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First records of pollen rain in bromeliad tanks in an area of *caatinga* in northeastern Brazil[1]

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ABSTRACT

Species of Bromeliaceae have leaves in a spiral configuration. Because of the shape of the rosette thus formed and the imbricate configuration of the leaf sheaths, there is usually a tank in which rainwater and other components of the environment, including pollen grains, accumulate, making such tanks effective pollen rain collectors. The objective of this study was to use bromeliads as a tool to increase knowledge about the vegetation of the *caatinga* (shrublands) in the Canudos region of the state of Bahia, located in the semi-arid zone of Brazil, as well as to analyze the dynamics of pollen dispersal and deposition. To that end, we collected samples of the water from the tanks of bromeliads at the Canudos Biological Station. A total of 149 pollen types were detected, 88 of which could be identified botanically. The families that were the most well-represented among the pollen types were Fabaceae (with 25), Asteraceae (with 9), and Euphorbiaceae (with 7). Ten pollen types were presented as potential indicators of *caatinga* vegetation. We conclude that tank bromeliads are useful for gathering information about pollen rain and pollen dynamics, as well as about the transport and deposition of pollen in the *caatinga*.

Key words: Bromeliaceae, pollen rain, natural pollen trap

Introduction

Pollen grains and spores have low specific gravity, can reach great altitudes in turbulent air, and are therefore transported over great distances before their fall, which is known as pollen rain (Melhem *et al*. 2003). When pollen falls in a new area, pollen grains will become part of the sediments and be exposed to the conditions present in that environment. One of the requirements for their preservation is that the depositional environment is a reducing environment, which explains their good conservation in peat bogs and lake bottoms, where conditions are partially or totally anaerobic (Salgado-Labouriau 2007).

Palynological studies of soil surface samples or samples from artificial or natural pollen traps can furnish important information about the relationships between the present vegetation and the pollen rain, thereby facilitating the determination of to what extent the pollen rain reflects the composition of the vegetation community. Such studies can also provide indirect information concerning pollen productivity from different sources (taxa), dispersal efficiency, and preservation (Lazarova *et al*. 2006).

In the *caatinga* (shrublands), typical of the semi-arid zone of Brazil, where there are adverse environmental conditions—high temperatures, low humidity, and lack of perennial lacustrine environments—bromeliads seem to be a viable option for investigating pollen records. The leaves of most bromeliads are arranged in overlapping rosettes, forming a "tank" in which water and nutrients can accumulate (Moreira *et al*. 2006), thereby creating micro-ecosystems with physical, chemical, and biological parameters similar to those of larger aquatic bodies such as ponds and lakes (Cole & Caraco 2001). The objective of the present study was to evaluate the potential use of bromeliads in analyzing the dynamics of pollen grain dispersal and deposition in *caatinga* environments by examining the pollen contents and organic residues in their tanks.

[1] Based on the Master's dissertation of the first author

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Materials and methods

Study area

The study was undertaken at the Canudos Biological Station (CBS) in the municipality of Canudos, which is in the northeastern part of the state of Bahia, Brazil, at 400 m AMSL (09°54'S; 39°07'W), as shown in Fig. 1. The region experiences average monthly temperatures ranging from 20.7°C to 26.8°C, the warmest period being from November to March and coinciding with the rainy season, and annual rainfall is generally less than 800 mm (SEI 2013).

The regional vegetation is highly xerophytic, with areas of open shrub vegetation but denser tree and shrub growth along riversides and in valleys. The herbaceous stratum is poorly developed in valleys but fares better on hillsides, although flourishing in both environments during the rainy season. A floristic list of the CBS, prepared by Silva (2007), included 194 species, among 141 genera and 54 families, and provided information concerning growth habits and flowering periods.

Sampling and analyses

Samples of the pollen rain were collected from the tanks of ten adult bromeliads of the genus *Aechmea* Ruiz & Pav, growing in a valley (Fig. 1). The samples were identified with the abbreviation BT (for "bromeliad tank") and numbered. Collections BT1 (9°56'44.4"S; 38°58'54.7"W), BT2 (9°57'03.5"S; 38°59'19.4"W), BT3 (9°56'48.6"S; 38°59'08.1"W), and BT4 (9°56'48.6"S; 38°59'09.1"W) were obtained in September 2003, whereas collections BT5 (9°56'50.7"S; 38°58'50.3"W), BT6 (9°56'50.6"S; 38°58'51.3"W), BT7 (9°56'44.7"S; 38°58'53.6"W), BT8 (9°56'44.5"S; 38°58'52.5"W), BT9 (9°57'03.4"S; 38°59'20.4"W), and BT10 (9°56'45.3"S; 38°59'12.9"W) were obtained in March 2005. The samples were collected using clean 10-ml pipettes, and the water in each tank was then stirred to re-suspend the pollen residues. To avoid decomposition of the pollen residue, we stored the samples in test tubes containing phenol.

To concentrate the pollen residue, the samples were processed following the protocols described by Faegri & Iversen (1989). In brief, 4 ml of hydrofluoric acid (45%) were added to each tube to dissolve siliceous particles, after which the samples were washed twice with distilled water. We then added 8 ml of hydrochloric acid (10%) to remove any fluorine residues. That was followed by another wash with distilled water, a 5-min bath in acetic acid and acetolysis according to Erdtman (1960). Before the exchange of solutions, the samples were centrifuged at 2500 rpm. Two tablets of exotic spores (*Lycopodium clavatum* L.) were initially added to each sample in order to calculate the concentrations of pollen grains (Stockmarr 1971). Permanent slides were prepared from the samples using glycerin jelly. Whenever possible, ≥ 1000 pollen grains were counted from five slides per bromeliad tank.

The botanical affinities of pollen grains were determined using information in the literature (Lima *et al*. 2006; Silva

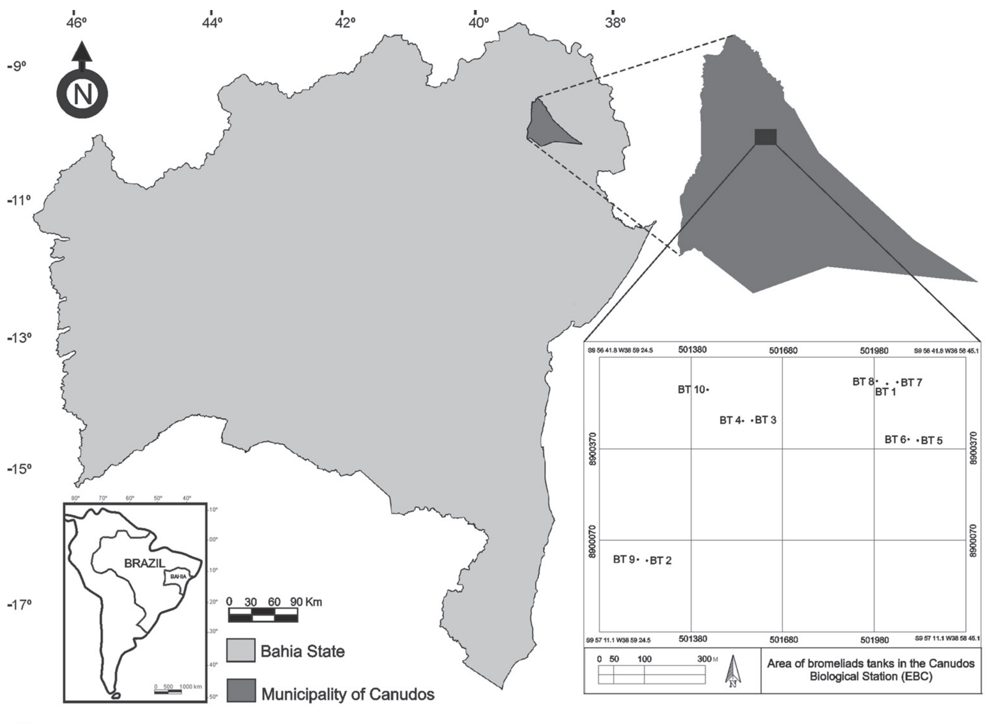

Figure 1. Location of bromeliad tanks (BTs) at the Canudos Biological Station (CBS), in the state of Bahia, within the semi-arid zone of Brazil.

2007; Lima *et al*. 2008), as well as by comparison with slides prepared from pollen samples collected in the Canudos region and deposited in the pollen collection of the Plant Micromorphology Laboratory at the (Bahia) State University of Feira de Santana and in the Palynology Laboratory at Bahia State University, Campus VII.

Results and discussion

All bromeliad tank sediment samples were found to contain pollen residue, composed of pollen grains and spores. A total of 149 pollen types were found (Tab. 1). Among those, we were able to determine the botanical affinity of 88, most to the species level (n = 51), although some were identified only to the level of genus (n = 16) or family (n = 21). There were 61 pollen types that could not be identified, because the grains were crushed, deformed, or in positions unfavorable to the observation of important exine characters. Such situations are commonly reported in palynological studies (Salgado-Labouriau 1973; Ávila & Bauermann 2001; Vergamini *et al*. 2006).

The families that were the most well-represented among the pollen types were Fabaceae (n = 25), Asteraceae (n = 9), and Euphorbiaceae (n = 7). According to Forzza *et al.* (2010), these families occupy the first, third and fourth positions in the ranking of the most diverse families in the *caatinga*, the second position being occupied by Poaceae. Therefore, at the family level, the diversity of the pollen types identified coincided for the most part with the floristic diversity reported for the *caatinga*.

Most of the pollen types identified to the species level were related to species found in the CBS. The three pollen types with the highest concentrations were from *Acalypha brasiliensis* (Euphorbiaceae), *Commiphora leptophloeos* (Burseraceae) and *Piptadenia moniliformis* (Fabaceae/ Mimosoideae). However, the most common (found in nine of the ten samples) was from *Mitracarpus scabrellus* (Rubiaceae). We found that the pollen spectrum at the species level also reflected the floristic diversity of the region.

During their research in the central Andes (in Peru, Bolivia, and Chile), Reese & Liu (2005) collected superficial soil samples and divided them into four collection groups by location (ecoregion). The authors found that the pollen in each of the four groups was indicative of the regional vegetation and that their signals characterized the principal vegetation zones. Their findings in soil samples are analogous to our findings in pollen rain samples obtained from bromeliad tanks, the examination of which allowed us to characterize the regional vegetation of the *caatinga* with a fair amount of efficiency.

We identified pollen types from *Mimosa sensitiva* and *Mimosa tenuiflora*, species that do not occur in the CBS but do grow in nearby regions. We also identified pollen types from *Sapium* spp., which have not been recorded for the region, although there are species of that genus in other areas of *caatinga* near the mid-course of the São Francisco River in northeastern Bahia (Sátiro & Roque 2008). Therefore, these pollen types were probably transported to the bromeliad tanks in the CBS by the wind or by animals.

In a three-year study conducted in Poland, Kasprzyk (2003) reported a similar situation. The author examined the relationship between the flowering of the genera *Alnus*, *Corylus*, and *Betula* and the occurrence of airborne pollen, reporting that pollen grains of species not found in the study area were nonetheless found in pollen rain samples. Green *et al*. (2004) noted that small pollen grains, such as those of the family Myrtaceae, can travel thousands of kilometers from their region of origin and contribute to aerobiological loads at other geographic localities. The authors pointed out that, after any initial deposition, pollen grains can be resuspended by gusts of wind during turbulent climatic events. The greatest wind velocities observed in the CBS (> 25 km/h) occurred between September and December and coincided with some of the driest months of the year (COELBA 2002).

Kasprzyk (2003) noted that the results of aerobiological studies are strongly related to phenological phenomena. In the present study, we did not collect samples from the bromeliad tanks on a monthly basis and analyze them in relation to the monthly phenological data for the region (Silva 2007). Nevertheless, we can draw some conclusions concerning the relationships between the pollen spectra of the CBS observed in the bromeliad tanks and the phenological conditions affecting the plant species that produced the pollen. For example, we noted that the presence of flowering individuals during the collection periods did not necessarily guarantee that their pollen would be found in the local pollen rain. The distances between the pollen production sources and the bromeliad tanks, low production of pollen grains by some species, and the large sizes of certain types pollen grains all might have influenced the composition of the pollen spectra.

Individually, the bromeliad tanks demonstrated variations in terms of the number of pollen types and their respective concentrations (Tab. 1). The *Acalypha brasiliensis* pollen type had some of the highest concentrations. According to Rodríguez *et al*. (2005), the presence of pollen in the atmosphere is related to the occurrence of anthesis among producer populations, and plants that are closer to the pollen traps have a greater chance of being represented in them. Therefore, the high representation of *A. brasiliensis* is probably associated with the presence of flowering adult individuals quite near the bromeliad tanks sampled. This observation is supported by our finding that there were high concentrations of *A. brasiliensis* pollen in tanks BT3 and BT4, which were 29 m apart but were much further from the eight other tanks, which contained low concentrations (or even none) of this pollen type. Within this context, Atanasova (2007) studied the pollen rain that accumulated in bryophyte mats and artificial traps in the central region of Bulgaria and noted that the high representativeness of

Table 1. Concentrations (pollen grains/ml) of pollen types found in bromeliad tanks at the Canudos Biological Station, in the state of Bahia, within the semi-arid zone of Brazil.

Pollen type	BT1	BT2	BT3	BT4	BT5	BT6	BT7	BT8	BT9	BT10	SUM
Acalypha brasiliensis (Euphorbiaceae)	-	-	60,230.5	5520.6	6.8	5256.1	-	-	15.4	-	71,029.3
Commiphora leptophloeos (Burseraceae)	60.4	-	-	-	-	-	3684.0	-	-	-	3744.4
Piptadenia moniliformis (Fab./Mimosoideae)	-	-	-	-	11.4	3.6	1348.0	2.2	-	-	1365.2
Copaifera (Fab./Caesalpinioideae)	-	3.1	1042.1	-	43.0	30.0	32.0	4.4	9.6	-	1164.2
Ipomoea brasiliana (Convolvulaceae)	15.1	-	-	-	-	-	1052.0	-	-	-	1067.1
Myrcia (Myrtaceae)	-	-	852.1	97.8	-	15.0	-	-	-	-	965.0
Croton zehntneri (Euphorbiaceae)	-	-	46.2	-	-	-	756.0	6.4	2.0	-	810.6
Piptadenia stipulacea (Fab./Mimosoideae)	-	-	-	10.9	-	18.8	658.0	-	-	-	687.7
Mitracarpus scabrellus (Rubiaceae)	75.5	-	41.1	10.9	22.8	9.2	131.6	2.2	5.8	20.6	319.7
Evolvulus glomeratus (Convolvulaceae)	271.9	1.6	-	-	-	-	-	-	-	-	273.5
Fabaceae/Papilionoideae 1	-	-	-	-	-	-	263.1	-	-	-	2631
Byrsonima vaccinifolia (Malpighiaceae)	-	-	20.5	-	45.4	11.2	164.4	-	-	-	241.5
Platypodanthera (Asteraceae)	15.1	-	20.5	10.9	4.6	3.6	98.0	-	2.0	-	154.7
Apocynaceae 1	-	-	-	108.7	-	-	-	-	-	-	108.7
Myrtaceae 1	-	-	-	108.7	-	-	-	-	-	-	108.7
Croton (Euphorbiaceae)	30.2	-	5.1	-	-	64.0	-	-	-	-	99.3
Poeppigia procera (Fab./Caesalpinioideae)	-	-	-	-	-	-	98.0	-	-	-	98.0
Cereus (Cactaceae)	-	-	-	-	-	-	66.0	-	-	-	66.0
Myrcia ovata (Myrtaceae)	-	-	-	-	-	-	66.0	-	-	-	66.0
Fabaceae/Mimosoideae 7	-	-	-	-	-	-	66.0	-	-	-	66.0
Stilpnopappus trichospiroides (Asteraceae)	-	1.6	25.7	-	-	-	32.0	-	2.0	-	61.2
Asteraceae 2	60.4	-	-	-	-	-	-	-	-	-	60.4
Cardiospermum corindum (Sapindaceae)	-	-	-	54.3	-	-	-	-	-	-	54.3
*Amaranthus viridis** (Amaranthaceae)	-	-	15.4	-	-	-	32.0	-	-	-	47.4
Chamaecrista ramosa (Fab./Caesalpinioideae)	-	-	-	-	-	41.4		-	-	-	41.4
Mimosa sensitiva (Fab./Mimosoideae)	-	-	-	-	2.2	1.8	32.0	-	3.8	-	39.8
Capparis jacobinae (Capparaceae)	-	-	15.4	10.9	4.6	7.4	-	-	-	-	38.3
Cordia (Boraginaceae)	-	-	20.5	10.9	-	1.8	-	-	2	-	35.2
Clidemia hirta (Melastomataceae)	-	-	-	32.6	-	-	-	-	-	-	32.6
Zornia echinocarpa (Fab./Papilionoideae)	-	-	30.8	-	-	-	-	-	-	-	30.8
Portulaca elaitor (Portulacaceae)	15.1	-	15.4	-	-	-	-	-	-	-	30.5
Cordia globosa (Boraginaceae)	30.2	-	-	-	-	-	-	-	-	-	30.2
*Froelichia humboldtiana** (Amaranthaceae)	30.2	-	-	-	-	-	-	-	-	-	30.2
Trichogonia campestris (Asteraceae)	-	-	5.1	-	-	-	-	2.2	-	20.6	27.9
Melochia (Malvaceae)	-	-	25.7	-	-	1.8	-	-	-	-	27.5
Sida (Malvaceae)	-	-	20.5	-	2.2	3.6	-	-	-	-	26.3
*Alternanthera ramosissima**(Amaranthaceae)	-	-	10.3	10.9	2.2	-	-	-	-	-	23.3
Fabaceae/Mimosoideae 2	-	-	20.5	-	-	-	-	-	-	-	20.5
Banisteriopisis muricata (Malpighiaceae)	-	-	20.5	-	-	-	-	-	-	-	20.5
Lepidaploa aurea (Asteraceae)	-	-	20.5	-	-	-	-	-	-	-	20.5
Microtea (Phytolaccaceae)	-	-	20.5	-	-	-	-	-	-	-	20.5
Cereus jamacaru (Cactaceae)	-	-	15.4	-	-	-	-	4.4	-	-	19.8
Asteraceae 1	15.1	-	-	-	-	-	-	-	-	-	15.1
Euphorbiaceae1	15.1	-	-	-	-	-	-	-	-	-	15.1

Continues

Table 1. Continuation.

Pollen type	BT1	BT2	BT3	BT4	BT5	BT6	BT7	BT8	BT9	BT10	SUM
Chamaecrista 1 (Fab./Caesalpinioideae)	15.1	-	-	-	-	-	-	-	-	-	15.1
Melocactus zehntneri (Cactaceae)	15.1	-	-	-	-	-	-	-	-	-	15.1
Pavonia glazioviana (Malvaceae)	15.1	-	-	-	-	-	-	-	-	-	15.1
Conocliniopsis prasiifolia (Asteraceae)	-	-	-	-	-	13.2	-	-	-	-	13.2
Cactaceae 1	-	-	-	-	-	13.2	-	-	-	-	13.2
Mimosa misera (Fab./Mimosoideae)	-	1.6	5.1	-	2.2	3.6	-	-	-	-	12.5
Myrcia laruotteana (Myrtaceae)	-	1.6		-	1.1	7.4	-	-	-	-	12.1
Asteraceae 3	-	-	10.3	-	-	-	-	-	-	-	10.3
Ziziphus joazeiro (Rhamnaceae)	-	-	10.3	-	-	-	-	-	-	-	10.3
Barnebya harleyi (Malpighiaceae)	-	-		-	9.0	-	-	-	-	-	9.0
Verbenaceae 1	-	-	-	-	-	7.4	-	-	-	-	7.4
Fabaceae/Mimosoideae 1	-	-	5.1	-	-	-	-	-	-	-	5.1
Fabaceae/Mimosoideae 3	-	-	5.1	-	-	-	-	-	-	-	5.1
Capparis yco (Capparaceae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Hapochilus (Acanthaceae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Hyptis martiusi (Lamiaceae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Mollugo verticillata (Molluginaceae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Oxalis divaricata (Oxalidaceae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Plathymenia reticulata (Fab./Mimosoideae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Senna rizinni (Fab./Caesalpinioideae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Zornia brasiliensis (Fab./ Papilionoideae)	-	-	5.1	-	-	-	-	-	-	-	5.1
Mimosa lewisii (Fab./Mimosoideae)	-	-	-	-	4.6	-	-	-	-	-	4.6
Mimosa tenuiflora (Fab./Mimosoideae)	-	-	-	-	-	-	-	2.2	2.0	-	4.2
Anadenanthera columbrina (Fab./ Mimosoideae)	-	-	-	-	-	3.6	-	-	-	-	3.6
Campomanesia (Myrtaceae)	-	-	-	-	-	3.6	-	-	-	-	3.6
Sapium (Euphorbiaceae)	-	-	-	-	-	3.6	-	-	-	-	3.6
Chamaecrista 2 (Fab./Caesalpinioideae)	-	-	-	-	-	3.6	-	-	-	-	3.6
Rubiaceae 1	-	-	-	-	2.3	-	-	-	-	-	2.3
Malvaceae 1	-	-	-	-	2.3	-	-	-	-	-	2.3
Caesalpinia pyramidalis (Fab./ Caesalpinioideae)	-	-	-	-	2.3	-	-	-	-	-	2.3
Croton heliotropiifolius (Euphorbiaceae)	-	-	-	-	2.3	-	-	-	-	-	2.3
Jatropha ribifolia (Euphorbiaceae)	-	-	-	-	2.3	-	-	-	-	-	2.3
Piriadacus erubescens (Bignoniaceae)	-	-	-	-	2.3	-	-	-	-	-	2.3
Solanum megalonix (Solanaceae)	-	-	-	-	2.3	-	-	-	-	-	2.3
Rutaceae 1	-	-	-	-	2.3	-	-	-	-	-	2.3
Solanaceae 1	-	-	-	-	-	-	-	2.2	-	-	2.2
Aspilia (Asteraceae)	-	-	-	-	-	-	-	-	2.0	-	2.0
*Erythroxylum caatingae** (Erythroxylaceae)	-	-	-	-	-	1.8	-	-	-	-	1.8
Fabaceae/Mimosoideae 5	-	-	-	-	-	1.8	-	-	-	-	1.8
Fabaceae/Mimosoideae 6	-	-	-	-	-	1.8	-	-	-	-	1.8

Continues

Table 1. Continuation

Pollen type	BT1	BT2	BT3	BT4	BT5	BT6	BT7	BT8	BT9	BT10	SUM
Borreria (Rubiaceae)	-	-	-	-	-	1.8	-	-	-	-	1.8
Capparaceae 1	-	-	-	-	-	1.8	-	-	-	-	1.8
Fabaceae/Mimosoideae 4	-	-	-	-	-	1.8	-	-	-	-	1.8
Spondias tuberosa (Anacardiaceae)	-	1.6	-	-	-	-	-	-	-	-	1.6
Unidentified**	[4] 60	[3] 10.8	[12] 129.4	[4] 641.1	[12] 79.3	[16] 126.4	[5] 1447.2	[2] 6.6	-	-	2500.8
Number of pollen types	19	9	48	16	34	46	22	10	10	2	-
Number of pollen grains/ml	740.0	22.0	62,730.0	10,411.0	261.0	5627.0	9933.0	74.0	58.0	41.0	-

BT – bromeliad tank; Fab. – Fabaceae.
*Pollen types related to anemophilous species.
**Numbers in brackets indicate the number of unidentified pollen types.

certain pollen types could be explained by their ability to remain intact in the type of collector utilized.

Adjacent bromeliad tanks, such as the BT5-BT6 pair (≈30 m apart) and the BT7-BT8 pair (≈34 m apart), showed differences in their total pollen concentrations and in the diversity of pollen types present. Cogliatti-Carvalho *et al.* (2010) noted that the bromeliad species with the highest capacities for water storage were generally those with the greatest biomass and the largest number of leaves per rosette, indicating a direct relationship between the external morphology of the plants and the maximum volume of water they can store. According to Benzing (1980), the maximum volume of water stored by individual bromeliads of the same species varies depending on factors specific to each specimen (such as the age of the plant and the size of its rosette) or external factors (such as rainfall and the degree of insolation, because evaporation is directly influenced by exposure to sunlight).

Pollen types of anemophilous families in the CBS flora (such as Fabaceae, Euphorbiaceae, and Asteraceae) were well represented in all of the tank samples in terms of their concentrations and in terms of their diversity. The phenological patterns in these species and in those of other anemophilous families are not always associated with the rainy season, as was demonstrated by Silva (2007). These plants are of great importance to the survival of many animal species during the driest periods of the year, especially pollinators that use the pollen grains and floral nectaries as their principal sources of nutrients. Likewise, during periods of extended drought or sporadic rainfall, bromeliad tanks can be the only sources of water in the *caatinga* and will be visited by a large variety of animals (including arthropods, mollusks, reptiles, birds, and mammals). Many of these animals also utilize bromeliads for protection and as reproduction sites (Benzing 1990). Given that many animals (especially floral visitors) will arrive with pollen grains adhering to their bodies, is possible that some grains will fall into the tanks and contribute to the richness and diversity of pollen types of anemophilous species. In the flora of the CBS, the diversity of anemophilous species is greater than is that of zoophilous species (Silva 2007), an aspect that was reliably reflected in the pollen rain within the bromeliad tanks sampled.

When the pollen types for which the botanical affinity had been determined were correlated with the habits of their respective species (Tab. 2), the representativeness of shrubs (31%) and trees (28%) was found to be higher than was that of herbaceous plants (26%), subshrubs (6%), cacti (6%), or lianas and vines (3%). According to Faegri & Iversem (1975), the greater representation of pollen types derived from trees and large shrubs would be expected due to their greater height, which favors efficient pollen dispersal by the wind. However, Reese & Liu (2005) observed that the lower representativeness of herbaceous plants (especially grasses) in the pollen rain could be related to the decrease in rainfall during a certain time of the year, because these plants usually do not have reserves that allow them to produce flowers during the dry period. In general, the hypotheses put forward by those authors can be used to determine the representativeness of plants, by growth habit, in the pollen rain in the CBS, because the trees and shrubs there are xerophytes, whereas most of the herbaceous plants and subshrubs die back during the dry season. Therefore, the pollen rain also reflects the general physiognomy of the area.

The quantification of pollen productivity of arboreal and non-arboreal taxa, as well as of their capacity for dispersal, deposition, and preservation at monitored sites, allows reconstructions of the paleoenvironmental conditions of a given region that are more detailed than are those obtained by analyzing the pollen spectra from ancient sediments in the same regions (Lazarova *et al.* 2006). The identification of the pollen types that are indicators of *caatinga* vegetation or semi-arid climates can further such studies. On the basis of criteria such as endemic species with specific pollen types, the representativeness of the pollen types in the samples, their morphological identity, and their resistance to palynological processing, we listed the following as being such indicators (Fig. 2): *Barnebya harleyi*, *Capparis jacobinae*, *Commiphora leptophloeos*, *Cereus jamacaru*,

Table 2. Growth habits of taxa related to the pollen types found in bromeliad tanks at the Canudos Biological Station, in the state of Bahia, within the semi-arid zone of Brazil.

Growth habit	Pollen types
Tree	*Anadenanthera columbrina* (Fabaceae/Mimosoideae), *Barnebya harleyi* (Malpighiaceae), *Caesalpinia pyramidalis* (Fabaceae/Caesalpinioideae), *Campomanesia* (Myrtaceae), *Commiphora leptophloeos* (Burseraceae), *Copaifera* (Fabaceae/Caesalpinioideae), *Cordia globosa* (Boraginaceae), *Erythroxylum caatingae* (Erythroxylaceae), *Mimosa tenuiflora* (Fabaceae/Mimosoideae), *Piptadenia moniliformis* (Fabaceae/Mimosoideae), *Piptadenia stipulacea* (Fabaceae/Mimosoideae), *Piriadacus erubescens* (Bignoniaceae), *Plathymenia reticulata* (Fabaceae/Mimosoideae), *Poeppigia procera* (Fabaceae/Caesalpinioideae), *Sapium* (Euphorbiaceae), *Senna rizinni* (Fabaceae/Caesalpinioideae), *Spondias tuberosa* (Anacardiaceae) and *Ziziphus joazeiro* (Rhamnaceae)
Shrub	*Acalypha brasiliensis* (Euphorbiaceae), *Byrsonima vaccinifolia* (Malpighiaceae), *Capparis jacobinae* (Capparaceae), *Capparis yco* (Capparaceae), *Chamaecrista ramosa* (Fabaceae/Caesalpinioideae), *Clidemia hirta* (Melastomataceae), *Conocliniopsis prasiifolia* (Asteraceae), *Cordia* (Boraginaceae), *Croton* (Euphorbiaceae), *Croton heliotropiifolius* (Euphorbiaceae), *Croton zehntneri* (Euphorbiaceae), *Hapochilus* (Acanthaceae), *Hyptis martiusi* (Lamiaceae), *Jatropha ribifolia* (Euphorbiaceae), *Melochia* (Malvaceae), *Mimosa lewisii* (Fabaceae/Mimosoideae), *Myrcia laruotteana* (Myrtaceae), *Myrcia ovata* (Myrtaceae), *Pavonia glazioviana* (Malvaceae) and *Solanum megalonix* (Solanaceae)
Subshrub	*Evolvulus glomeratus* (Convolvulaceae), *Lepidaploa aurea* (Asteraceae), *Mimosa misera* (Fabaceae/Mimosoideae) and *Mimosa sensitiva* (Fabaceae/Mimosoideae)
Herb	*Alternanthera ramosissima* (Amaranthaceae), *Amaranthus viridis* (Amaranthaceae), *Aspilia* (Asteraceae), *Borreria* (Rubiaceae), *Cardiospermum corindum* (Sapindaceae), *Froelichia humboldtiana* (Amaranthaceae), *Microtea* (Phytolacaceae), *Mitracarpus scabrellus* (Rubiaceae), *Mollugo verticillata* (Molluginaceae), *Oxalis divaricata* (Oxalidaceae), *Platypodanthera* (Asteraceae), *Portulaca elaitor* (Portulacaceae), *Sida* (Malvaceae), *Stilpnopappus trichospiroides* (Asteraceae), *Trichogonia campestris* (Asteraceae), *Zornia brasiliensis* (Fabaceae/Papilionoideae) and *Zornia echinocarpa* (Fabaceae/Papilionoideae)
Cactus	Cactaceae 1, *Cereus*, *Cereus jamacaru* and *Melocactus zehntneri*
Liana	*Banisteriopisis muricata* (Malpighiaceae) and *Ipomoea brasiliana* (Convolvulaceae)

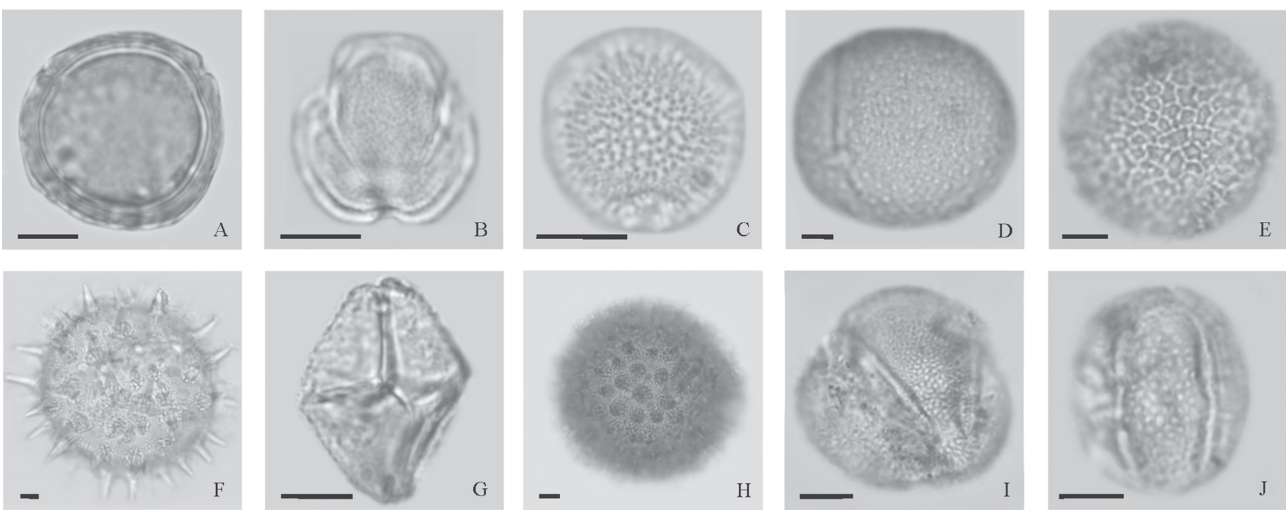

Figure 2. Pollen types found in bromeliad tanks at the Canudos Biological Station, in the state of Bahia, within the semi-arid zone of Brazil, related to species endemic to the *caatinga* (shrublands): (A) *Barnebya harleyi* (Malpighiaceae); (B) *Capparis jacobinae* (Capparaceae); (C) *Commiphora leptophloeos* (Burseraceae); (D) *Cereus jamacaru* (Cactaceae); (E) *Cordia globosa* (Boraginaceae); (F) *Ipomoea brasiliana* (Convolvulaceae); (G) *Mimosa misera* (Fabaceae/Mimosoideae); (H) *Pavonia glazioviana* (Malvaceae); (I) *Piriadacus erubescens* (Bignoniaceae); and (J) *Zornia echinocarpa* (Fabaceae/Papilionoideae). Bar = 10 μm.

Cordia globosa, *Ipomoea brasiliana*, *Mimosa misera*, *Pavonia glazioviana*, *Piriadacus erubescens*, and *Zornia echinocarpa*.

In this pioneering study, we have demonstrated for the first time that bromeliad tanks can be utilized as natural pollen grain collectors in the semi-arid zone of Brazil. This approach shows significant potential for gathering information about the pollen rain and pollen dynamics in the *caatinga*, where there are only rare opportunities for the natural deposition of pollen. The largest fraction of the pollen types found in the samples from the bromeliad tanks in the CBS comprised pollen grains produced by the local native vegetation itself. Considering that many of these pollen types were related to endemic species, we can define some of them as indicators of *caatinga* vegetation, which will prove useful in (future) paleoenvironmental studies. In addition, important structural (physiognomic) and ecological (pollination syndrome) aspects of the vegetation are reflected in the pollen rain captured in the bromeliad tanks, demonstrating the potential of these tanks to aid in studies beyond the limits of palynology and paleoecology.

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References

Atanassova, J.R. 2007. Pollen deposition in moss polsters and pollen traps in the Central Stara Planina Mts (2002-2005). **Phytologia Balcanica 13**(2): 223-228.

Ávila, I.R. & Bauermann, S.G. 2001. Espectros de precipitação polínica durante as estações de outono-inverno no município de Novo Hamburgo, Rio Grande do Sul, Brasil. **Pesquisas**, Série Botânica **51**: 51-58.

Benzing, D.H. 1980. **The Biology of the Bromeliads**. California, Mad River Press.

Benzing, D.H. 1990. **Vascular Epiphytes: General Biology and Related Biota**. Cambridge, Cambridge University Press.

COELBA - Companhia de Eletricidade do Estado da Bahia. 2002. **Estado da Bahia - Atlas do potencial eólico**. Salvador, COELBA.

Cogliatti-Carvalho, L.; Rocha-Pessoa, T.C.; Nunes-Freitas, A.F. & Rocha, C.F.D. 2010. Capacity water stored in the tank bromeliads in salt marshes along the Brazilian coast. **Acta Botanica Brasilica 24**: 84-95.

Cole, J.J. & Caraco, N.F. 2001. Carbon in catchments: connecting terrestrial carbonlosses with aquatic metabolism. **Marine Freshwater Research 52**: 101-110.

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

Faegri, K. & Iversen, J. 1975. **Textbook of pollen analysis**. Oxford, Blackwell Scientific Publications.

Faegri, K. & Iversen, J. 1989. **Textbook of pollen analysis**. New York, John Wiley & Sons.

Forzza, R.C.; Baumgratz, J.F.A.; Bicudo, C.E.M.; Carvalho Jr., A.A.; Costa, A.; Costa, D.P.; Hopkins, M.; Leitman, P.M.; Lohmann, L.G.; Maia, L.C.; Martinelli, G.; Menezes, M.; Morim, M.P.; Coelho, M.A.N.; Peixoto, A.L.; Pirani, J.R.; Prado, J.; Queiroz, L.P.; Souza, V.C.; Stehmann, J.R.; Sylvestre, L.S.; Walter, B.M.T. & Zappi, D. 2010. **Catálogo de plantas e fungos do Brasil** (vol. 1). Rio de Janeiro, Andrea Jakobsson Estúdio & Instituto de Pesquisas Jardim Botânico do Rio de Janeiro.

Green, B.J.; Dettmann, M.E.; Yli-Panula, E.; Rutherford, S. & Simpson, R. 2004. Aeropalynology of Australian native arboreal species in Brisbane, Australia. **Aerobiologia 20**: 43-52.

Kasprzyk, I. 2003. Flowering phenology and airborne pollen grains of chosen tree taxa in Rzesz´ow (SE Poland). **Aerobiologia 19**: 113-120.

Lazarova, M.; Petrova, M. & Jordanova, M. 2006. Pollen monitoring in surface samples in mosses and pollen traps from the Beglika region (WRhodopes). **Phytologia Balcanica 12**: 317-25.

Lima, L.C.L.; Silva, F.H.M.; Araújo, S.S. & Santos, F.A.R. 2006. Morfologia polínica de espécies de *Mimosa* L. (Leguminosae) apícolas do Semi-Árido. Pp. 87-102. In: Santos, F.A.R. (Ed.). **Apium plantae**. Recife, Instituto do Milênio do Semi-Árido.

Lima, L.C.L.; Silva, F.H.M. & Santos, F.A.R. 2008. Palinologia de espécies de Mimosa L. (Leguminosae - Mimosoideae) do Semi-Árido brasileiro. **Acta Botanica Brasilica 22**: 794-805.

Melhem, T.S.; Cruz-Barros, M.A.V.; Corrêa, A.M.S.; Makino-Watanabe, H.; Silvestre-Capelato, M.S.F. & Esteves, V.L.G. 2003. Variabilidade polínica em plantas de Campos de Jordão (São Paulo, Brasil). **Boletim do Instituto de Botânica 16**: 1-104.

Moreira, B.A.; Wanderley, M.G.L. & Barros, M.A.V.C. 2006. **Bromélias: importância ecológica e diversidade**. São Paulo, Instituto de Botânica.

Reese, C.A. & Liu, K.B. 2005. A modern pollen rain study from the central Andes region of South America. **Journal of Biogeography 32**: 709-718.

Rodriguez, A.F.M.; Molina, R.F.; Palacios, I.S.; Corchero, A.M. & Munhoz, J.T. 2005. Airborne behaviour of Echium pollen. **Aerobiologia 21**: 125-130.

Salgado-Labouriau, M.L. 1973. **Contribuição à palinologia dos cerrados**. Rio de Janeiro, Academia Brasileira de Ciências.

Salgado-Labouriau, M.L. 2007. **Critérios e técnicas para o Quaternário**. São Paulo, Edgard Blucher.

Sátiro, L.N. & Roque, N. 2008. A família Euphorbiaceae nas caatingas arenosas do médio rio São Francisco, BA, Brasil. **Acta Botanica Brasilica 22**: 99-118.

SEI – Superintendência de Estudos Econômicos e Sociais da Bahia. 2013. **Informações geoambientais**: informações geográficas e tipologia climática (Bahia). Disponível em: <http://www.sei.ba.gov.br/side/frame_tabela.wsp?tmp.volta=sg6&tmp.tabela=t78 >. Acesso em: 16 de outubro de 2013.

Silva, F.H.M. 2007. **Contribuição à palinologia das caatingas**. Tese de Doutorado, Universidade Estadual de Feira de Santana, Feira de Santana.

Stockmarr, J. 1971. Tablets with spores used in absolute pollen analysis. **Pollen Spores 13**: 615- 621.

Vergamini, S.M.; Valencia-Barrera, R.; Maria-Sbersi, F. & Fedrizzi, T.M. 2006. Palinologia do componente herbáceo na atmosfera de Caxias do Sul, RS, Brasil. **Acta Botanica Brasilica 20**(4): 937-941.