Mundo Novo, Bahia, being predominant pollen in the majority of the samples where it was observed.

Costa [17] working with bee pollen in Cruz das Almas, Bahia, observed that 60.00% of the pollen types were rare and 61.00% minor pollen. In the county of Castro Alves, Carvalho and Marchini [16] observed that 58.33% of the plant species visited by bees were rare versus 41.67% considered frequent. The greatest quantity of pollen types identified by these authors were rare, as occurred also in the present work.

Some pollen types that occurred as predominant and very frequent pollen belongs to the Mimosaceae and the *Mimosa*, having their species classified as polliniferous plants. Members of the Anacardiaceae, Asteraceae, Euphorbiaceae and Sapindaceae were observed as secondary and frequent pollen, with species classified as nectariferous plants (Table 1).

Oliveira [26] verified the presence of predominant pollen types in 33 honey samples of melliferous bees in Bahia, within a total of 66 samples, represented by 15 pollen types having the family Mimosaceae and genus *Mimosa* with four predominant pollen types. In the present study, the presence of predominant pollen types was registered in 27 samples, represented by 18 types. Family Mimosaceae was also prominent with the highest number of types, all belonging to the genus *Mimosa*. Among all counties, only Castro Alves and Elisio Medrado had no samples with predominant pollen types. This fact can be explained by the local vegetal diversity. The vegetation in Castro Alves and Elísio Medrado vegetation consists of deciduous seasonal forest in contact with Caatinga-seasonal forest, semideciduous seasonal forest and dense ombrophilous forest [16]. Apiaries where samples for Castro Alves were collected, the predominant vegetation is the savanna, with trees, weeds and shrubs, characteristic of seasonal forest. The Serra da Jibóia is a hill massif situated in the southern part of the Recôncavo Baiano, where the municipalities of Castro Alves and Elísio Medrado are located. The most significant area of the Atlantic Forest of the Recôncavo Baiano lies in this region, and the Serra da Jibóia, which comprises the municipality

of Elísio Medrado, was turned into an area of Environmental Protection.

Studies performed in the region of the Reconcavo of Bahia by Carvalho et al. [27] and Nascimento et al. [28] with *Melipona quadrifasciata* (Apidae: Meliponinae) honey, showed similar results to the present study. These authors found types *Acacia*, *Eugenia uniflora*, *Eucalyptus*, *M. arenosa*, *M. caesalpiniaefolia*, *M. pudica*, *M. verrucosa* and *Syzygium malaccensis* as predominant pollen.

Different works in the State of Bahia, Brazil, showed that *A. mellifera* uses different plant sources, as in the caatinga biome, where Oliveira et al. [29] identified the presence of types as *Salvia*, *M. arenosa* and *M. sensitive* within the samples. In different regions of Brazil, a variety of species of Mimosaceae are most frequently encountered in pollen spectrum of *A. mellifera* honey [2,30].

Nascimento et al. [9] conducted a study in the Recôncavo Baiano and identified 240 plant species visited by *A. mellifera*. The authors observed that most plants are herbaceous (44%), followed by arboreal (26%) and shrubby (18%). Lianas (4%), vines (4%) and palm trees (1%) had less representation. The greatest preference for bee visitation to the flowers of herbaceous plants may be associated with the abundance of these plants in the region, the flowering period with a higher concentration of species between March and June, and the rainy season in the region.

Additional plant species have also important participation in *A. mellifera* honey, as for example those considered as weeds, possessing honey production potential. Among these species, Almeida et al. [31] highlights *Commelina benghalensis*, *Croton campestri* and *Portulaca* sp. Similar to the results found by these authors, pollen types with affinity with those species were identified in the Reconcavo da Bahia samples, as for example *Borreria verticillata*, *Commelina benghalensis*, *Crotalaria incana*, *Croton* and *Portulaca oleracea* (Table 1), stressing the provable potential of these plants for beekeeping in the region.

Samples from the counties of Amargosa, Cachoeira, Cruz das Almas, Governador Mangabeira and Sapeaçu, had *M. arenosa*, *M.*

pudica and *Syagrus coronata* as common types. This region had a mean of 27 pollen types among samples. Oliveira [26], working with honey form this region observed *Borreria verticillata*, *Eupatorium*, *M. sensitiva*, *M. tenuiflora*, *S. coronata* and *Vernonia* types in all the samples, with predominant pollen types found in samples from Amargosa (*Schinus*), Cruz das Almas (*M. tenuiflora*) and Sapeaçu (*S. coronata*).

Santos Jr. and Santos [32] demonstrated that *S. coronata* pollen type was the most frequent, being observed in the monosulcate and tricotomosulcate pollen forms in the counties of the micro-region of the river Paraguassu, in Bahia, Brazil. In the present study, species of the Arecaceae, Asteraceae and Fabaceae families had relevant pollen contribution in honey samples of the same micro-region. The *S. coronata* type was also preponderant in samples collected in the present work, being observed in both pollen forms (Fig. 2).

Due to its diversified flora, honey classification as monofloral is not common in Brazil. According to Zander and Maurizio [33] honey of *Citrus* and *Lavandula* (10–20% of the total pollen grains)*,* are considered pure honey subrepresented in pollen. Considering the percentages referred by these authors, two samples originated from the county of Cruz das Almas, with accessory pollen of *Citrus* may be classified as being monofloral. In this county, the installation of apiaries next to orange tree orchards is common, contributing for the occurrence of such pollen type.

Pollen types of anemophilous species found in the honey pollen spectrum are considered not important for its composition, but significant for the geographical identification of the honey and for protein supplying for the colonies [7]. Among the three pollen types of anemophilous species identified in the samples of the Reconcavo da Bahia region, the type *Cecropia* was prominent.

5. CONCLUSION

Honey produced by *Apis mellifera* in the Reconcavo of Bahia, Brazil, has a multi-floral pattern with great contribution of the Mimosaceae species. In that sense, programs of implementation or expansion for beekeeping

foraging in the region must consider members of this family in the floral composition.

ACKNOWLEDGMENTS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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