Acta Botanica Brasilica 29(4): 532-542. 2015.
doi: 10.1590/0102-33062015abb0128

First report of modern pollen deposition in moss polsters in a semiarid area of Bahia, Brazil[1]

Daiane Alves dos Santos[2], Luciene Cristina Lima e Lima[3], Francisco de Assis Ribeiro dos Santos[4] and Francisco Hilder Magalhães e Silva[2*]

Received: May 20, 2015. Accepted: August 6, 2015

ABSTRACT

Recent studies have shown that pollen analyses of natural substrates can produce data valuable for understanding the local pollen productivity and dispersal, deposition, and preservation potential of pollen grains. In this study, we aimed to acquire novel information about the dynamics and preservation of pollen in Caatinga environment through the palynological study of moss polsters. Samples of moss polsters in soil (MPS) and on rock (MPR) were collected from the Canudos Biological Station in the Bahia State (Brazil) and subjected to standard chemical treatments for the extraction of pollen residues. In total, 372 pollen types were recorded from the samples of which the taxonomical affinity of 140 was determined. The most represented families were Fabaceae (23 pollen types/16.42%) and Asteraceae (12 pollen types/8.57%). The MPS samples had a higher pollen concentration (21,042.04 pollen grains/cm^2) than the MPR samples (7,829.35 pollen grains/cm^2). On the other hand, the MPR samples had a greater diversity (68.26% of the identified pollen types). Qualitative analysis showed that the plants of shrub and subshrub habits had the greatest representation among the pollen types (35.0%). Overall, moss polsters proved to be excellent natural air pollen collectors in Caatinga environment, provided they had moist microhabitats for their development.

Keywords: Brazilian NE, moss, natural pollen trap, pollen rain, semiarid

Introduction

Aerobiology is the study of the release, retention, dispersion, deposition and atmospheric incidence of airborne particles such as pollen, spores and bacteria (Pathirane 1975). Fontana (2003) stated that the relationship between modern pollen and current vegetation and the establishment of modern analogies between them help in interpreting paleoenvironments. In this sense, recent studies have related modern pollen rain, which is the atmospheric dispersal and deposition of current pollen grains, to different types of vegetation from both natural and artificial collectors (e.g., lacustrine sediments, peat, soil, moss polsters).

According to Lazarova *et al.* (2006), the use of natural substrates in modern pollen rain studies has been an effective method for understanding pollen productivity, potential dispersion, deposition and preservation and has contributed to a more detailed reconstruction of paleoecological conditions in a particular area. For example, information on pollen grains in samples from soil surfaces of the Ceará State recently provided important support for paleoenvironmental interpretations of the ecological response mechanisms of a tropical rainforest microrefuge in northeastern Brazil to paleoclimatic changes that occurred in this region (Montade *et al.* 2014). Coincidentally, 2014 also saw the publication of the first study regarding the record of pollen rain in natural collectors for the Caatinga environment (Gomes *et al.* 2014). In this pioneering study, the authors demonstrated the importance of bromeliad tanks as pollen deposits for local and regional vegetation that are able to store and preserve palynomorphs, which together reveal important information about the physiognomic and ecological aspects of Caatinga vegetation.

Along these lines, the present study aimed to expand the knowledge of the dynamics of pollen grains in the Caatinga environment and generate unprecedented information on pollen rain records in moss polsters that are present in this type of environment to provide support for future paleoecological and paleoclimatic studies in the Brazilian semiarid region.

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

[2] Programa de Pós-Graduação em Biodiversidade Vegetal, Departamento de Educação, Universidade do Estado da Bahia, Campus VII, 48.970-000, Senhor do Bonfim, BA, Brazil
[3] Programa de Pós-Graduação em Biodiversidade Vegetal, Departamento de Ciências Exatas e da Terra, Universidade do Estado da Bahia, Campus II, 48.040-210, Alagoinhas, BA, Brazil
[4] Programa de Pós-Graduação em Botânica, Universidade Estadual de Feira de Santana, Feira de Santana, 44.031-460, BA, Brazil
[*] Corresponding author: hildermagalhaes@hotmail.com

Material and methods

Study area

The present study was undertaken in the Canudos Biological Station (CBS) in the municipality of Canudos in northeastern Bahia State, Brazil (400 m a.m.s.l.; 09°54'S; 39º07'W), as shown in Fig. 1. This region experiences average monthly temperatures ranging from 20.7°C to 26.8°C, with 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 dry period (April to October) is defined as the period when total monthly precipitation, in millimeters, is equal to or lower than double the mean monthly temperature, as expressed in degrees Celsius ($P \leq 2T$) (Bagnouls & Gaussen 1962).

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

Collection of moss polsters

We first performed survey work to locate moss polsters by hiking in the CBS. In dry periods, moss polsters were found only in cavities or in the outer areas of sandstone caves that had water drips inside. Only during rainy periods were moss polsters found outside sheltered caves, though they were nevertheless found very near sandstone hills and on rocks with the same composition. Samples were collected from an area of the CBS named Gruta do Minadouro (40 m length, 5 m width, 28 m height, approximately). Outside the cave was found open vegetation with a predominance of shrubs, subshrubs and herbs, but many trees were also present. Three samples were collected in September 2003, during the dry period, and five samples were collected in March 2005, during the rainy period. The codes MPS and MPR were applied to moss polster collected from soil surfaces and rocky walls, respectively. Two points were sampled: one was inside the cave, with collections in 2003 (MPR1, MPR2, MPS1) and 2005 (MPS2, MPS3), and the other was outside (09º56'45.3"S 38º59'12.9"W), with collections only in 2005 (MPR3, MPR4, MPR5). Any moss polters in soil samples or on rock samples were collected in close proximity to one another (approximately 2 m), but the distance between moss polters samples in soil and moss polters on rock was approximately 20 m. Moss samples were extracted in block shapes, using a stylus for cutting, and were then packaged in paper bags and stored in a freezer.

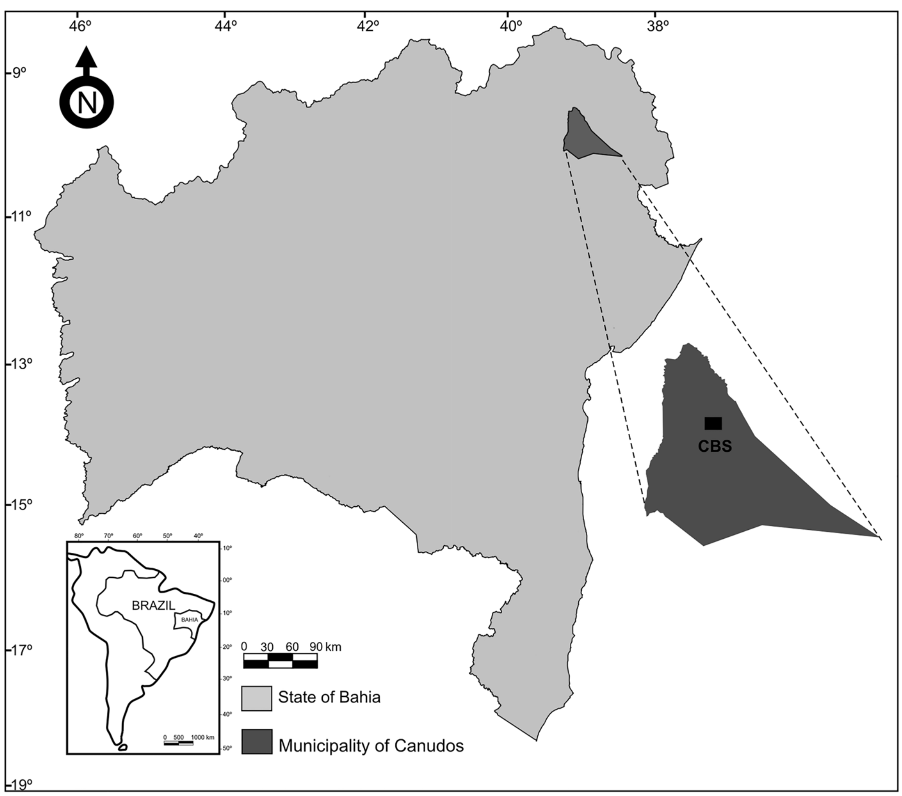

Figure 1. Location of moss polsters in Canudos Biological Station, Bahia State, Semi-arid of Brazil.

Sample processing

Samples were processed using the method of Grabandt (1980) with modifications due to the specific conditions of the samples. Thus, the following procedures were performed: (1) 4 cm² was cut from each sample; (2) the material was disrupted with a glass rod, after which two tablets of exotic spore (*Lycopodium clavatum* L. spores, ca. 18,583 per tablet, previously dissolved in 3 ml of 10% HCl) were added, and the sample boiled for 20 minutes in 10 ml of 10% KOH solution; (3) the mixture was filtered through a steel mesh with an approximately 198-μm aperture, and the final liquid was transferred to a polypropylene test tube for centrifugation; (4) the residue was washed with distilled water and centrifuge; (5) the final residue was then incubated in acetic acid for 5 min and centrifuged again; (6) acetolysis was performed according to Erdtman (1960); and (7) finally, six permanent slides were mounted with glycerin jelly and melted paraffin for each sample. All centrifugation steps were performed at 2,500 rpm.

Qualitative and quantitative analysis

Whenever possible, pollen grains were identified at the species level, using the pollen catalog available for the local flora (Silva 2007) and other works containing pollen descriptions of genera and families recorded in the CBS. We also consulted the pollen collection of the Laboratory of Palynological Studies, Universidade do Estado da Bahia (UNEB /Campus VII) and the Laboratory of Plant Micromorphology, Universidade Estadual de Feira de Santana (UEFS), which have slides of several species that are found in the Brazilian semiarid region. For the quantitative analysis, we sought to count at least 500 pollen grains for each sample. To calculate pollen concentration per cm², we used a rule of three, wherein the amount of pollen grains for each pollen type is multiplied by the total number of spores of *L. clavatum* contained in the tablets, and finally divided by the number of spores counted per sample. This result was then divided by four (value in cm² used for each bryophyte sample) to express the pollen concentration per cm².

Comparative analysis

Comparative analysis was performed with the pollen spectra obtained. We performed a cluster analysis, using the Dice similarity coefficient (McCune & Grace 2002), to evaluate the formation of groups among the samples studied based on the pollen types identified in the samples. All pollen types identified were considered for the presence–absence data matrix (Hammer *et al*. 2001). The similarity analysis was performed with the software PAST – Palaeontological Statistics – version 3.07 (Hammer *et al*. 2001).

Results

Pollen spectra and representative pollen types

All of the moss polsters samples on rocks (MPR) and in soil (MPS) contained pollen grains. Of the 372 total types registered, 140 had their taxonomical affinity identified (Tab. 1) and 232 were unidentified. Among the identified pollen types, 58 had a botanical affinity established at the species level, 47 at the genus level, and 35 at the family level.

Table 1. Concentration (pollen grains/cm²) of pollen types found in moss polsters at the Canudos Biological Station, in the state of Bahia, Brazil.

Pollen types (related botanic family)	2003			2005					Sum
	MPR1	MPR2	MPS1	MPR3	MPR4	MPR5	MPS2	MPS3	
1. *Mitracarpus/Spermacoce* (Rubiaceae)	43.20	226.62	1,606.94	471.64	83.58	27.98	12,344.78	1,906.60	16,711.34
2. *Conocliniopsis prasiifolia* (Asteraceae)	172.86	212.44	1,019.78	62.88	–	7.98	8,607.14	6,101.12	16,184.20
3. *Copaifera* (Fab./Caesalpinioideae)	86.42	8,016.74	154.50	1,933.76	706.96	599.70	368.50	432.16	12,298.74
4. *Trichogonia campestris* (Asteraceae)	8.64	14.16	1,885.08	–	3.48	43.96	6,290.84	3,190.36	11,436.52
5. *Pityrocarpa moniliformis* (Fab./Mimosoideae)	276.58	4,178.34	164.80	31.44	114.92	299.84	263.21	101.68	5,430.81
6. *Celtis* (Cannabaceae)	43.20	56.64	–	3,270.10	10.44	19.98	–	–	3,400.36
7. *Alternanthera ramosissima* (Amaranthaceae)	8.64	42.48	401.72	691.75	–	–	658.02	419.44	2,222.05
8. *Commiphora leptophloeos* (Burseraceae)	8.64	325.76	432.64	–	24.36	27.98	1,079.18	317.76	2,216.32
9. *Trachypogon spicatus* (Poaceae)	–	–	–	15.72	–	–	1,210.78	394.02	1,620.52
10. *Anadenanthera colubrina* (Fab./Mimosoideae)	8.64	1,033.96	30.9	47.16	16.92	79.96	50.64	63.54	1,331.72
11. *Varronia globosa* (Boraginaceae)	–	155.80	175.1	–	6.96	23.98	526.42	381.32	1,269.58
12. *Platypodanthera* (Asteraceae)	484.02	368.26	247.22	47.16	3.48	7.98	–	–	1,158.12
13. *Cereus jamacaru* (Cactaceae)	–	56.64	113.30	–	–	15.98	289.52	406.74	882.18
14. *Acalypha brasiliensis* (Euphorbiaceae)	8.64	14.16	473.84	–	–	15.98	–	279.62	792.24

Continues.

Table 1. Continuation.

Pollen types (related botanic family)	2003			2005					Sum
	MPR1	MPR2	MPS1	MPR3	MPR4	MPR5	MPS2	MPS3	
15. *Vernonia* (Asteraceae)	–	–	–	–	–	–	605.38	152.52	757.90
16. *Piptadenia stipulacea* (Fab./Mimosoideae)	129.64	538.22	–	31.44	6.96	7.98	–	–	714.24
17. *Stilpnopappus scaposus* (Asteraceae)	207.43	467.40	–	–	6.96	3.98	–	–	685.77
18. *Mimosa sensitiva* (Fab./Mimosoideae)	25.92	14.16	92.70	110.04	17.40	31.98	368.50	–	660.70
19. Malpighiaceae 4	–	–	103.00	–	–	–	500.10	25.42	628.52
20. *Mimosa arenosa* (Fab./Mimosoideae)	–	396.58	164.80	31.44	10.44	–	–	–	603.26
21. *Herissantia* (Malvaceae)	43.20	382.42	41.20	47.16	3.48	7.98	50.64	12.70	588.78
22. *Chamaecrista swainsonii* (Fab./Caesalpinioideae)	25.92	424.90	–	47.16	20.88	19.98	–	38.12	576.96
23. *Campomanesia* (Myrtaceae)	17.28	396.58	–	94.32	13.93	39.98	–	–	562.09
24. *Eupatorium* (Asteraceae)	–	–	504.74	–	–	–	–	–	504.74
25. *Amaranthus viridis* (Amaranthaceae)	–	42.48	82.40	62.88	–	–	105.28	177.94	470.98
26. *Mimosa lewisii* (Fab./Mimosoideae)	60.50	212.44	–	140.00	17.40	3.98	–	12.70	447.02
27. *Plathymenia reticulata* (Fab./Mimosoideae)	–	439.08	–	–	–	–	–	–	439.08
28. *Zizyphus joazeiro* (Rhamnaceae)	60.50	509.88	–	15.72	3.48	31.98	–	–	621.56
29. *Enteropogon mollis* (Poaceae)	–	–	391.42	–	–	–	–	–	391.42
30. *Chamaecrista ramosa* (Fab./Caesalpinioideae)	–	354.08	–	–	–	–	–	–	354.08
31. *Gomphrena demissa* (Amaranthaceae)	–	–	41.20	–	–	–	157.92	127.10	326.22
32. *Pilosocereus tuberculatus* (Cactaceae)	–	297.44	20.60	–	3.48	–	–	–	321.52
33. *Froelichia lanata* (Amaranthaceae)	–	–	113.30	–	–	–	131.60	63.54	308.44
34. *Sida* (Malvaceae)	–	42.48	41.20	15.72	–	3.98	26.32	165.22	294.92
35. *Anemopaegma laeve* (Bignoniaceae)	–	–	51.50	–	–	–	210.56	25.42	287.48
36. *Myrcia* 1 (Myrtaceae)	–	226.62	–	15.72	–	3.98	–	–	246.32
37. Asteraceae 3	–	–	164.80	–	–	–	–	76.26	241.06
38. *Phyllanthus* (Phyllanthaceae)	–	–	123.60	62.88	6.96	43.96	–	–	237.40
39. *Clidemia* (Melastomataceae)	–	212.44	–	–	–	–	–	–	212.44
40. *Aspilia bonplandiana* (Asteraceae)	34.57	–	154.50	–	10.44	3.98	–	–	203.49
41. Myrtaceae 3	–	184.12	–	–	17.40	–	–	–	201.52
42. *Chomelia* (Rubiaceae)	8.64	184.12	–	–	6.96	–	–	–	199.72
43. *Croton zehntneri* (Euphorbiaceae)	–	70.81	30.90	15.72	6.96	39.98	–	12.70	177.07
44. *Harpochilus* (Acanthaceae)	–	–	10.30	15.72	6.96	–	–	139.80	172.78
45. *Hyptis* (Lamiaceae)	25.92	113.30	20.60	–	–	–	–	12.70	172.52
46. *Senna* (Fab./Caesalpinioideae)	–	–	30.90	–	–	–	131.60	–	162.50
47. Poaceae	–	–	154.50	–	–	–	–	–	154.50
48. *Jacquemontia* 1 (Convolvulaceae)	17.28	–	82.40	–	–	–	50.64	–	150.32
49. *Solanum megalonyx* (Solanaceae)	8.64	42.48	–	62.88	27.86	3.98	–	–	145.84
50. *Erythroxylum caatingae* (Erythroxylaceae)	–	127.46	–	–	–	15.96	–	–	143.42
51. *Melocactus zehntneri* (Cactaceae)	–	42.48	–	–	–	7.98	50.64	38.12	139.22
52. *Croton heliotropiifolius* (Euphorbiaceae)	–	28.32	–	62.88	27.86	7.98	–	–	127.04
53. *Jatropha ribifolia* (Euphorbiaceae)	–	99.14	–	–	6.96	19.98	–	–	126.08
54. Bignoniaceae	–	–	92.70	31.44	–	–	–	–	124.14
55. Asteraceae 2	–	–	123.60	–	–	–	–	–	123.60
56. *Digitaria tenuis* (Poaceae)	–	28.32	61.80	–	–	3.98	26.32	–	120.42
57. *Helicteres* (Malvaceae)	–	–	–	94.32	–	–	–	–	94.32
58. Rubiaceae 1	–	–	–	94.32	–	–	–	–	94.32

Continues.

Table 1. Continuation.

Pollen types (related botanic family)	2003			2005					Sum
	MPR1	MPR2	MPS1	MPR3	MPR4	MPR5	MPS2	MPS3	
59. Myrtaceae 2	–	84.98	–	–	3.48	–	–	–	88.46
60. *Poincianella pyramidalis* (Fab./Caesalpinioideae)	17.28	70.81	–	–	–	–	–	–	88.09
61. *Andropogon selloanus* (Poaceae)	17.28	–	10.30	–	–	7.98	26.32	25.42	87.30
62. Solanaceae 1	–	–	–	–	–	7.98	–	76.26	84.24
63. *Heteropterys* (Malpighiaceae)	–	–	30.90	–	–	–	50.64	–	81.54
64. Rubiaceae 2	–	–	–	78.60	–	–	–	–	78.60
65. Myrtaceae 4	–	70.81	–	–	–	–	–	–	70.81
66. *Eucalyptus* (Myrtaceae)	–	42.48	–	–	–	–	26.32	–	68.80
67. *Cnidoscolus loefgrenii* (Euphorbiaceae)	8.64	56.64	–	–	–	–	–	–	65.28
68. Verbenaceae	–	–	–	–	–	–	–	63.54	63.54
69. *Barnebya harleyi* (Malpighiaceae)	–	–	–	47.16	3.48	–	–	12.70	63.34
70. *Mimosa misera* (Fab./Mimosoideae)	–	42.48	20.60	–	–	–	–	–	63.08
71. *Diodia* (Rubiaceae)	8.64	28.32	–	–	–	11.99	–	12.70	61.65
72. Malpighiaceae 2	–	–	10.30	–	–	–	50.64	–	60.94
73. *Spondias tuberosa* (Anacardiaceae)	–	–	–	–	24.36	7.98	26.32	–	58.66
74. *Jatropha mutabilis* (Euphorbiaceae)	–	56.64	–	–	–	–	–	–	56.64
75. *Mimosa* 2 (Fab./Mimosoideae)	–	–	–	–	–	27.98	26.32	–	54.30
76. *Banisteriopsis stellaris* (Malpighiaceae)	–	–	10.30	15.72	–	–	26.32	–	52.34
77. *Melochia* (Malvaceae)	–	28.32	–	–	17.40	–	–	–	45.72
78. *Mimosa* 1 (Fab./Mimosoideae)	–	–	–	–	45.26	–	–	–	45.26
79. *Piriadacus erubescens* (Bignoniaceae)	–	–	–	–	6.96	–	–	38.12	45.08
80. *Jacquemontia montana* (Convolvulaceae)	–	42.48	–	–	–	–	–	–	42.48
81. *Tacinga inamoema* (Cactaceae)	–	28.32	–	–	–	–	–	12.70	41.02
82. Fabaceae/Mimosoideae	–	14.16	–	–	–	–	26.32	–	40.48
83. *Oxalis psoralioides* (Oxalidaceae)	–	28.32	–	–	3.48	7.98	–	–	39.78
84. Rutaceae	34.57	–	–	–	–	3.98	–	–	38.55
85. *Lepidaploa aurea* (Asteraceae)	25.92	–	10.30	–	–	–	–	–	36.22
86. Polygalaceae	–	–	–	–	–	7.98	–	25.42	33.40
87. *Cardiospermum corindum* (Sapindaceae)	8.64	–	–	–	13.92	–	–	12.70	35.26
88. Cyperaceae	–	–	–	31.44	–	–	–	–	31.44
89. *Byrsonima* (Malpighiaceae)	–	–	30.90	–	–	–	–	–	30.90
90. Malpighiaceae 1	–	–	30.90	–	–	–	–	–	30.90
91. *Cleome* (Capparaceae)	17.28	–	–	–	3.48	7.98	–	–	28.74
92. Lamiaceae	–	42.48	20.60	–	–	7.98	–	–	71.06
93. Loranthaceae 1	–	28.32	–	–	–	–	–	–	28.32
94. *Poeppigia procera* (Fab./Caesalpinioideae)	–	28.32	–	–	–	–	–	–	28.32
95. *Roupala* (Proteaceae)	–	28.32	–	–	–	–	–	–	28.32
96. Solanaceae 3	–	14.16	–	–	–	–	–	12.70	26.86
97. *Myrcia* 3 (Myrtaceae)	–	–	–	–	–	–	26.32	–	26.32
98. Malpighiaceae 3	–	14.16	10.30	–	–	–	–	–	24.46
99. *Myrcia* 2 (Myrtaceae)	–	–	–	–	3.48	19.98	–	–	23.46
100. *Manihot dichotoma* (Euphorbiaceae)	–	14.16	–	–	6.96	–	–	–	21.12

Continues.

Table 1. Continuation.

Pollen types (related botanic family)	2003			2005					Sum
	MPR1	MPR2	MPS1	MPR3	MPR4	MPR5	MPS2	MPS3	
101. Malvaceae	–	–	20.60	–	–	–	–	–	20.60
102. *Vernonia chalybaea* (Asteraceae)	–	–	–	15.72	–	3.98	–	–	19.70
103. *Poincianella microphylla* (Fab./Caesalpinioideae)	–	14.16	–	–	–	3.98	–	–	18.14
104. *Angelonia* (Scrophulariaceae)	17.28	–	–	–	–	–	–	–	17.28
105. *Senna rizzinii* (Fab./Caesalpinioideae)	17.28	–	–	–	–	–	–	–	17.28
106. *Solanum paniculatum* (Solanaceae)	17.28	–	–	–	–	–	–	–	17.28
107. *Jacquemontia* 2 (Convolvulaceae)	–	–	–	–	3.48	–	–	12.70	16.18
108. Fabaceae	–	–	–	–	–	15.98	–	–	15.98
109. *Chamaecrista* (Fab./Caesalpinioideae)	–	14.16	–	–	–	–	–	–	14.16
110. Loranthaceae 2	–	14.16	–	–	–	–	–	–	14.16
111. *Paullinia* (Sapindaceae)	–	14.16	–	–	–	–	–	–	14.16
112. *Psittacanthus* (Loranthaceae)	–	14.16	–	–	–	–	–	–	14.16
113. *Ipomoea* (Convolvulaceae)	–	–	–	–	–	–	–	12.70	12.70
114. *Solanum* (Solanaceae)	–	–	–	–	–	–	–	12.70	12.70
115. *Zornia* (Fab./Papilionoideae)	8.64	–	–	–	–	3.98	–	–	12.62
116. *Microtea* (Phytolaccaceae)	8.64	–	–	–	3.48	–	–	–	12.12
117. *Simaba* (Simaroubaceae)	–	–	–	–	–	11.99	–	–	11.99
118. *Mollugo verticillata* (Molluginaceae)	–	–	–	–	6.96	3.98	–	–	10.94
119. Euphorbiaceae	–	–	–	–	10.44	–	–	–	10.44
120. Myrtaceae 1	–	–	–	–	10.44	–	–	–	10.44
121. *Senna velutina* (Fab./Caesalpinioideae)	–	–	–	–	10.44	–	–	–	10.44
122. Asteraceae 1	–	–	10.30	–	–	–	–	–	10.30
123. *Polygala* (Polygalaceae)	–	–	10.30	–	–	–	–	–	10.30
124. Solanaceae 2	–	–	10.30	–	–	–	–	–	10.30
125. Anacardiaceae	8.64	–	–	–	–	–	–	–	8.64
126. Capparaceae	8.64	–	–	–	–	–	–	–	8.64
127. *Froelichia humboldtiana* (Amaranthaceae)	8.64	–	–	–	–	–	–	–	8.64
128. *Miconia* (Melastomataceae)	8.64	–	–	–	–	–	–	–	8.64
129. Passifloraceae	8.64	–	–	–	–	–	–	–	8.64
130. Simaroubaceae	8.64	–	–	–	–	–	–	–	8.64
131. *Waltheria* (Malvaceae)	8.64	–	–	–	–	–	–	–	8.64
132. *Ouratea* (Ochnaceae)	–	–	–	–	–	7.98	–	–	7.98
133. *Jatropha* (Euphorbiaceae)	–	–	–	–	3.48	3.98	–	–	7.46
134. Apocynaceae	–	–	–	–	–	3.98	–	–	3.98
135. *Aspicarpa harleyi* (Malpighiaceae)	–	–	–	–	–	3.98	–	–	3.98
136. Acanthaceae	–	–	–	–	3.48	3.98	–	–	7.46
137. *Anacardium occidentale* (Anacardiaceae)	–	–	–	–	3.48	–	–	–	3.48
138. *Heisteria* (Olacaceae)	–	–	–	–	3.48	–	–	–	3.48
139. *Securidaca* (Polygalaceae)	–	–	–	–	3.48	–	–	–	3.48
140. *Simarouba* (Simaroubaceae)	–	–	–	–	3.48	–	–	–	3.48
[Number of unidentified pollen types] Pollen grains/cm^2	[14] 155.52	[75] 3,441.32	[56] 1,792.24	[19] 628.80	[30] 177.48	[56] 378.93	[15] 1,338.34	[18] 559.14	–
[Number of identified pollen types] Pollen grains/cm^2	[44] 2,082.77	[64] 21,415.23	[50] 9,641.37	[33] 7,812.01	[51] 1,392.25	[53] 1,662.46	[33] 34,390.05	[40] 15,404.98	–
Total number of pollen grains/cm^2	2,238.29	24,856.55	11,433.62	8,440.81	1,569.73	2,041.39	35,728.39	15,964.12	–

The failure to identify the undetermined types was mainly due to the pollen being crumpled or deformed or in an unfavorable position for observing important features of the exine, such as details of ornamentation and openings.

The families with the highest representation from the pollen types were Fabaceae (n = 23) and Asteraceae (n = 12), followed by Euphorbiaceae, Malpighiaceae and Myrtaceae (all n = 9). The pollen types identified only at the genus level had 39 records of respective genera in CBS, and there was no local record for eight types [*Celtis* (Cannabaceae), *Eucalyptus* (Myrtaceae), *Heisteria* (Olacaceae), *Miconia* (Melastomataceae), *Paullinia* (Sapindaceae), *Roupala* (Proteaceae), *Securidaca* (Polygalaceae) and *Simarouba* (Simaroubaceae)]. Among the 58 pollen types identified at the species level, 54 were related to species that were recorded in the flora of CBS, while the records were restricted to the genus level for the other four pollen types [*Banisteriopsis stellaris* (Malpighiaceae), *Froelichia lanata* (Amaranthaceae), *Mimosa arenosa* (Fabaceae/Mimosoideae) and *Senna velutina* (Fabaceae/Caesalpinioideae)].

Despite a qualitative difference, the pollen concentrations/cm^2 were very similar between 2003 and 2005 (12,842.82 and 12,748.88 pollen grains/cm^2, respectively). As for the two types of substrates in which the moss polsters were collected, the soil samples contained higher pollen concentrations (21,042.04 pollen grains/cm^2) than the rock samples (7,829.35 pollen grains/cm^2). On the other hand, 68 (48.57%) pollen types were unique to the rock samples, whereas only 24 were unique to the soil samples (17.14%). Forty-eight other pollen types (34.28%) had records in both the rock and soil samples (Tab. 1).

Among the pollen types, only five were recorded in all samples from the two years [*Mitracarpus/Spermacoce* (Rubiaceae), *Copaifera* (Fabaceae/Caesalpinioideae), *Pityrocarpa moniliformis* (Fabaceae/Mimosoideae), *Anadenanthera colubrina* (Fabaceae/Mimosoideae), and *Herissantia* (Malvaceae)]. Moreover, the sums of the concentrations of these pollen types varied substantially, from 16,711.34 pollen grains of *Mitracarpus/Spermacoce* (1,876.76 in 2003 and 14,834.58 in 2005) to 588.78 pollen grains of *Herissantia* (Tab. 1).

Table 2. Growth habits of taxa related to the pollen types found in moss polsters at the Canudos Biological Station, in the state of Bahia, Brazil.

Habits* %	Pollen types
Shrub 26.43%	*Acalypha brasiliensis* (Euphorbiaceae), Acanthaceae, *Aspicarpa harleyi* (Malpighiaceae), *Byrsonima* (Malpighiaceae), *Campomanesia* (Myrtaceae), *Chomelia* (Rubiaceae), *Clidemia* (Melastomataceae), *Cnidoscolus loefgrenii* (Euphorbiaceae), *Croton heliotropiifolius* (Euphorbiaceae), *Croton zehntneri* (Euphorbiaceae), *Eupatorium* (Asteraceae), *Harpochilus* (Acanthaceae), *Heisteria* (Olacaceae), *Helicteres* (Malvaceae), *Heteropterys* (Malpighiaceae), *Jatropha* (Euphorbiaceae), *Jatropha mutabilis* (Euphorbiaceae), *Jatropha ribifolia* (Euphorbiaceae), *Manihot dichotoma* (Euphorbiaceae), *Melochia* (Malvaceae), *Mimosa arenosa* (Fabaceae/Mimosoideae), *Mimosa lewisii* (Fabaceae/Mimosoideae), *Myrcia* 1 (Myrtaceae), *Myrcia* 2 (Myrtaceae), *Myrcia* 3 (Myrtaceae), Myrtaceae 1, Myrtaceae 2, Myrtaceae 3, Myrtaceae 4, *Securidaca* (Polygalaceae), *Senna* (Fabaceae/Caesalpinioideae), *Senna velutina* (Fabaceae/Caesalpinioideae), Solanaceae 2, *Solanum* (Solanaceae), *Solanum megalonyx* (Solanaceae), *Solanum paniculatum* (Solanaceae), *Varronia globosa* (Boraginaceae).
Herb 22.14%	*Alternanthera ramosissima* (Amaranthaceae), *Amaranthus viridis* (Amaranthaceae), *Andropogon selloanus* (Poaceae), *Angelonia* (Scrophulariaceae), *Aspilia bonplandiana* (Asteraceae), *Cardiospermum corindum* (Sapindaceae), *Cleome* (Capparaceae), *Conocliniopsis prasiifolia* (Asteraceae), Cyperaceae, *Digitaria tenuis* (Poaceae), *Diodia* (Rubiaceae), *Enteropogon mollis* (Poaceae), *Froelichia humboldtiana* (Amaranthaceae), *Froelichia procera* (Amaranthaceae), *Gomphrena demissa* (Amaranthaceae), *Microtea* (Phytolaccaceae), *Mimosa* 2 (Fabaceae/Mimosoideae), *Mitracarpus/Spermacoce* (Rubiaceae), *Mollugo verticillata* (Molluginaceae), *Oxalis psoralioides* (Oxalidaceae), *Phyllanthus* (Phyllanthaceae), *Platypodanthera* (Asteraceae), Poaceae, *Polygala* (Polygalaceae), Polygalaceae, *Sida* (Malvaceae), *Stilpnopappus scaposus* (Asteraceae), *Trachypogon spicatus* (Poaceae), *Trichogonia campestris* (Asteraceae), *Vernonia* (Asteraceae), *Zornia* (Fabaceae/Papilionoideae).
Tree 18.57%	Anacardiaceae, *Anacardium occidentale* (Anacardiaceae), *Anadenanthera colubrina* (Fabaceae/Mimosoideae), *Barnebya harleyi* (Malpighiaceae), *Celtis* (Ulmaceae), *Commiphora leptophloeos* (Burseraceae), *Copaifera* (Fabaceae/Caesalpinioideae), *Erythroxylum caatingae* (Erythroxylaceae), *Eucalyptus* (Myrtaceae), *Miconia* (Melastomataceae), *Ouratea* (Ochnaceae), *Piptadenia stipulacea* (Fabaceae/Mimosoideae), *Piriadacus erubescens* (Bignoniaceae), *Pityrocarpa moniliformis* (Fabaceae/Mimosoideae), *Plathymenia reticulata* (Fabaceae/Mimosoideae), *Poeppigia procera* (Fabaceae/Caesalpinioideae), *Poincianella microphylla* (Fabaceae/Caesalpinioideae), *Poincianella pyramidalis* (Fabaceae/Caesalpinioideae), *Roupala* (Proteaceae), Rutaceae, *Senna rizzinii* (Fabaceae/Caesalpinioideae), *Simaba* (Simaroubaceae), *Simarouba* (Simaroubaceae), Simaroubaceae, *Spondias tuberosa* (Anacardiaceae), *Zizyphus joazeiro* (Rhamnaceae).
Subshrub 8.57%	*Chamaecrista* (Fabaceae/Caesalpinioideae), *Chamaecrista ramosa* (Fabaceae/Caesalpinioideae), *Chamaecrista swainsonii* (Fabaceae/Caesalpinioideae), *Herissantia* (Malvaceae), *Hyptis* (Lamiaceae), Lamiaceae, *Lepidaploa aurea* (Asteraceae), *Mimosa* 1 (Fabaceae/Mimosoideae), *Mimosa misera* (Fabaceae/Mimosoideae), *Mimosa sensitiva* (Fabaceae/Mimosoideae), *Vernonia muricata* (Asteraceae), *Waltheria* (Malvaceae).
Liana 6.43%	*Anemopaegma laeve* (Bignoniaceae), Apocynaceae, *Banisteriopsis stellaris* (Malpighiaceae), *Ipomoea* (Convolvulaceae), *Jacquemontia* 1 (Convolvulaceae), *Jacquemontia* 2 (Convolvulaceae), *Jacquemontia montana* (Convolvulaceae), Passifloraceae, *Paullinia* (Sapindaceae).
Cacti 2.86%	*Cereus jamacaru* (Cactaceae), *Melocactus zehntneri* (Cactaceae), *Pilosocereus tuberculatus* (Cactaceae), *Tacinga inamoema* (Cactaceae).
Hemiparasite 2.14%	Loranthaceae 1, Loranthaceae 2, *Psittacanthus* (Loranthaceae).
Undefined 12.86%	Asteraceae 1, Asteraceae 2, Asteraceae 3, Bignoniaceae, Capparaceae, Euphorbiaceae, Fabaceae, Fabaceae/Mimosoideae, Malpighiaceae 1, Malpighiaceae 2, Malpighiaceae 3, Malpighiaceae 4, Malvaceae, Rubiaceae 1, Rubiaceae 2, Solanaceae 1, Solanaceae 3, Verbenaceae.

* According Silva (2007) and Moro *et al.* (2014)

Pollen groups based on the cluster analysis

The resulting phenogram (cophenetic coefficient 0.88, Fig. 2) presents two groups: rock samples (A) and soil samples (B). The similarity between A and B was only 0.38. Pollen types related to Fabaceae were predominant in the rock samples, and pollen types related to Asteraceae were predominant in the soil samples. The pollen types most common to both groups and with the highest concentrations (> 5,000.00 pollen grains/cm^2) were *Mitracarpus/Spermacoce* (Rubiaceae), *Conocliniopsis prasiifolia* (Asteraceae), *Copaifera* (Fabaceae/Caesalpinioideae), *Trichogonia campestris* (Asteraceae) and *Pityrocarpa moniliformis* (Fabaceae/Mimosoideae).

The level of similarity within group B (0.54) was higher than within group A (0.46). Specifically, other pollen types also exhibited high concentrations within group B [*Alternanthera ramosissima* (Amaranthaceae), *Eupatorium* (Asteraceae), *Commiphora leptophloeos* (Burseraceae); *Acalypha brasiliensis* (Euphorbiaceae) and *Trachypogon spicatus* (Poaceae)] and group A [*Platypodanthera*, *Stilpnopappus scaposus* (Asteraceae); *Commiphora* (Burseraceae); *Chamaecrista swainsonii* (Fabaceae/Caesalpinioideae); *Anadenanthera colubrina*, *Piptadenia stipulacea*, *Mimosa lewisii* (Fabaceae/Mimosoideae); *Campomanesia* (Myrtaceae); *Zizyphus joazeiro* (Rhamnaceae); and *Celtis* (Cannabaceae)].

The cluster analysis revealed the formation of subgroups within the main groups. Subgroup B1 (MPS1 and MPS2, 2003 and 2005, respectively) had the highest similarity among all groups (0.62). Within group A, subgroup A3 (MPR4 and MPR5, both 2005) showed the greatest similarity (0.58). The other two subgroups, A2 and A1, were formed by samples from 2003 and 2005, respectively, and the similarities for the subgroups were comparable (0.53 and 0.48, respectively).

Representations of life forms and pollination syndromes

The qualitative analysis showed that the shrub and subshrub habits were most representative of the pollen types related to the CBS species (35.0%), followed by the herbaceous habit (22.14%), trees (18.57%) and other types (cactus, lianas, hemiparasites and indefinite) that together accounted for 24.29% (Tab. 2).

Through the analysis of the diversity of pollen types represented in the CBS flora (Silva 2007), pollen grains related to taxa with zoophilous pollination were predominant (91.4%) in the pollen spectrum of moss polsters. On the contrary, pollen grains of anemophilous pollination were represented by only 12 pollen types related to five families [Amaranthaceae: (1) *Alternanthera ramosissima*, (2) *Froelichia humboldtiana*, (3) *Froelichia lanata*, and (4) *Gomphrena demissa*; (5) Cyperaceae; Erythroxylaceae: (6) *Erythroxylum caatingae*; Poaceae: (7) *Andropogon selloanus*, (8) *Digitaria tenuis*, (9) *Enteropogon mollis*, (10) Poaceae, and (11) *Trachypogon spicatus*; and Cannabaceae: (12) *Celtis*].

Discussion

Throughout the analysis, the high number of pollen types was surprising considering that the samples came from a semiarid area that generally does not have ideal conditions for the preservation of palinomorphs. The climatic conditions of the CBS may have contributed to the successful representation of pollen types in natural substrates. Considering the predominance of high temperatures, low humidity and high winds for most of the year, the release and deposition of pollen grains are favored (Koff 2001; Veriankaite *et al*. 2010).

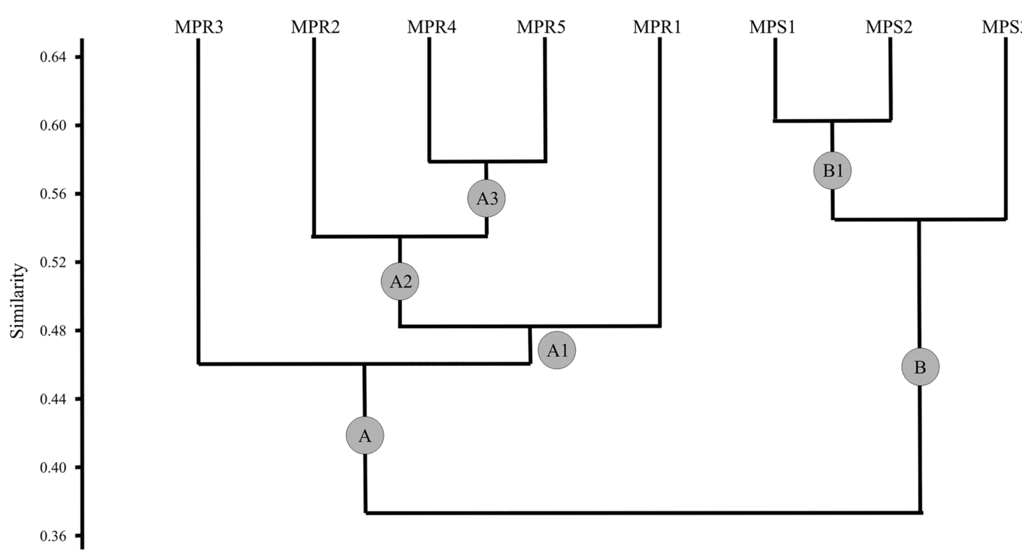

Figure 2. Phenogram generated from de cluster analysis, using the Dice similarity coefficient, of the pollen spectra of eigth samples of moss polsters in Canudos Biological Station, Bahia State, Semi-arid of Brazil. Cophenetic coefficient: 0.88.

The diversity in the present study was even higher than that reported by Gomes *et al.* (2014), which is the only available study of natural deposits of pollen grains in the semiarid region of Brazil; the authors recorded 149 pollen types (88 determined and 61 indeterminate) in bromeliad tanks in the CBS (Canudos, Bahia). However, unlike these tanks, which were in open areas and in bright sunshine, the moss polsters in the present study were in sheltered areas that were wetter and less exposed to adverse conditions. Thus, one of the reasons for the greater diversity of pollen types in the moss polsters compared to bromeliad tanks may be that the environmental conditions where the samples were collected were more conducive to pollinic preservation.

As mentioned earlier, the two families with the greatest diversity of pollen types were Fabaceae and Asteraceae. In Gomes *et al*. (2014), these two families, along with Euphorbiaceae, were the most represented in the tanks of bromeliads; the authors also highlighted the diversity of pollen types. According to Forzza *et al.* (2010), these three families are among the four most diverse families in the domain of the Caatinga. Thus, at this level, the diversity of the pollen types in moss polsters coincided largely with the diversity reported in the Caatinga vegetation. This similarity was also noted by Gomes *et al.* (2014).

Other studies on pollen rain have been conducted in other biomes with open vegetation in Brazil. Four studies were performed in Rio Grande do Sul State, which is dominated by Campos Sulinos. However, three of the studies were conducted in urban areas with high levels of human disturbance (Bauermann *et al.* 1998; Bauermann & Neves 1999; Ávila & Bauermann 2001), and the other restricted the analysis to pollen types of herbaceous plants (Vergamini *et al.* 2006). Because these studies did not reflect the natural aspects of vegetation, the results were not considered for comparison in this study.

A fifth study was conducted in the municipality of Aparecida, in Goiás State, an area that is dominated by Cerrado vegetation (Salgado-Labouriau 1973). The author's ranking of families with the highest quantities of pollen grains/mg of pollen rain included Poaceae, Fabaceae (*Stryphnodendron*, *Lupinus*), Asteraceae (Heliantheae group), Anacardiaceae (*Anacardium*), Euphorbiaceae (*Acalypha*, *Alchornea*), Sapindaceae and Malvaceae (*Pseudobombax*). Poaceae pollen grains amounted to 73.8% of the total pollen grains found in the samples. Thus, the most remarkable difference between the pollen spectra of the Caatinga area in the CBS and the Cerrado area in Salgado-Labouriau's study was that eudicots were predominant in the former [(*Mitracarpus*/*Spermacoce* (Rubiaceae), *Conocliniopsis prasiifolia* (Asteraceae), *Copaifera* (Fabaceae/Caesalpinioideae), *Trichogonia campestris* (Asteraceae) and *Pityrocarpa moniliformis* (Fabaceae/Mimosoideae)], whereas monocots (Poaceae) were predominant in the latter.

In studies of local pollen rain, most of the pollen types are expected to be autochthonous, or related to local species. This was the case in our study: only four pollen types identified at the species level (*Banisteriopsis stellaris*, *Froelichia lanata*, *Mimosa arenosa* and *Senna velutina*) and eight identified at the genus level (*Celtis*, *Eucalyptus*, *Heisteria*, *Miconia*, *Paullinia*, *Roupala*, *Securidaca* and *Simarouba*) lacked records of the respective taxa in the CBS. Although these taxa are not included in the floristic list for the CBS, the possibility that one or more of them occurs in the area cannot be excluded, as the botanical collections did not cover the entire extent of the area.

The *Celtis* pollen type, for example, had a high representation in the local pollen rain, with more than 3,400 pollen grains/cm^2. *Celtis* ranked among the ten pollen types with the highest concentrations (Tab. 1). This bears strong evidence of the possibility of the genus occurring in the CBS without being sampled in the floristic inventory. On the contrary, the possibility that the pollen grains related to other pollen types are from plants from other areas of the region (i.e., allochthonous) should also not be ruled out. Overall, pollen grains from other areas, especially if they were not from anemophilous species, had low representation in the local pollen spectra. For example, the concentrations of other pollen types in the above group were less than 70 pollen grains/cm^2. Moro *et al.* (2014) recently reported the occurrence of species and genera related to the group mentioned in other areas of Caatinga, with the exception of *Roupala*.

These pollen types are all possibly related to allochthonous species and insect pollination. An alternative explanation other than long-range wind transport could account for their presence in moss polsters: during the most critical periods of aridity, insect fauna find an alternative source of moisture in moss polsters because of their recognized ability to retain water. This was observed in the CBS during the collections. Every time we accessed the sampling area, *Apis mellifera* Linnaeus 1758 bees were observed on the moss polsters, mainly along rock walls. The pollen in the honey of these bees is considered contamination, as the pollen may fall from their bodies onto the comb (Jones & Bryant 1996). This may also occur on the moss polsters. Information in the literature shows that the species *A. mellifera* L. 1758 has a great capacity for adaptation and exploration in diverse environments, including over several climatic and vegetation zones (Koppler *et al.* 2007). The bee is considered a generalist because its foraging behavior shows no food preference for specific taxa of plants and can survive on a range of available flora.

The representation of flora in the pollen spectra was more diverse in the rock samples than in the soil samples. Due to the nature of the sandy soil, many pollen grains may have been translocated to the lower levels below the cover of the moss polsters. Additionally, the longevity of the moss polsters needs to be considered. It is probable that the older the moss polsters, the higher the recorded pollen accumulation. The age of the moss polsters was not possible to determine, but the moss polsters along the rocky walls appeared to be more developed than those seen in soils. The differing appearance may be a result of the rocky walls, which are constantly wet due to the natural capacity of the sandstone matrix to retain water; therefore, the rocky walls provide ideal conditions for moss polsters to develop and survive for much longer than those in the sandy soil.

Favorable conditions for preserving pollen grains in the moss polsters in the CBS and the possibility of identifying them at the genus or species level were critical for other aspects besides revealing the floristic details. For example, the available information on the habits of the species related to the pollen types (Silva 2007; Moro *et al*. 2014) allowed the study to verify that 35% of the pollen types represented shrubs or subshrubs. This percentage as well as the percentages of other types of habits generally corresponded to what was observed in the physiognomy of the local vegetation. Similar results were obtained by Gomes *et al*. (2014). Furthermore, regarding the pollen representation of local and regional flora in natural collectors, Reese & Liu (2005) provided an extensive report for Puna vegetation in the central Andes. In a modern pollen rain study of 40 soil surface samples, the authors detected four distinct pollen assemblages in which the pollen types reflected their local vegetation.

Indirectly, aspects related to pollination syndromes in species present in the CBS were also revealed by matching the pollen information with previous data available for the area (Silva 2007). As reported in the results, the predominance of pollen types related to zoophilous species was remarkable. Together, they accounted for 91.4% of the pollen spectrum of moss polsters. Overall, this representation aligned with expectations, as there is a clear predominance of zoophilous species in the CBS. In addition, as previously mentioned, pollen grains that adhered to the bees that visited the moss polsters probably fell on them. Further evidence of this hypothesis is revealed by the presence of large pollen grains that would not likely have depended on wind for transport. This category of large pollen grains includes those with respective pollen types related to the Cactaceae and Convolvulaceae families, most Euphorbiaceae, many Fabaceae and some Malvaceae. Bawa (1990) analyzed the zoophilous pollination syndromes and found that the insect pollination system was the most common, occurring regardless of the vegetation type.

On the contrary, the low representation of pollen types related to anemophilous species may be linked to the flowering period of the respective species. In the CBS, for example, the five pollen types of grasses that were detected in this study bloom during or immediately after the rainy period. Consequently, rainfall events or high humidity can promote a rapid deposition of pollen grains next to their production source, causing a low representation in the pollen rain records in faraway natural collectors of the populations of these plants (Silva 2007).

In general, moss polsters, as well as the bromeliad tanks that were palynologically surveyed by Gomes *et al*. (2014), are excellent natural air pollen collectors in Caatinga environments, provided that are present favorable conditions (moist microhabitats). As was highlighted in the preceding paragraphs, aspects related to floristic diversity, physiognomy and CBS pollination systems were viewed microscopically using the pollen spectra of the samples.

This study provides new information on the pollen records in moss polsters for Caatinga vegetation. Our results and future research on other areas of the Caatinga will shed light on the dynamics of pollen grains in an environment where palynological knowledge is scarce. This research is of substantial value for further paleoecological and paleoclimatic studies in semiarid Brazil.

Acknowledgements

We gratefully acknowledge the CAPES for the Masters scholarship to the first author, the Biodiversitas Foundation for allowing us to carry out our research at the CBS and the anonymous referees for their constructive comments. This study received financial support from the FAPESB and CNPq.

References

Ávila IR, Bauermann SG. 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.

Bagnouls F, Gaussen H. 1962. Estação seca e índice xerotérmico. Boletim Geográfico 20: 338-369.

Bauermann SG, Neves PCP. 1999. Espectros da chuva polínica na região de Canoas – Estação Caixa D'água. Pesquisas – série Botânica 49: 143-154.

Bauermann SG, Neves PCP, Giordani G, Ávila IR. 1998. Espectros de chuva polínica no município de Canoas/RS (Campus da ULBRA e arredores). Pesquisas – série Botânica 48: 193-205.

Bawa KS. 1990. Plant-pollinator interactions in tropical rain forests. Annual Review of Ecology and Systematics 21: 399-422.

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

Fontana SL. 2003. Pollen deposition in coastal dunes, south Buenos Aires Province, Argentina. Review of Paleobotany and Palynology 126: 17-37.

Forzza RC, Baumgratz JFA, Bicudo CEM, *et al.* 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.

Gomes JMS, Lima LCL, Santos FAR, Silva FHM. 2014. First records of pollen rain in bromeliad tanks in a semi-arid area of Caatinga vegetation in Northeastern Brazil. Acta Botanica Brasilica 28: 176-183.

Grabandt RAJ. 1980. Pollen rain in relation to arboreal vegetation in the Colombian Cordillera Oriental. Review of Palaeobotany and Palynology 29: 65-147.

Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Palaeontological Statistics software package for education and data analysis. Palaeontologia Electronica 4: 9p. http://palaeo-electronica.org/2001_1/past/issue1_01.htm. 26 Jun. 2015.

Jones GD, Bryant VM Jr. 1996. Melissopalynology. In: Jansonius, J, McGregor DC. (eds.) Palynology: principles and applications. Salt Lake City, American Association of Stratigraphic Palynologists Foundations. p. 933-938.

Koff T. 2001. Pollen influx into Tauber traps in Estonia in 1997-1998. Review of Paleobotany and Palynology 117: 53-62.

Koppler 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.

Lazarova M, Petrova M, Jordanova M. 2006. Pollen monitoring in surface samples in mosses and pollen traps from the Beglika region (W Rhodopes). Phytologia Balcanica 12: 317-325.

McCune B, Grace J. 2002. Analysis of Ecological Communities. Gleneden Beach, MjM Software.

Montade V, Ledru MP, Burte J, *et al*. 2014. Stability of a Neotropical microrefugium during climatic instability. Journal of Biogeography 41: 1215-1226.

Moro MF, Lughadha EN, Filer DL, Araújo FS, Martins FR. 2014. A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and phytosociological surveys. Phytotaxa 160: 001-118.

Pathirane L. 1975. Aerobiological literature in scientific periodicals. Grana 15: 145-147.

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

Salgado–Labouriau ML. 1973. Contribuição à Palinologia dos Cerrados. Rio de Janeiro, Academia Brasileira de Ciências.

SEI – Superintendência de Estudos Econômicos e Sociais da Bahia. 2013. Informações geoambientais: informações geográficas e tipologia climática (Bahia). http://www.sei.ba.gov.br/side/frame_tabela.wsp?tmp.volta=sg6&tmp.tabela=t78. 21 Jul. 2015.

Silva FHM. 2007. Contribuição à palinologia das caatingas. PhD Thesis, Universidade Estadual de Feira de Santana, Brazil.

Vergamini SM, Valencia-Barrera RM, Sbersi F, Maffazzioli TF. 2006. Palinologia do componente herbáceo na atmosfera de Caxias do Sul, RS, Brasil. Acta Botanica Brasilica 20: 937-941.

Veriankaite L, Siljamo P, Sofiev M, Sauliene I, Kukkonen J. 2010. Modelling analysis of source regions of long-range transported birch pollen that influences allergenic seasons in Lithuania. Aerobiologia 26: 47-62.