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***Geastrum* from the Atlantic Forest in northeast Brazil — new records for Brazil**

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ABSTRACT — Expeditions to remnants of the Brazilian Atlantic Forest in the Northeast Region resulted in three noteworthy *Geastrum* species. *Geastrum morganii* and *G. quadrifidum* are reported for the first time from Brazil, while *G. albonigrum* is reported for the second time in South America. Detailed descriptions with taxonomic observations, photos of basidiomes in situ, and SEM photos are provided.

KEY WORDS — *Geastraceae*, *Geastrales*, gasteroid fungi, taxonomy, biodiversity, neotropics

Introduction

The Atlantic Forest domain that covers most of the east South American coast represents one of the most extensive rainforests on the continent (Tabarelli et al. 2005). This biome, a biodiversity hotspot with a wide range of fungal species, is considered the second most threatened domain on the planet (Brooks et al. 2006, Myers et al. 2000). Northeastern Brazil encompasses four of the five centers of endemism that occur in the Brazilian Atlantic Forest and includes the most degraded sectors of this domain, harboring dozens of endangered species (Tabarelli et al. 2006).

In Brazil, knowledge of the gasteroid fungi in the Atlantic Forest has increased over the last ten years so that currently more than 40 gasteroid species have been recorded for this biome in the Northeast Region (Baseia 2004, 2005;

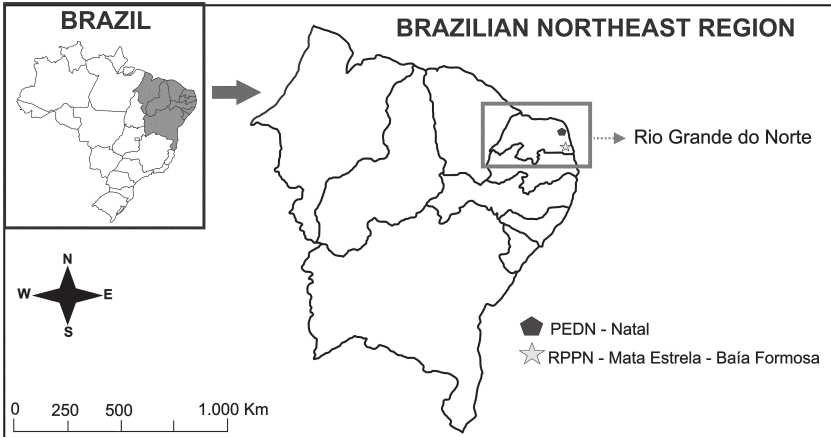


FIGURE 1. Map of Brazil's Northeast Region showing the remnants of Atlantic Rainforest studied.

Baseia et al. 2003a,b, 2006; Baseia & Calonge 2005, 2006, 2008; Leite & Baseia 2007; Leite et al. 2007a,b; Silva et al. 2007, 2013; Fazolino et al. 2008, 2010; Gurgel et al. 2008; Trierveiler-Pereira & Baseia 2009, 2011; Trierveiler-Pereira et al. 2009, 2010, 2011a; Barbosa et al. 2011; Cruz et al. 2012).

Sixteen *Geastrum* species have previously been reported from the northeastern Brazilian Atlantic Forest: *G. coronatum* Pers., *G. elegans* Vittad., *G. entomophilum* Fazolino et al., *G. fimbriatum* Fr., *G. fornicatum* (Huds.) Hook., *G. hieronymi* Henn., *G. hirsutum* Baseia & Calonge, *G. javanicum* Lév., *G. lageniforme* Vittad., *G. lloydianum* Rick, *G. ovalisporum* Calonge & Mor.-Arr., *G. saccatum* Fr., *G. schweinitzii* (Berk. & M.A. Curtis) Zeller, *G. setiferum* Baseia, *G. rusticum* Baseia et al., and *G. triplex* Jungh. These species were collected in various ecosystems including riparian, sand dunes, 'Restinga', and coastal tableland. This work provides additional knowledge about *Geastrum* in Brazil.

Material & methods

Field expeditions were conducted during the rainy seasons of 2010 and 2012 to two Atlantic Forest remnants in Rio Grande do Norte State of northeastern Brazil (FIG.1): 'Parque Estadual Dunas de Natal' (PEDN) (5°50'31.23"S 35°11'39.21"W) and the 'Reserva Particular do Patrimônio Natural Mata Estrela' (RPPN Mata Estrela) (6°22'27.56"S 35°1'24.87"W). Tissues containing basidiospores, eucapillitium, and exoperidial hyphae were mounted in 5% KOH and then examined with an Olympus BX41 optical microscope, and scanning electron microscopy (SEM) was used to observe in detail basidiospore ornamentation, the eucapillitium, and the endoperidial surface

with a Phillips XL30-ESEM electronic microscope; preparation for SEM observation followed Silva et al. (2011). All measurements include basidiospore ornamentation. Basidiospore abbreviations follow Bates (2004): n = number of randomly measured basidiospores; x = mean \pm standard deviation of basidiospore diameter and height (including ornamentation); Q_m = mean height/width quotient. Color descriptions were based on Kornerup & Wanscher (1978). All collected specimens were deposited in the Herbarium of the Federal University of Rio Grande do Norte, Natal, Brazil (UFRN).

Taxonomy

Geastrum albonigrum Calonge & M. Mata, Bol. Soc. Micol. Madrid 28: 332 (2004).

PLATE 1

Unexpanded basidiome epigeous, globose to subglobose, 10–16 \times 9–13 mm, surface hairy, brown (6E4) to dark brown (6E4), not encrusted with debris; rhizomorph \leq 30 mm long, persistent. Expanded basidiome saccate, 10–13 \times 17–26 mm. Exoperidium splitting into 5–7 revolute rays, non-hygroscopic. Mycelial layer grayish brown (6D3) to dark brown (6F4), hairy, not encrusted, peeling away in irregular patches with age exposing the fibrous layer. Fibrous layer white (4A1) to yellowish white (4A2), coriaceous, thick, glabrous, with rhizomorph attached. Pseudoparenchymatous layer dark brown (6F4, 6F3), glabrous to rimose, peeling away in irregular patches. Endoperidial body subglobose 11–13 \times 10–11.5 mm, sessile, glabrous, dark brown (7F3), lightly pruinose, apophysis absent. Peristome fibrillose becoming lacerated with age, not delimited, concolorous with the endoperidium. Gleba grayish brown (7F2). Basidiospores globose to subglobose, 3.8–5 \times 3.8–5 μ m [x = 4.6 \pm 0.2 \times 4.6 \pm 0.4 μ m, Q_m = 1.01, n = 30], brownish, verrucose; warts short cylindrical with rounded tips; apiculus inconspicuous. Eucapillitium 2.5–5 μ m diam., walls straight, encrusted, lumen present, surface verrucose, brown. Mycelial layer composed of sinuous-walled hyphae, 2.5–5 μ m diam., lumen absent, brownish. Fibrous layer composed of straight-walled hyphae, 2.5–5 μ m diam., greenish yellow to hyaline, lumen absent. Pseudoparenchymatous layer composed of thin-walled ($<$ 1 μ m) hyphal cells, subglobose to pyriform hyphae, 26.6–53.3 \times 16.5–34.2 μ m, hyaline to yellowish.

SUBSTRATE: Sandy soil covered with litter and decaying wood.

SPECIMENS EXAMINED: BRAZIL. RIO GRANDE DO NORTE: Baía Formosa, RPPN Mata Estrela, 14.VII.2011, leg. J.O. Sousa & B.D.B. Silva (UFRN-Fungos 1745); 14.VII.2011, leg. B.D.B. Silva & J.O. Sousa (UFRN-Fungos 1747).

DISTRIBUTION: Central America: Costa Rica (Calonge & Mata 2004); North America: Mexico (Calonge & Mata 2004); South America: Brazil, Mato Grosso State (Treirveiler-Pereira et al. 2011b), Rio Grande do Norte State (this paper).

TAXONOMIC REMARKS: *Geastrum albonigrum* is characterized by the pseudoparenchymatous layer and black endoperidium, white fibrous layer

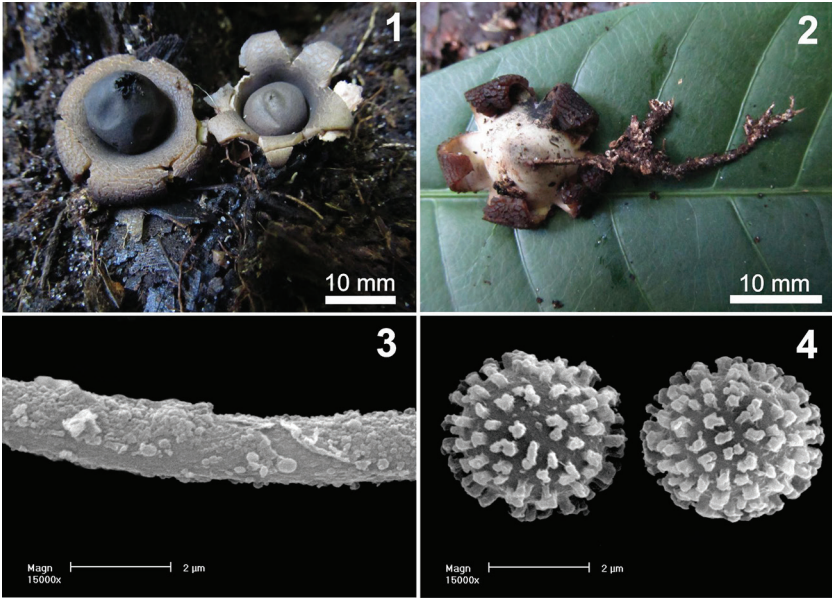


PLATE 1. *Geastrum albonigrum*. 1. Fresh basidiomes (UFRN-Fungos 1745). 2. Basidiome showing the rhizomorph (UFRN-Fungos 1747). 3. Eucapillitium (SEM) (UFRN-Fungos 1745). 4. Basidiospores (SEM) (UFRN-Fungos 1745).

with adhering rhizomorphs, and ephemeral hairy mycelial layer. *Geastrum coronatum*, *G. lloydianum*, and *G. ovalisporum* also exhibit dark endoperidia, but these species differ by arched basidiomes, pedicellate endoperidia with apophysis, and delimited peristomes (Ponce de Leon 1968, Sunhede 1989, Calonge et al. 2000, Bates 2004). *Geastrum hirsutum* has immature basidiomes very similar to those of *G. albonigrum*, being globose to subglobose with their surfaces covered with hairs. However, *G. hirsutum* exhibits distinctly expanded basidiomes with smaller basidiospores (2.5–3 µm), persistent mycelial layer, a delimited peristome, grayish endoperidium and the presence of a well-developed subiculum (Calonge & Mata 2004, Baseia & Calonge 2006). *Geastrum fimbriatum* is also a closely related species, distinguished by the light brown to grayish brown endoperidium, hairless mycelial layer with incrustations, and rhizomorphs that are absent in the expanded basidiome (Sunhede 1989, Bates 2004, Calonge & Mata 2004). Our SEM image of the eucapillitium demonstrating a verrucose surface and photos of the fresh expanded basidiome augment the protologue of *G. albonigrum*. This constitutes a second report for South America and a first report for northeastern Brazil for *Geastrum albonigrum*.

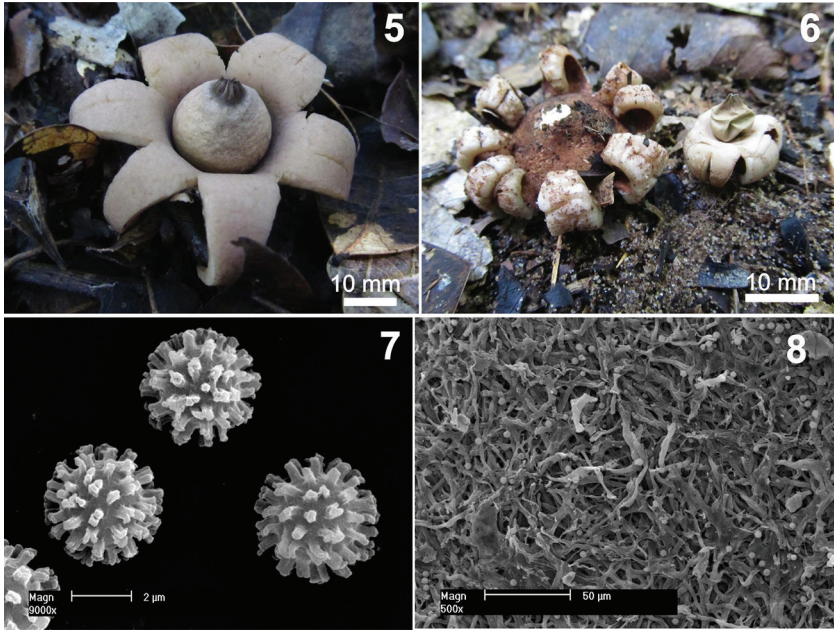


PLATE 2. *Geastrum morganii*. 5–6. Fresh basidiome (UFRN- Fungos 1793) – (UFRN- Fungos 1744). 7. Basidiospores (SEM) (UFRN- Fungos 1793). 8. Surface of the endoperidium (SEM) (UFRN- Fungos 1793).

***Geastrum morganii* Lloyd, Myc. Writ. 1: 80 (1901).**

PLATE 2

Unexpanded basidiome epigeous, lageniform, subglobose to irregular, 24 × 16 mm, surface papery to rugulose, brown (6E4) to yellowish brown (5D5), not encrusted, rhizomorph not observed. Expanded basidiome saccate to arched, 9–28 × 10–62 mm. Exoperidium splitting into 6–7 rays, revolute to arched, elongated with slender tips, non-hygroscopic. Mycelial layer brown (6E5) to dark brown (6F5), papery, not encrusted, persistent or peeling away with age. Fibrous layer yellowish white (4A2) to white orange (5A2), coriaceous, rigid. Pseudoparenchymatous layer dark brown (7F4), thick (≤ 3 mm when fresh), peeling away in irregular patches from the base of the rays, forming longitudinal cracks or a collar-like structure surrounding the endoperidium. Endoperidial body globose to subglobose, 6–24 × 7–26 mm, sessile, with protruding hyphae, orange brown (5C3) to light brown (6D4), apophysis absent. Peristome irregularly plicate, not delimited, conical, with 5–11 irregular folds, 2–4 mm high, lighter or darker than the endoperidium. Gleba dark brown (7F3). Basidiospores globose to subglobose, 3.8–6(–6.9) × 3.8–6(–6.8) μm [$\bar{x} = 5.3 \pm 0.4 \times 5.2 \pm 0.4 \mu\text{m}$, $Q_m = 1.03$, $n = 30$], dark brown, strongly verrucose; verrucae

long and columnar with plane tips, slightly truncated; apiculus inconspicuous. Eucapillitium 2.5–6 µm diam., walls sinuous thin (<1 µm), surface encrusted, verrucose, yellowish white. Mycelial layer composed of thick (>1 µm) sinuous-walled hyphae, 2.5–4.0 µm diam., lumen absent, clamp connections present, yellowish. Fibrous layer composed of straight-walled hyphae, 2.5–5 µm diam., lumen absent, hyaline to slightly greenish. Pseudoparenchymatous layer composed of thin-walled (<1 µm) hyphal cells, oval, ellipsoid to pyriform, 29.2–82.5 × 20–42 µm, hyaline to slightly brownish. Endoperidium with protruding hyphae agglutinated.

SUBSTRATE: Sandy soil covered with litter.

SPECIMENS EXAMINED: BRAZIL. RIO GRANDE DO NORTE: Baía Formosa, RPPN Mata Estrela, 14.VII.2010, leg. B.D.B. Silva, J.O. Sousa & I.G. Baseia (UFRN-Fungos 1744); 14.VII.2011, leg. J.O. Sousa & B.D.B. Silva (UFRN-Fungos 1746); 14.VII.2012, leg. J.O. Sousa, B.D.B. Silva & J.C. Bezerra (UFRN-Fungos 1793); Serra Negra do Norte, Estação Ecológica do Seridó, 19.IV.2008, leg. E.P. Fazolino, B.B.B. Silva & J.J.S. Oliveira (UFRN-Fungos 816).

DISTRIBUTION: Africa: Congo (Dissing & Lange 1962); Central America: Costa Rica (Calonge & Mata 2006); Europe: France (Sunhede 1989); North America: United States (Coker & Couch 1928), Hawaii (Hemmes & Desjardin 2011); South America: Argentina (Caffot et al. 2013), Brazil (this paper).

TAXONOMIC REMARKS: This species is characterized by its non-delimited, irregularly plicate peristome, a mycelial layer lacking incrustations, saccate to arched basidiomes, and a sessile endoperidium (Hemmes & Desjardin 2011, Sunhede 1989). Some *G. morganii* basidiomes may develop a collar-like structure around the endoperidium as in *G. triplex*, but the latter is distinguished by the delimited fibrillose peristome and basidiomes larger than 25–150 µm (Sunhede 1989). *Geastrum morganii* is also very similar to *G. elegans*, which differs by its distinctly delimited peristome with a larger number of regular folds (10–20), a mycelial layer encrusted with debris, and a slightly pruinose endoperidium (Sunhede 1989, Bates 2004, Calonge & Mata 2006). *Geastrum reticulatum* Desjardin & Hemmes from Hawaii is morphologically similar but differs from *G. morganii* in the immature basidiomata with hyphae projecting above the surface, as well as a regularly plicate peristome that is distinctly delimited and depressed in the endoperidium (Hemmes & Desjardin 2011). *Geastrum episcopale* F. Kuhar & L. Papin., which can be confused with *G. morganii*, has smaller basidiospores (approximately 2.2 µm in diam.), calcium oxalate crystals on the endoperidium and a magenta exoperidium and purple endoperidium (Kuhar & Papinutti 2009). Calonge (1998) considers *G. morganii* as the American form of *G. badium* Pers., but Sunhede (1989) regards them as different species. This is the first report of *G. morganii* from Brazil.

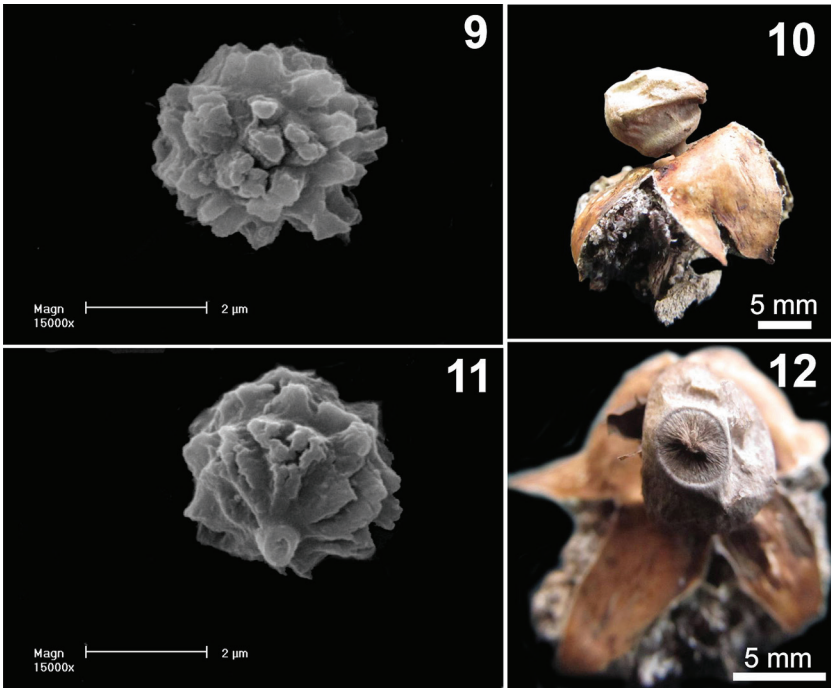


PLATE 3. *Geastrum quadrifidum* (UFRN-Fungos 1748). 9-11. Basidiospores (SEM). 10-12. Dry basidiomes.

Geastrum quadrifidum Pers., Neues Mag. für die Bot. 1: 86 (1794).

PLATE 3

Unexpanded basidiome not observed. Expanded basidiome fornicate, 11 × 26 mm. Exoperidium splitting into 5 rays, fornicate, adhering to the mycelial layer, non-hygroscopic. Mycelial layer yellowish white (4A2), felted, encrusted with organic matter and sand, persistent, forming a cup under the basidiome. Fibrous layer white orange (5A2), papery, thin. Pseudoparenchymatous layer brown (6E5), rigid, peeling away in irregular patches with age to expose the fibrous layer. Endoperidial body subglobose, 8 × 9 mm, stalked, brownish orange (5C3), slightly pruinose. Stalk 1.5 mm high, distinct, lighter than the endoperidium. Apophysis reduced, concolorous with the endoperidium. Peristome fibrillose, distinctly delimited, delimitation white orange (5A2), mammiform, concolorous with to darker than endoperidium. Gleba dark brown (6F4). Basidiospores globose to subglobose, 3.8–6.3 µm × 3.8–6 µm [$x = 5.4 \pm 0.5 \times 5 \pm 0.7$, $Q_m = 1.1$, $n = 30$], brownish, densely verrucose; verrucae long, columnar, truncate, with planar or confluent tips; apiculus prominent,

surrounded by columnar processes. Eucapillitium 1.9–6.3 μm diam., thick sinuous walls ($>1 \mu\text{m}$), encrusted, lumen absent, surface glabrous, yellowish brown. Mycelial layer composed of thin hyphae, $<1 \mu\text{m}$ diam., hyaline. Fibrous layer composed of thin straight-walled ($<1 \mu\text{m}$) hyphae, 2.5–6.8 μm diam., lumen absent, hyaline to slightly yellowish. Pseudoparenchymatous layer composed of collapsed thick-walled ($>1 \mu\text{m}$) hyphal cells, subglobose to oval, brownish.

SUBSTRATE: Sandy soil.

SPECIMEN EXAMINED: BRAZIL. RIO GRANDE DO NORTE: Natal, Parque Estadual Dunas do Natal, 3.IV.2012, leg. J.O. Sousa, R.H.S.F. Cruz & J.C. Bezerra (UFRN-Fungos 1748).

DISTRIBUTION: Africa: South Africa (Bottomley 1948); Asia: Japan (Kasuya et al. 2011); Europe: Spain (Calonge 1998), England (Pegler et al. 1995, Demoulin & Marriott 1981), Norway (Eckblad 1995), Estonian, Finland, Latvia, Sweden, Norway, (Sunhede 1989); North America: United States (Bates 2004), Hawaii: (Smith & Ponce de Leon 1982); South America: Argentina (Soto & Wright 2000), Brazil (this paper).

TAXONOMIC REMARKS: *Geastrum quadrifidum* is characterized by the fornicate basidiome, a small (4–6) number of rays, a mycelial layer forming a cup on the expanded basidiome, and a distinctly delimited fibrillose peristome (Bates 2004, Sunhede 1989). *Geastrum minimum* Schwein. is distinguished by larger (5–11) number of rays, a densely pruinose endoperidium, and basidiomes that are frequently not fornicate (Bates 2004, Sunhede 1989). *Geastrum quadrifidum* also resembles *G. fornicatum*, which differs by its larger basidiomes (≤ 40 mm wide), a non-delimited peristome, basidiospores with rarely confluent warts, and an endoperidium with projecting hyphae (Bates 2004, Sunhede 1989). Another closely related species, *G. leptospermum* G.F. Atk. & Coker, is distinguished by the smaller basidiomes (2–3 mm wide) (Bates 2004). The also similar *G. welwitschii* Mont. is distinguished by its indistinctly delimited peristome and a mycelial layer lacking incrustations (Calonge 1998). This is the first report of *G. quadrifidum* from Brazil.

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