

This article was downloaded by: [200.128.81.2]

On: 26 February 2015, At: 12:58

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Grana

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/sgra20>

Pollen diversity in honey from Sergipe, Brazil

Ana Paula Conceição Silva^a & Francisco de Assis Ribeiro Dos Santos^a

^a Programa de Pós-Graduação em Botânica, Laboratório de Micromorfologia Vegetal, Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil

Published online: 01 May 2014.



CrossMark

[Click for updates](#)

To cite this article: Ana Paula Conceição Silva & Francisco de Assis Ribeiro Dos Santos (2014) Pollen diversity in honey from Sergipe, Brazil, *Grana*, 53:2, 159-170, DOI: [10.1080/00173134.2014.896941](https://doi.org/10.1080/00173134.2014.896941)

To link to this article: <http://dx.doi.org/10.1080/00173134.2014.896941>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Pollen diversity in honey from Sergipe, Brazil

ANA PAULA CONCEIÇÃO SILVA & FRANCISCO DE ASSIS RIBEIRO DOS SANTOS

Programa de Pós-Graduação em Botânica, Laboratório de Micromorfologia Vegetal, Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil

Abstract

The pollen contents of honeys from 22 different municipalities of the Brazilian state of Sergipe were analysed. A total of 90 pollen types distributed in 32 plant families were identified. Fabaceae had the highest representation in number of pollen types (29 types), followed by Asteraceae (eight types), Rubiaceae (seven types), Anacardiaceae and Malvaceae (four each) and Euphorbiaceae and Myrtaceae (three each). The presence of dominant pollen was detected in 14 samples, with the dominant types *Mimosa pudica* in five samples, *Alternanthera* in two samples, *Angelonia*, *Cocos nucifera*, *Mimosa arenosa*, *Mimosa tenuiflora*, *Myrcia*, *Prosopis juliflora*, *Protium* and *Schinus* in one sample each. Eleven pollen types were recorded as accessory pollen: *Borreria verticillata*, *Mimosa pudica*, *Tapira* in three samples, *Mitracarpus hirtus* in two samples, *Angelonia*, *Baccharis*, *Cocos nucifera*, *Melastomataceae*, *Protium*, *Salvia* and *Senna macranthera* in one sample each. Pollen types from the genus *Mimosa* were prominent in the samples indicating the important contribution of species with palynological affinities with the pollen types found in this genus in the apicultural production of the region. Pollen types from species endemic to the Caatinga were found in the pollen spectrum for Sergipe: *Mimosa adenophylla*, *Mimosa ophthalmocentrica*, *Mimosa setuligera* and *Mimosa xiquexiquensis* from Fabaceae, and *Ziziphus joazeiro* from Rhamnaceae.

Keywords: *pollen analysis, native flora, floral resources, pollen types*

The knowledge regarding local bee floras allows the recognition of main floral resources used by the bees. This allows beekeepers to locate hives near the most appropriate and richer sources of nectar and pollen in their environment. The role of nectar and pollen on the diet of bees is vital, the first being the source of proteins to the bee offspring, and the second is the source of energy for the whole colony (Freitas 1991; Ramalho et al. 1991; Winston 1991). Besides, surveys for plants from a certain area, building knowledge of the resources utilised by bees represents an important step for the rational exploitation and development of programmes for bee conservation. These actions may help beekeeping management actions and also the identification, preservation and persistence of the most important plant species in the area (Wiese 1985).

According to Santos et al. (2005), north-eastern Brazil has a great beekeeping potential due to the favourable climate, the richness of its flora and the

diversity of native honeybees. However, this activity is only little exploited, making room for indiscriminate extractivism without a rational planning aiming the optimisation of main bee and plant resources.

The melissopalynological analysis of honey samples is an effective tool to recognise the bee flora of a given region, and thus to determinate its beekeeping potential. This method is based on the identification of pollen grains by comparison of morphological similarities with pollen grains from plant species that contributed in honey formation. It is also possible to provide information on the frequency of species by counting the amount of pollen grains and to determine the botanical and geographical origin of the honey sample (Moar 1985; Freitas & Silva 2006).

This study aims to identify the pollen content of *Apis mellifera* L. honeys from the state of Sergipe, Brazil, and to recognise possible pollen types associated to their geographical origins.

Correspondence: Ana Paula Conceição Silva, Laboratório de Micromorfologia Vegetal, Departamento de Ciências Biológicas, Universidade Estadual de Feira de Santana, Av. Transnordestina s/n, Novo Horizonte, 44036-900 Feira de Santana, Bahia, Brazil. E-mail: anapaula.csilva1@gmail.com

(Received 12 December 2013; accepted 2 February 2014)



Figure 1. State of Sergipe, Brazil, with the identification (•) of the sampled municipalities.

Material and methods

Study area

The state of Sergipe is situated in north-eastern Brazil and is considered the smallest of all Brazilian states, with a total of 21 910 km², representing 0.26% of the Brazilian land and 1.4% of the north-eastern Brazil territory. The state is bordered on the north by the São Francisco River and the state of Alagoas, on the south and west by the state of Bahia and on the east by the Atlantic Ocean. Its vegetation includes mangroves and a portion of tropical rain-forest on the coastal line, but most of its area is covered by Caatinga vegetation, a kind of semi-desertic vegetation. Its climate is tropical Atlantic on the coast and semi-arid inland. The state is divided into 75 municipalities distributed into three economic mesoregions (Figure 1): Sertão, Agreste and Leste Sergipano (Secretaria de Planejamento do Estado 2007).

Honey samples were collected from apiaries in all mesoregions of Sergipe from 2008 to 2011. A total of 22 samples were studied from the following municipalities:

- Mesoregion Sertão Sergipano: Canindé do São Francisco, Carira, Monte Alegre de Sergipe, Nossa Senhora da Glória, Poço Redondo, Porto da Folha and Ribeirópolis.
- Mesoregion Agreste Sergipano: Lagarto, Nossa Senhora das Dores, Poço Verde and Tobias Barreto.

- Mesoregion Leste Sergipano: Aracaju, Barra dos Coqueiros, Brejo Grande, Estância, Itaporanga d'Ajuda, Japaratuba, Japoatã, Neópolis, Nossa Senhora do Socorro, Propriá and São Cristóvão.

All municipalities were chosen according to samples availability, with one sample by municipality being provided by beekeepers and apicultural cooperatives from the production period 2008–2011.

Pollen analyses

Honey samples were analysed using the methodology of Louveaux et al. (1978) as adapted by Jones et al. (2004) in order to concentrate pollen grains. Ten grams of honey were dissolved in 10 ml of warm water, to which 50 ml of a 95% ethanol solution was added. The solution was centrifuged for 10 min at 1048g. The pollen sediment was prepared using the acetolysis method (Erdtman 1960) and mounted in permanent slides with glycerine jelly.

At least, a total of 500 pollen grains were counted in order to determine the frequency class of the pollen types. The pollen types were classified according to the categories defined by Louveaux et al. (1978): predominant pollen (> 45%), secondary pollen (16–45%), important minor pollen (3–15%), minor pollen (1–3%) and trace pollen (< 1%). The frequency of occurrence of the pollen types in the set of samples followed the classification of Jones and Bryant (1996): very frequent (> 50%), frequent (20–50%), infrequent (10–20%) and rare (< 10%).

For the calculation of the pollen concentration in the honey samples, one tablet of spores of *Lycopodium clavatum* L. was added as a foreign marker (Stockmarr 1971; Moar 1985; Jones & Bryant 1996), each tablet with 18 583 spores. The concentration of pollen grains in 10 g honey was estimated for each sample, and the results were grouped into five categories (Maurizio 1975): category I (< 20 000 pollen grains), category II (20 000–100 000), category III (100 000–500 000), category IV (500 000–1 000 000) and category V (> 1 000 000).

Additionally, an analysis of similarity among the samples investigated was performed using the PAST software (Palaeontological Statistics, Ver. 1.84; Hammer et al. 2001). The Jaccard similarity coefficient was used because this coefficient does not consider shared absence as evidence of similarity. Only information of presence/absence of pollen types in the samples was used in the analysis.

The pollen types were identified following the recommendations of Santos (2011), by comparison with the reference pollen of the Laboratory of Plant Micromorphology (LAMIV-UEFS), Feira de Santana, Brazil, and with the aid of available pollen

catalogues, such as Melhem et al. (2003); Palácios et al. (1991); Roubik and Moreno (1991) and Silva (2007); Lima et al. (2008) for the *Mimosa* species from the semi-arid region of Brazil, and Souza (2008) for *Mitracarpus* species.

Results

Pollen assemblages

A total of 90 pollen types assigned to 32 families were recorded from honey samples of the state of Sergipe (Figure 2, Table I). Another 32 pollen types, occurring in nine samples, could not be assigned to any plant family. These unidentified pollen types had a low representation in the samples (< 5.4%), occurring in frequency classes of important minor pollen, minor pollen and the majority was registered as trace pollen.

Among the 32 families identified in the pollen spectrum of honey from Sergipe, six occurred in more than 50% of the samples. The most frequent

is Fabaceae, present in all samples, followed by Asteraceae and Rubiaceae present in 90.9%, Amaranthaceae in 72.7%, Lamiaceae in 59% and Arecaceae in 54% of the samples. Moreover, the diversity of Fabaceae was a highlight, yielding 29 pollen types.

Families that made a significant contribution to the number of pollen types: Asteraceae (eight pollen types), Rubiaceae (seven pollen types), Anacardiaceae and Malvaceae (four each), Euphorbiaceae and Myrtaceae (three each), Acanthaceae, Amaranthaceae, Convolvulaceae, Cyperaceae, Lamiaceae, Melastomataceae and Sapindaceae (two each). Remaining families recorded a single pollen type each one.

Predominant pollen was found in 15 analysed samples, with *Mimosa pudica* L. in five samples, *Alternanthera* in two samples, *Angelonia*, *Cocos nucifera* L., *Mimosa arenosa* Poir., *Mimosa tenuiflora* Poir., *Myrcia*, *Prosopis juliflora* DC., *Protium* and *Schinus* in one sample, totalling in ten predominant pollen types. Eleven secondary pollen types were

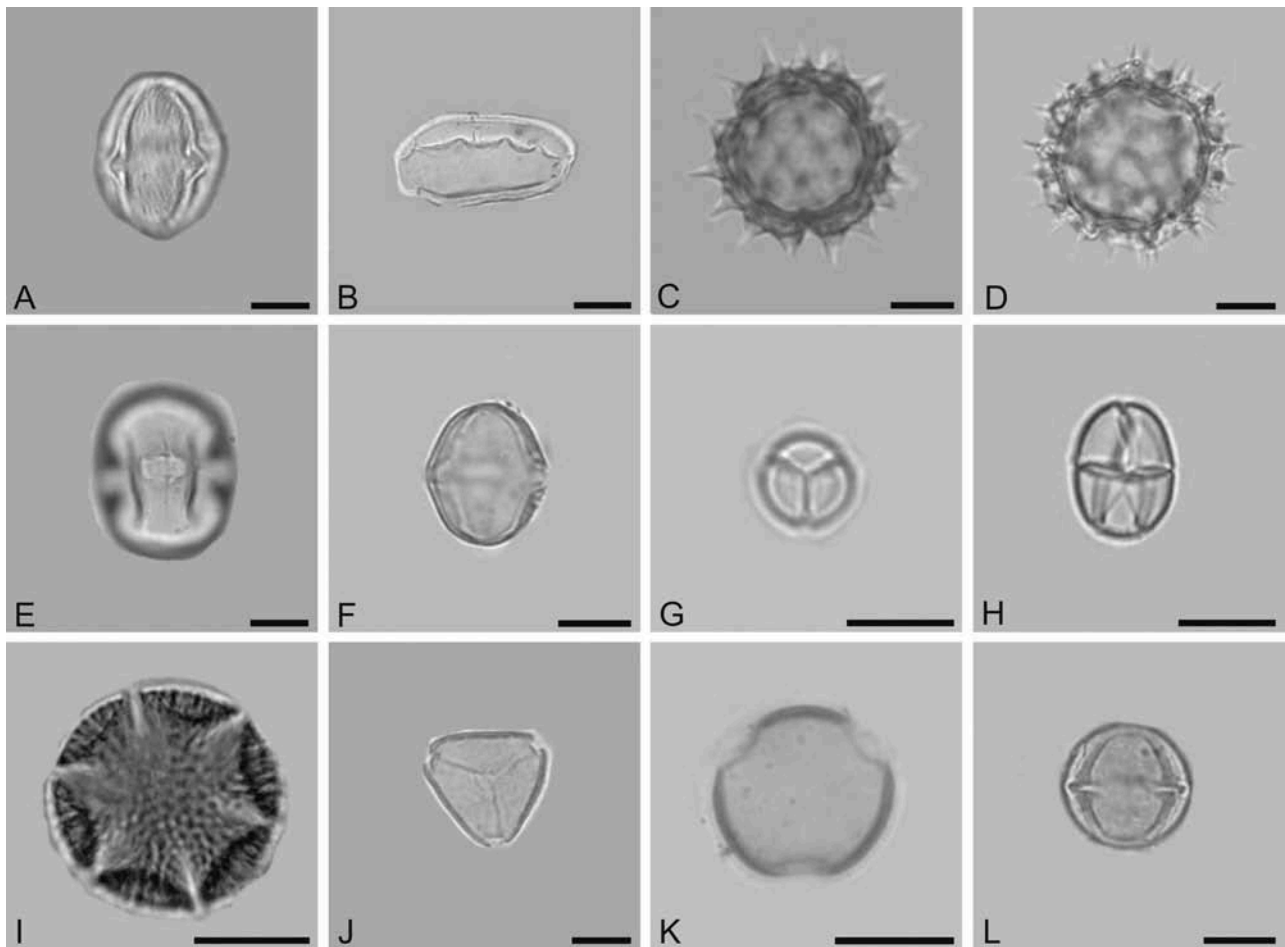


Figure 2. Pollen types found in *Apis mellifera* L. honey samples from Sergipe, Brazil. **A.** Anacardiaceae: *Tapirira*. **B.** Arecaceae: *Cocos nucifera*. **C.**, **D.** Asteraceae: **C.** *Baccharis*. **D.** *Vernonanthura*. **E.** Burceraceae: *Protium*. **F–H.** Fabaceae: **F.** *Chamaecrista*. **G.** *Mimosa sensitiva*. **H.** *Mimosa tenuiflora*. **I.** Lamiaceae: *Salvia*. **J.** Myrtaceae: *Myrcia*. **K.** Plantaginaceae: *Angelonia*. **L.** Solanaceae: *Solanum*. Scale bars: – 10 μ m.

Table I. Pollen analysis of honey samples from Sergipe, Brazil.

	Sertão Sergipano	Agreste Sergipano	Leste Sergipano
Municipalities sampled	CAR, CSF, PR, PF, MAS, NSG, RIB	LAG, NSD, PV, TB	ARA, BC, BG, EST, IA, JAPA, JAPO, NEO, NSS, PRO, SC
Families/pollen types	21/50	16/41	27/62
Unidentified pollen types	10	1	25
Fabaceae pollen type number	17	18	15
Predominant pollen types	<i>Alternanthera</i> <i>Angelonia</i> <i>Mimosa arenosa</i> <i>Mimosa tenuiflora</i>	<i>Mimosa pudica</i>	<i>Cocos nucifera</i> <i>Myrcia</i> <i>Mimosa pudica</i> <i>Prosopis juliflora</i> <i>Protium</i> <i>Schinus</i>
Secondary pollen types	<i>Angelonia</i> , <i>Borreria verticillata</i> <i>Mimosa pudica</i> Melastomataceae <i>Mitracarpus hirtus</i>	<i>Baccharis</i> <i>Borreria verticillata</i> <i>Mimosa pudica</i> <i>Salvia</i> <i>Senna macranthera</i>	<i>Cocos nucifera</i> <i>Mimosa pudica</i> <i>Mitracarpus hirtus</i> <i>Protium</i> <i>Tapirira</i>
Pollen types shared by all honeys form the municipalities	–	<i>Alternanthera</i> <i>Borreria verticillata</i> <i>Mimosa pudica</i> <i>Mikania</i> <i>Vernonanthura</i>	<i>Cocos nucifera</i> <i>Mimosa pudica</i>
Pollen concentration range	7055–546 558	12 833–98 845	15 910–238 243

Municipalities: ARA – Aracaju, CSF – Canindé do São Francisco, MAS – Monte Alegre de Sergipe, CAR – Carira, JAPO – Japoatã, IA – Itaporanga d'Ajuda, JAPA – Japaratuba, NSS – Nostra Senhora do Socorro, BG – Brejo Grande, BC – Barra dos Coqueiros, SC – São Cristóvão, NEO – Neópolis, EST – Estância, PR – Poço Redondo, TB – Tobias Barreto, PF – Porto da Folha, RIB – Ribeirópolis, NSG – Nostra Senhora da Glória, NSD – Nostra Senhora das Dores, LAG – Lagarto, PV – Poço Verde, PRO – Propriá.

found: *Borreria verticillata* G. Mey., *Mimosa pudica* and *Tapirira* in three samples, *Mitracarpus hirtus* DC. in two, *Angelonia*, *Baccharis*, *Cocos nucifera*, Melastomataceae, *Protium*, *Salvia* and *Senna macranthera* (DC. ex Collad.) H.S. Irwin et Barneby in one sample.

Nine pollen types were found in more than 50% of honey samples and were recorded as very frequent (Table II): *Alternanthera*, *Borreria verticillata* and *Mimosa pudica* occurred in 72.7% of samples, *Mikania* and *Mimosa tenuiflora* in 63.6%, *Vernonanthura* in 59% and *Cocos nucifera*, *Hyptis* and *Mimosa arenosa* in 54.5% of the samples.

An average of 17 pollen types was found in the analysed samples. The highest pollen diversity (29 pollen types) was recorded at Barra dos Coqueiros, in the Leste Sergipano mesoregion, and the lowest (ten pollen types) at Neópolis, also in the Leste Sergipano mesoregion.

Based on the absolute pollen count per 10 g of honey, most samples were found to belong to categories I (23.8%) and II (61.9%). The remaining samples belong to categories III (9.5%) and IV (4.8%).

Extreme values of pollen concentration were recorded for the Sertão Sergipano mesoregion, in

the municipalities of Canindé do São Francisco with 7055 pollen grains/10 g of honey, and in Ribeirópolis with 546 558 pollen grains/10 g of honey, in categories I and IV, respectively (Table III). In the sample from Propriá (Leste Sergipano mesoregion), spores of *Lycopodium clavatum* were not accounted due to its absence on counting, even though it was recorded on the analysed slides. Thus, it was not possible to infer the concentration of pollen grains in the honey.

Similarity of pollen samples

A conducted similarity analysis showed a grouping tendency of municipalities per mesoregion (Figure 3), with the recognition of three groups. Group A is a mixed group, formed of honey samples from three municipalities from the Sertão Sergipano mesoregion and one municipality from the Leste Sergipano mesoregion, with a similarity index of about 0.18. The municipality Aracaju, from Leste Sergipano, formed a group with Canindé do São Francisco from Sertão Sergipano, and Monte Alegre de Sergipe formed a group with Carira from Sertão Sergipano, both with a similarity index of about 0.25.

Table II. Frequency class and frequency of occurrence of pollen types in the honeys from Sergipe, Brazil.

Mesorregiões Pollen types	Sertão Sergipano							Agreste Sergipano							Leste Sergipano							FO	
	CSF	PR	PF	MAS	NSG	CAR	RIB	NSD	LAG	PV	TB	PRO	NEO	BG	JAPO	JAPA	NSS	BC	SC	ARA	IA		EST
Acanthaceae																							
<i>Dicliptera</i>							+																R
<i>Ruellia</i>																				+			R
Amaranthaceae																							
<i>Alternanthera</i>	D	+	+	I		D		I	+	+	I	+			I	+	+		+	m	+		VF
<i>Amaranthus</i>								+												+			R
Anacardiaceae																							
<i>Mangifera indica</i>							+																R
<i>Schinus</i>							I						I	S		D	m	S	S			+	F
<i>Tapirira</i>	+				+	I																	F
<i>Tapirira guianensis</i>																							F
Arecaceae																							R
<i>Cocos nucifera</i>														D	m	I	m	S	+	I	+	I	VF
Asteraceae																							
<i>Asteraceae</i>						I																	R
<i>Ageratum</i>					+																		R
<i>Asplia</i>					+																	+	F
<i>Baccharis</i>								S															R
<i>Gochmatia</i>																							R
<i>Mikania</i>		+	+		+		+	m	+	I	+	m									+	+	VF
<i>Sphagneticola</i>	m																						R
<i>Vernonanthura</i>	m	+	+		I	I	m	I	I	I	m					+			+		+		VF
Begoniaceae																							
<i>Begonia</i>							I																R
Boraginaceae																							
<i>Cordia</i>																							
Burseraceae																						+	R
<i>Protium</i>																							
Cactaceae																							
<i>Harrisia</i>						+																	F
Cannabaceae																							R
<i>Celtis</i>																							

(Continued)

Table II. (Continued).

Mesorregiões Pollen types	Sertão Sergipano						Agreste Sergipano						Leste Sergipano										FO
	CSF	PR	PF	MAS	NSG	CAR	RIB	NSD	LAG	PV	TB	PRO	NEO	BG	JAPO	JAPA	NSS	BC	SC	ARA	IA	EST	
<i>Croton heliconiifolius</i>			+	I																			R
Fabaceae																							
<i>Aschynomene</i>						+				m							m						R
<i>Anadenanthera colubrina</i>																							R
<i>Chamaecrista</i>							I								+							+	F
<i>Chamaecrista nictitans</i>		+							+									I	I				R
<i>Desmanthus</i>					I			+															R
<i>Erythrina</i>						I		+															IF
<i>Inga</i>			+										+										IF
<i>Mimosa acutistipula</i>					I				+	+													R
<i>Mimosa adenophylla</i>	I									+													VF
<i>Mimosa arenosa</i>		D	+		m		m		m		I			+	I	m	I	+		+	m		R
<i>Mimosa ophiadnocentra</i>																							R
<i>Mimosa pithecolobioides</i>											+												VF
<i>Mimosa pudica</i>					S			S	I	D	D	S	m	I	D	m	D	I	+	I	D	m	IF
<i>Mimosa quadrivalves</i>					+					m													
<i>Mimosa setuligera</i>			+	+						+			I										R
<i>Mimosa somnians</i>					+																		F
<i>Mimosa subnervis</i>			+							m													R
<i>Mimosa tenuiflora</i>	+		+	+	I	m	D			+					I	m	I	m	m	I	+		VF
<i>Mimosa ursina</i>									m														R
<i>Mimosa verrucosa</i>					I																		R
<i>Mimosa xiquexiquensis</i>									m														R
<i>Phaseolus</i>																+	+						R
<i>Piptadenia stipulacea</i>				+																			R
<i>Pithecellobium Prosopis juliflora</i>																		+		D			R
<i>Senna</i>	+					+	m	m	S		+	+											F
<i>Senna macranthera</i>																							R
<i>Stylosanthes Zornia</i>														I				I					R
Gentianaceae																							R
<i>Schultesia</i>																							
Lamiaceae																							
<i>Hyptis</i>	+		+		m		I	+	m	I		m		+				+	+		+		VF

	I	S	I	+ + + +	F
<i>Salvia</i>					F
Loranthaceae					R
Loranthaceae				+	
Lytracae					R
<i>Cuphea tenella</i>					+
Malvaceae					R
<i>Pachira</i>					R
<i>Sida</i>					R
<i>Triumfetta</i>					R
<i>Waltheria</i>					R
Melastomataceae					IF
Melastomataceae					IF
<i>Miconia</i>					R
Myrtaceae					IF
<i>Eucalyptus</i>					F
<i>Myrcia</i>					R
<i>Psidium</i>					R
Passifloraceae					R
<i>Passiflora</i>					R
Plantaginaceae					F
<i>Angelonia</i>					F
Poaceae					F
Poaceae					F
Polygalaceae					R
<i>Polygala</i>					R
Rhamnaceae					R
<i>Zyziphus joazeiro</i>					R
Rubiaceae					R
<i>Borreria I</i>					R
<i>Borreria II</i>					R
<i>Borreria tenera</i>					R
<i>Borreria verticillata</i>					VFF
<i>Mitracarpus frigidus</i>					F
<i>Mitracarpus hirsus</i>					F
<i>Richardia</i>					F
Rutaceae					R
<i>Citrus</i>					R
Sapindaceae					R
<i>Paulinia</i>					R
<i>Serjania</i>					R
Solanaceae					F
<i>Solanum</i>					F
Urticaceae					F
<i>Cecropia</i>					F

Mesoregions and municipalities: **Sertão Sergipano**: Canindé do São Francisco (CSF), Carira (CAR), Monte Alegre de Sergipe (MAS), N^a Senhora da Glória (NSG), Poco Redondo (PR), Porto da Folha (PF) and Ribeirópolis (RIB); **Agreste Sergipano**: Lagarto (LAG), N^a Senhora das Dores (NSD), Poço Verde (PV) and Tobias Barreto (TB); **Leste Sergipano**: Aracaju (ARA), Barra dos Coqueiros (BC), Brejo Grande (BG), Estância (EST), Itaporanga d'Ajuda (IA), Japaratuba (JAP), Japoatã (JAO), Neópolis (NEO) N^a Senhora do Socorro (PRO) and São Cristóvão (SC).
Frequency class: D – predominant pollen (> 45%), I – important minor pollen (3–15%), m – minor pollen (1–3%), + – trace pollen (< 1%).
Frequency of occurrence (FO): VF – very frequent (> 50%), F – frequent (> 20–50%), IN – infrequent (> 10–20%) and R – rare (< 10%).

Table III. Pollen concentration of honey samples from Sergipe, Brazil.

Mesoregions	Municipalities	Number of spores counted	Pollen concentration	Categories
Sertão	CSF	1317	7055	I
	CAR	130	71 473	II
	MAS	989	9394	I
	NSG	167	55 637	II
	PR	354	26 247	II
	PF	869	10 692	I
	RIB	17	546 558	VI
Agreste	LAG	182	51 052	II
	NSD	724	12 833	I
	PV	184	50 497	II
	TB	94	98 845	II
Leste	ARA	389	23 885	II
	BC	109	85 243	II
	BG	93	99 908	II
	EST	231	40 222	II
	IA	39	238 243	III
	JAPA	176	52 792	II
	JAPO	584	15 910	I
	NEO	129	72 027	II
	NSS	82	113 310	III
	PRO	—	—	—
	SC	236	39 370	II

Mesoregions and municipalities: **Sertão**: Canindé do São Francisco (CSF), Carira (CAR), Monte Alegre de Sergipe (MAS), N^a Senhora da Glória (NSG), Poço Redondo (PR), Porto da Folha (PF) and Ribeirópolis (RIB); **Agreste**: Lagarto (LAG), N^a Senhora das Dores (NSD), Poço Verde (PV) and Tobias Barreto (TB); **Leste**: Aracaju (ARA), Barra dos Coqueiros (BC), Brejo Grande (BG), Estância (EST), Itaporanga d'Ajuda (IA), Japarutuba (JAPA), Japoatã (JAPO), Neópolis (NEO) N^a Senhora do Socorro (NSS), Propriá (PRO) and São Cristóvão (SC).

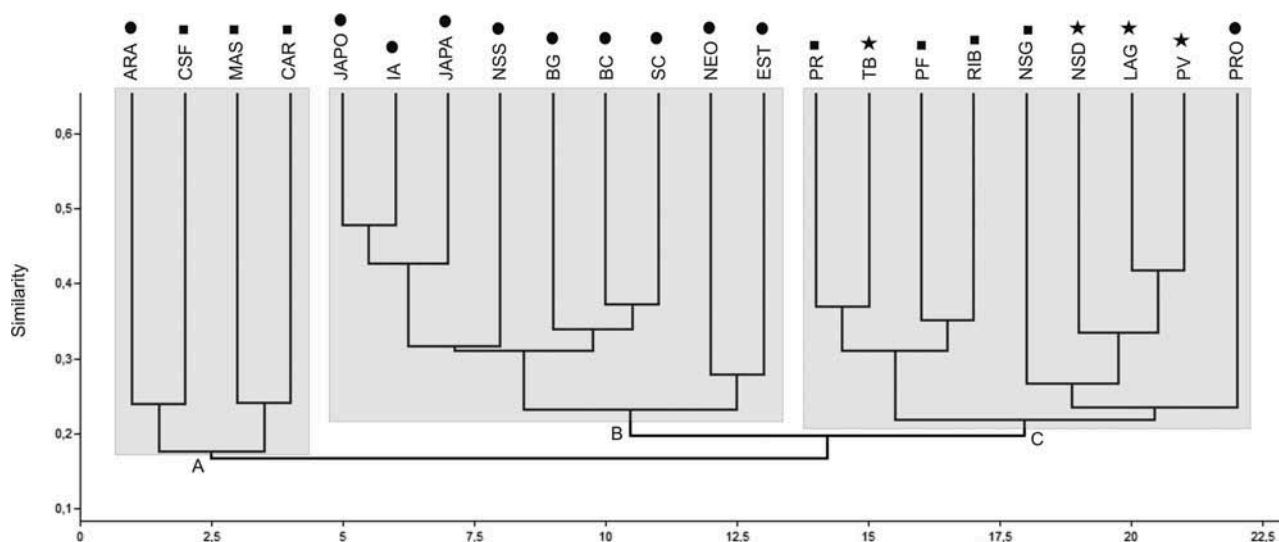


Figure 3. Similarity dendrogram among honey samples from state of Sergipe, Brazil. Municipalities: Group A: ARA – Aracaju, CSF – Canindé do São Francisco, MAS – Monte Alegre de Sergipe, CAR – Carira. Group B: JAPO – Japoatã, IA – Itaporanga d'Ajuda, JAPA – Japarutuba, NSS – Nossa Senhora do Socorro, BG – Brejo Grande, BC – Barra dos Coqueiros, SC – São Cristóvão, NEO – Neópolis, EST – Estância. Group C: PR – Poço Redondo, TB – Tobias Barreto, PF – Porto da Folha, RIB – Ribeirópolis, NSG – Nossa Senhora da Glória, NSD – Nossa Senhora das Dores, LAG – Lagarto, PV – Poço Verde, PRO – Propriá. Mesoregion: Sertão Sergipano (■), Agreste Sergipano (★) and Leste Sergipano (●).

Group B were exclusively samples from municipalities in the Leste Sergipano mesoregion. Nine of the 11 studied municipalities had a similarity index

of about 0.24. The samples from Japoatã and Itaporanga d'Ajuda had the highest similarity index (0.48). These honey samples shared ten

pollen types (*Alternanthera*, *Aspilia*, *Borreria verticillata*, *Cecropia*, *Cocos nucifera*, *Mikania*, *Mimosa arenosa*, *Mimosa pudica*, *Mimosa tenuiflora* and *Myrcia*), and also five pollen types exclusive from Japoatã and six exclusive from Itaporanga d'Ajuda honey. Group C includes honeys from municipalities in all three mesoregions. It includes four municipalities from Agreste Sergipano, four municipalities from Sertão Sergipano and one from Leste Sergipano, with a similarity index of about 0.23. Samples from Lagarto and Poço Verde (Agreste Sergipano) have also formed a group with a similarity index of 0.43. These samples shared ten pollen types (*Alternanthera*, *Borreria verticillata*, *Hyptis*, *Mikania*, *Mimosa acutistipula* Benth., *Mimosa pudica*, *Mitracarpus frigidus* K. Schum., *Richardia*, *Salvia* and *Vernonanthura*) and each one presented seven exclusive pollen types.

Discussion

The pollen spectrum found in the analysis of honey samples from Sergipe showed a large diversity of plant species foraged by *Apis mellifera*. The presence of pollen types related to species from different environments and with peculiar characteristics corroborates the generalist behaviour of these bees, which allows an easy adaptation and exploration of different environments (Köppler et al. 2007).

The pollen types showed the use of plants with different ecological niches by honeybees, some of them being important for eco-geographical honey characterisation: *Ziziphus joazeiro* Mart. (Rhamnaceae), endemic to Caatinga and characteristic for dry environments (Giulietti et al. 2002), *Mimosa sensitiva* L. and *Mimosa pudica* (Fabaceae) are both considered invasive species, the first characteristic of anthropic environments and the latter colonising degraded areas (Queiroz 2009); *Eucalyptus* (Myrtaceae) and *Citrus* (Rutaceae), both representatives of exotic trees cultivated by the economic potential (Souza & Lozenzi 2008). In Sergipe, mainly on the coastal zone and sometimes in Agreste, there are many areas of orange trees (*Citrus* spp.) for juice production, and eucalyptus plantations exploited for cellulose production. *Cocos nucifera* (Arecaceae) is a common species from coastal Sergipe but frequently found within the semi-arid region of the state. This pollen type, occurring as the Neópolis honey, is present with 53.4% of the pollen spectrum (predominant pollen).

Other pollen types found in the honey samples are also related to native species of the semi-arid region of Brazil, some of them are endemic to the Caatinga vegetation – the domain that covers most of the

Sergipe state territory: *Mimosa adenophylla* Taub. var. *armandiana* (Rizzini) Barneby, *Mimosa ophthalmocentra* Mart. ex Benth., *Mimosa setuligera* Harms and *Mimosa xiquexiquensis* Barneby assigned to Fabaceae (Giulietti et al. 2002; Queiroz 2002). Pollen types of these species are good geographical markers for honeys from this region.

Honey samples from north-eastern Brazil are characterised by pollen types assigned to Asteraceae, *Croton*, *Eucalyptus*, *Mimosa* (spp.) and *Piptadenia moniliformis* Benth. as stated by Barth (2004). These pollen types were recorded for Sergipe, except for *Piptadenia moniliformis*, which was represented in the state by pollen type of a different species of the same genus, *Piptadenia stipulacea* Ducke.

Pollen types assigned to Asteraceae and *Mimosa* play an important role in the pollen spectrum, occurring in all mesoregions of the state. Within the Asteraceae, pollen types of *Mikania* and *Vernonanthura* (= *Vernonia*-type in other analyses) were frequent, as well as pollen types of *Mimosa arenosa*, *Mimosa pudica* and *Mimosa tenuiflora* within *Mimosa* (Fabaceae). These pollen types were also recorded in the pollen spectrum of honey samples from Bahia, a neighbouring state of Sergipe (Oliveira 2009).

Honey samples from Lagarto in Agreste Sergipano had 23.6% of *Salvia* pollen type. According to Louveaux et al. (1978), this pollen type is under-represented in honey samples, so that honey with 10–20% of it can be labelled as monofloral.

A total of 92.8% of the plant families recorded in the pollen spectrum analysed from honeys of Sergipe were recorded by Santos et al. (2006) as important floral resources for bees within the semi-arid region of Brazil. Some of these families are important by accounting for more than 10% of the pollen spectrum (Ramalho et al. 1985), occurring in Sergipe honey. This includes plants in the Amaranthaceae, Anacardiaceae, Arecaceae, Asteraceae, Burseraceae, Euphorbiaceae, Fabaceae, Lamiaceae, Melastomataceae, Myrtaceae and Rubiaceae. In fact, some may not be essential for honey production, because they are polleniferous species rather than nectariferous. Nevertheless, these polleniferous species are extremely important as they supply protein to bee colonies.

Fabaceae play a central role in the pollen spectrum of honey samples analysed from Sergipe, having a large diversity of pollen types (29 types), and being recorded in all analysed samples from all mesoregions of the state. The importance of this family for the production of honey has been pointed out not only within the semi-arid region of Brazil, but also in other regions of the world (Santos et al. 2006; Forcone 2008; Novais et al. 2009; Oliveira et al. 2010; Ramirez-Arriaga et al. 2011).

Within the 29 pollen types recorded for Fabaceae, 14 are from *Mimosa*, the most representative genus in the pollen spectrum of honeys from Sergipe, recorded in all samples from all municipalities and mesoregions. According to Ramalho et al. (1990), *Mimosa* is one of the most important genera for native honeybees and for *Apis mellifera* within the Neotropical region. Its pollen types are commonly found in other studies regarding north-eastern Brazil (Lima 2007; Oliveira 2009).

Pollen types *Mimosa arenosa*, *Mimosa pudica* and *Mimosa tenuiflora* were very frequent in the studied samples (> 50%), as predominant pollen in seven samples, *Mimosa pudica* in five samples and *Mimosa arenosa* and *Mimosa tenuiflora* one sample each.

Mimosa arenosa is mainly an invasive species in the Caatinga, occurring in abandoned crops, often on sandy soils and periodically submerged (Queiroz 2009). Its pollen type was recorded in most parts of Sergipe, in 54.5% of the samples, as predominant pollen in honey from Poço Redondo (Alto Sertão Sergipano, a semi-arid region of the state).

Mimosa tenuiflora occurs in areas subjected to periodic droughts, showing great potential on colonising degraded areas with the formation of homogeneous bushes (Queiroz 2009). Its pollen type recorded a frequency of 63.6% within the municipalities in the pollen spectrum of Sergipe, also present in most parts of the state. In the municipalities of Ribeirópolis in Sertão Sergipano, it was the predominant pollen type.

The pollen type *Mimosa pudica* was the most frequent in the pollen spectrum, present in 72.7% of the samples. This type of pollen was predominant in five municipalities within the Agreste and Leste Sergipano mesoregions. This pollen type corresponds to the species *Mimosa pudica* and *Mimosa sensitiva*, both recorded as invasive species in north-eastern Brazil (Queiroz 2009). In honey samples from other regions of Brazil (south and southeast), this pollen type is mostly identified as *Mimosa scabrella* Benth. – a species, which does not occur in north-eastern Brazil.

The nectariferous Asteraceae occurred in 90.9% of the analysed samples with eight pollen types. It is an important floral resource for *Apis mellifera* in the Sergipe state. The family was recorded in all mesoregions and the pollen types of *Mikania* and *Vernonantura* recorded a frequency of 63.3% and 59.0%, respectively. According to Coronel (2010), most species of Asteraceae are nectar source and frequently visited by honeybees, producing good quality honey.

Like Asteraceae, pollen types of Rubiaceae were recorded in all mesoregions of the state, present in 90.9% of honey samples. The pollen type of *Borreria*

verticillata was very frequent in the samples with 72.7%, being characterised by an important nectar resource (Freitas & Silva 2006).

The *Ziziphus joazeiro* pollen type (Rhamnaceae) is an important geographical marker for honey samples from the semi-arid region of Brazil; it was recorded for a single honey, from the municipality Nossa Senhora das Dores (Agreste Sergipano). In other studies of honeys from the semi-arid region, mostly on Caatinga of Bahia, this type of pollen was frequently present (Carvalho & Marchini 1999; Novais et al. 2010; Oliveira et al. 2010).

Within the most important species for beekeeping in north-eastern Brazil, according to Santos et al. (2005), four of them had pollen types that were recorded for Sergipe: *Anadenanthera colubrina* (Vell.) Brenan, *Borreria verticillata*, *Mimosa tenuiflora* and *Ziziphus joazeiro*. From those, *Borreria verticillata* and *Mimosa tenuiflora* were the most representative in the state, the former was present in 16 honeys and the latter in 14 honeys, both being widespread species and important for beekeeping in Sergipe. Other species, such as *Anadenanthera colubrina* and *Ziziphus joazeiro*, were recorded for a single honey each only.

In addition, some pollen types (*Croton*, *Hyptis* and *Ricardia*) might be related to species from the list of important plants for beekeeping in north-eastern Brazil (Santos et al. 2005), such as *Croton sonderianus* Müll. Arg., *Hyptis suaveolens* (L.) Poit. and *Richardia grandiflora* Britton. These pollen types have a widespread distribution among honeys of Sergipe, with *Croton* and *Richardia* occurring in two mesoregions each, and *Hyptis* occurring in all mesoregions and found as important minor pollen, minor pollen and trace pollen, respectively.

A similarity analysis of the pollen spectrum from the honey samples demonstrates a tendency of honeys from the same mesoregion to be near each other in the dendrogram. However, the similarity indices for the groups formed were low, showing specific changes to the resources used by *Apis mellifera* during foraging activities in the mesoregions of Sergipe. This is confirmed by pollen types classified as rare in the sample set and which are not often representative of the samples, and placed in frequency classes of minor and trace pollen.

Conclusion

The richness of pollen types found in honey samples from the Sergipe state of Brazil shows the great diversity of floral resources used by *Apis mellifera* in the region. The presence of pollen types related to endemic species of the Caatinga vegetation shows that honeybees use native vegetation as floral resources,

corroborating the importance of these pollen types as geographic markers for honey samples from the semi-arid region of Brazil. The honey samples analysed here can be entitled as organic honey, characteristic from the semi-arid region of Brazil. Their pollen content is a mirror of native flora used by bees for foraging. Among the families recorded in Sergipe honeys, Fabaceae is the most important one for beekeeping in the region, with *Mimosa* being recorded in samples from all studied municipalities and responsible for a great individual representativeness on the samples.

Acknowledgements

The authors thank CAPES for granting a master's degree scholarship to APCS, CNPq for providing a productivity grant to FARS, the apiculturists, Sebrae/SE and the Laboratory of Food Research of the Institute of Technology and Research (Tiradentes University) for donating the honey samples used in this study. The programme of postgraduation in Botany and the Laboratory of Plant Micromorphology of the State University of Feira de Santana are acknowledged for allowing the use of their facilities for the research conducted.

References

- Barth OM. 2004. Melissopalynology in Brazil: A review of pollen analysis of honeys, propolis and pollen loads of bees. *Scientia Agricola* 61: 342–350. doi:10.1590/S0103-90162004000300018.
- 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.
- Coronel BM. 2010. La Miel. Uma mirada científica. Paraná: UNER.
- Erdtman G. 1960. The acetolysis method. A revised description. *Svensk Botanisk Tidskrift* 39: 561–564.
- Forcone A. 2008. Pollen analysis of honey from Chubut (Argentinean Patagonia). *Grana* 47: 147–158. doi:10.1080/10652460802106340.
- Freitas BM, Silva EMS. 2006. Potencial apícola da vegetação do semi-árido brasileiro. In: Santos FAR, ed. *Apium plantae*, 19–32. Recife: IMSEAR.
- Freitas BM. 1991. Potencial da caatinga para produção de pólen e néctar para a exploração apícola. Dissertação de Mestrado. Fortaleza: Universidade Federal do Ceará.
- Giulietti AM, Harley RM, Queiroz LP, Barbosa MRV, Neta ALB, Figueiredo MA. 2002. Espécies endêmicas da Caatinga. In: Sampaio EVSB, Giulietti AM, Virgínio J, Gamarra-Rojas CFL, eds. *Vegetação e flora da Caatinga*, 103–118. Recife: APNE.
- Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologica Electronica* 4: 1–9.
- Jones GD, Bryant Jr VM. 2004. The use of EtOH for the dilution of honey. *Grana* 43: 174–182. doi:10.1080/00173130410019497.
- Jones GD, Bryant VM. 1996. Melissopalynology. In: Jansonius J, McGregor DC, eds. *Palynology, principles and applications*, 933–938. Salt Lake City: AASP Foundation.
- 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. doi:10.1051/apido:2007020.
- Lima LCL. 2007. Espécies de *Mimosa* L. (Leguminosae) do semi-árido nordestino: palinologia, fenologia, biologia floral e potencial apícola. PhD Thesis, UEFS, Feira de Santana, Brazil.
- Lima LCL, Silva FHM, Santos FAR. 2008. Palinologia de espécies de *Mimosa* L. (Leguminosae - Mimosoideae) do semi-árido brasileiro. *Acta Botanica Brasílica* 22: 794–805. doi:10.1590/S0102-33062008000300016.
- Louveaux J, Maurizio A, Vorwohl G. 1978. Methods of melissopalynology. *Bee World* 59: 139–157.
- Maurizio A. 1975. Microscopy of honey. In: Crane E, ed. *Honey, a comprehensive survey*, 240–257. New York: Russak & Co.
- Melhem TS, Cruz-Barros MAV, Corrêa AMS, Makino-Watanabe H, Silvestre-Capelato MSF, Gonçalves-Esteves VL. 2003. Variabilidade polínica em plantas de Campos do Jordão (São Paulo, Brasil). *Boletim do Instituto de Botânica* 16: 1–104.
- Moar NT. 1985. Pollen analysis of New Zealand honeys. *New Zealand Journal of Agricultural Research* 28: 39–70. doi:10.1080/00288233.1985.10426997.
- Novais JS, Lima LCL, Santos FAR. 2009. Botanical affinity of pollen harvested by *Apis mellifera* L. in a semi-arid area from Bahia, Brazil. *Grana* 48: 224–234. doi:10.1080/00173130903037725.
- 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. doi:10.1016/j.jaridenv.2010.05.005.
- Oliveira PP. 2009. Análise palinológica de amostras de mel de *Apis mellifera* L. produzidas no estado da Bahia. PhD Thesis, UEFS, Feira de Santana, Brazil.
- Oliveira PP, van den Berg C, Santos FAR. 2010. Pollen analysis of honeys from Caatinga vegetation of the state of Bahia, Brazil. *Grana* 49: 66–75. doi:10.1080/00173130903485122.
- Palacios CR, Ludlow WR, Villanueva GR. 1991. Flora palinológica de la reserva de la biosfera de Sian Ka'an Quintana Roo, México. Chetumal: Centro de Investigaciones Quintana Roo.
- Queiroz LP. 2002. Distribuição das espécies de Leguminosae na caatinga. In: Sampaio EVSB, Giulietti AM, Virgínio J, Gamarra-Rojas CFL, eds. *Vegetação e flora da Caatinga*, 141–153. Recife: APNE.
- Queiroz LP. 2009. Leguminosae da Caatinga. Feira de Santana: UEFS/Kew: Royal Botanic Gardens.
- Ramalho M, Imperatriz-Fonseca VL, Kleinert-Giovannini A, Cortopassi-Laurino M. 1985. Exploitation of floral resources by *Plebeia remota* Holmberg (Apidae - Meliponinae). *Apidologie* 16: 307–330. doi:10.1051/apido:19850306.
- Ramalho M, Imperatriz-Fonseca VL, Kleinert-Giovannini A. 1991. Ecologia nutricional de abelhas sociais. In: Panizzi AR, Parra JRP, eds. *Ecologia nutricional de insetos e suas implicações no manejo de pragas*, 225–252. São Paulo: Editora Manole.
- Ramalho M, Kleinert-Giovannini A, Imperatriz-Fonseca VL. 1990. Important bee plants for stingless bees (*Melipona* and *Trigonini*) and Africanized honeybees (*Apis mellifera*) in neotropical habitats: A review. *Apidologie* 21: 469–488. doi:10.1051/apido:19900508.
- Ramirez-Arriaga E, Navarro-Calvo LA, Diaz-Carbajal E. 2011. Botanical characterisation of Mexican honeys from a subtropical region (Oaxaca) based on pollen analysis. *Grana* 50: 40–54. doi:10.1080/00173134.2010.537767.

- Roubik DW, Moreno JE. 1991. Pollen and spores of Barro Colorado. New York: Missouri Botanical Garden.
- Santos FAR. 2011. Identificação botânica do pólen apícola. *Magistra* 23: 4–9.
- Santos FAR, Oliveira AV, Lima LCL, Barros RFM, Schlindwein CP, Martins CF, Camargo RCR, Freitas BM, Kiill LHP. 2005. Apícolas. In: Sampaio EVSB, Pareyn FGC, Figueroa JM, Santos Jr AG, eds. *Espécies da flora nordestina com importância econômica potencial*, 15–26. Recife: APNE.
- Santos FAR, Oliveira JM, Oliveira PP, Leite KRB, Carneiro CE. 2006. Plantas do semi-árido importantes para as abelhas. In: Santos FAR, ed. *Apium Plantae*, 61–86. Recife: IMSEAR.
- Secretaria de Planejamento do Estado, Sergipe em Dados. 2007. Caracterização do território. http://www.se.gov.br/index/leitura/id/725/Caracterizacao_do_Territorio.htm; accessed 11 March 2010.
- Silva FHM. 2007. Contribuição à palinologia das caatingas. PhD Thesis, Universidade Estadual de Feira de Santana, Feira de Santana, Brazil.
- Souza EB. 2008. Estudos sistemáticos em *Mitracarpus* (Rubiaceae – Spermacoceae) com ênfase em espécies brasileiras. PhD Thesis, Universidade Estadual de Feira de Santana, Feira de Santana, Brazil.
- Souza VC, Lorenzi H. 2008. *Botânica Sistemática: Guia ilustrado para identificação das famílias de Fanerógamas nativas e exóticas do Brasil, baseado em APG II*. Nova Odessa: Instituto Plantarum.
- Stockmarr J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13: 615–621.
- Wiese H. 1985. *Novo manual de apicultura*. Porto Alegre: Agropecuária.
- Winston ML. 1991. *The biology of the honey bee*. Cambridge: Harvard University Press.