



Updates on the geographic distribution of three *Geastrum* species from Brazilian semi-arid region

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Abstract

Taxonomic studies on Brazilian semi-arid collections of earthstars revealed the occurrence of three species: *Geastrum floriforme* (first record for Brazil), *Geastrum violaceum* (new for the tropical region) and *Geastrum xerophilum* (second record for the Neotropics). Detailed basidiomata descriptions with taxonomic remarks, photos and drawings of macro- and micro-morphological data are given.

Key words – gasteromycetes – Geastrales — neotropical fungi – taxonomy

Introduction

Earthstars are fungi belong to the family Geastraceae (Phallomycetidae, Basidiomycota) and are distributed in two genera: *Geastrum* Pers. and *Myriostoma* Desv., both characterized by gasteroid basidiomata, which are star-shaped when mature, and passively released by the bellows mechanism (Sunhede 1989, Hemmes & Desjardin 2011, Jeppson et al. 2013). *Geastrum* is one of the most diversified gasteroid genera, with a cosmopolitan distribution, and may be found in a wide range of habits (Kuhar & Papinutii 2009, Zamora et al. 2013).

Despite recent publications with new species of earthstars, such as *Geastrum setiferum* Baseia (Baseia & Milanez 2003), *G. hirsutum* Baseia & Calonge (Baseia & Calonge 2006), *G. entomophilum* Fazolino, Calonge & Baseia (Fazolino et al. 2008), *G. aculeatum* B.D.B. Silva & Baseia, *G. echinulatum* T.S. Cabral, B.D.B. Silva & Baseia (Silva et al. 2013) and *G. rusticum* Baseia, B.D.B. Silva & T.S. Cabral (Cabral et al. 2014), taxonomic studies and systematic phylogenetic analysis of the genus *Geastrum* in the Neotropics remain scarce, especially in the semi-arid areas of Brazil (Drechsler-Santos et al. 2008, Silva et al. 2011, 2013).

The semi-arid region, which covers 13% of the country, is characterized by water deficiency, high temperatures and xerophytic vegetation. This region contains distinct phyto-physiognomies such as Atlantic Rainforest enclaves, popularly known as “Brejos de Altitude” and the Caatinga, an exclusively Brazilian plant domain, which shelters high biodiversity and is submitted to intense anthropic pressures (Sá et al. 2004, Leal et al. 2005).

This study aims at widening knowledge on species richness and distribution of the genus *Geastrum* in the semi-arid region of Brazil.

Materials & Methods

The descriptions are based on specimens deposited in the semi-arid collection of the Herbarium of the Federal University of Rio Grande do Norte (UFRN Herbarium). Specimens were collected in the rainy season of 2007 in the Parque Nacional Vale do Catimbau (8° 37' 0" S, 37° 9' 0" W) – Caatinga vegetation, and during the rainy season of 2013 in the Reserva Ecológica Mata do Pau Ferro (6° 58' 12" S, 35° 42' 15" W) – “Brejo de Altitude”. Both collection sites are located in semi-arid northeastern Brazil. Macro and microscopical studies were conducted with dry basidiomata and according to procedures described in the literature (Ponde de Leon 1968, Sunhede 1989, Calonge 1998, Bates 2004). Color descriptions followed Kornerup & Wanscher (1978). Taxonomic nomenclature was based in Kirk et al. (2008). For light microscopy, free-hand sections were mounted in 5% (w/v) KOH. Thirty randomly selected basidiospores were measured using light microscopy (LM), and all measurements included surface ornamentation. Scanning electron microscopy (SEM) was performed for meticulous observations of the ornamentation patterns of basidiospores and capillitium, surface. Preparation of the material examined under SEM followed Silva et al. (2011). Statistical measurements used in basidiospore analysis were in accordance with Bates (2004), where “n” corresponds to the number of randomly measured basidiospores, “x” is the mean width and basidiospore length, “±” is the standard deviation and “Qm” the quotient between mean width and length.

Results

Geastrum floriforme Vittad., Monographia Lycoperdineorum 23 (1842) Plate 1, Figure 1A

Expanded basidioma saccate, 12 mm high × 10 mm wide. Exoperidium splitting into 9 rays, involute, entirely covering the endoperidial body, some rays splitting at tips, strongly hygroscopic. Mycelial layer ephemeral, with some remnants on the fibrous layer. Fibrous layer light orange (5A2), coriaceous. Pseudoparenchymatous layer brown (6F4), glabrous, persistent. Endoperidium depressed globose, 6 mm high × 9 mm wide, sessile, surface furfuraceous, brown (6E4). Apophysis and stalk absent. Peristome fibrillose, becoming lacerate with age, not delimited, mammiform (up to 1 mm high), concolorous with endoperidium. Gleba yellowish brown (5E4).

Basidiospores globose to subglobose, 4.8–7.1 × 4.6–6.8 μm [$x = 6 \pm 0.7 \times 5.8 \pm 0.6$, Qm = 1.02, n = 30], yellowish brown, warts evident under LM. Densely verrucose under SEM; warts irregular, strongly truncate with planar or confluent tips; apiculus not seen. Capillitium 3.6–5.1 μm diam., walls straight, thin (<1 μm diam.), surface not encrusted, glabrous lumen evident, not branched, yellowish. Mycelial layer absent. Fibrous layer composed of thick-walled hyphae (> 1 μm), 3.5–7 μm diam., surface not encrusted, lumen evident, hyaline to yellowish. Pseudoparenchymatous layer composed of thick-walled (<1 μm) hyphal cells, subglobose 12.6–33.6 μm diam., hyaline to yellowish.

Known distribution – Africa: South Africa (Bottomley 1948). North America: United States (Bates 2004); Mexico (Esqueda et al. 1995, 2009). South America: Argentina (Soto & Wright 2000; Kuhar et al. 2012). Asia: China (Liu 1984). Europe: Spain (Calonge 1998); Finland (Sunhede 1989); England (Pegler et al. 1995); Sweden (Sunhede, 1989; Carlsson et al. 2008; Jeppson et al. 2013). Hawaii (Hemmes & Desjardin 2011). Oceania: Australia (Grgurinovic 1997); New Zealand (Cunningham 1944).

Material examined – Brazil, Pernambuco, Buíque, Parque Nacional Vale do Catimbau, growing on soil, 21 Jul 2007, T.B.S. Ottoni, UFRN Fungos – 1278.

Geastrum violaceum Rick, Brotéria 5: 26 (1906) Plate 2, Figure 1B
= *Geastrum episcopale* F. Kuhar & L. Papinutti, Mycologia 101: 535 (2009)

Expanded basidiomata saccate, 12–25 mm high × 9–26 mm wide, rhizomorphs attached,

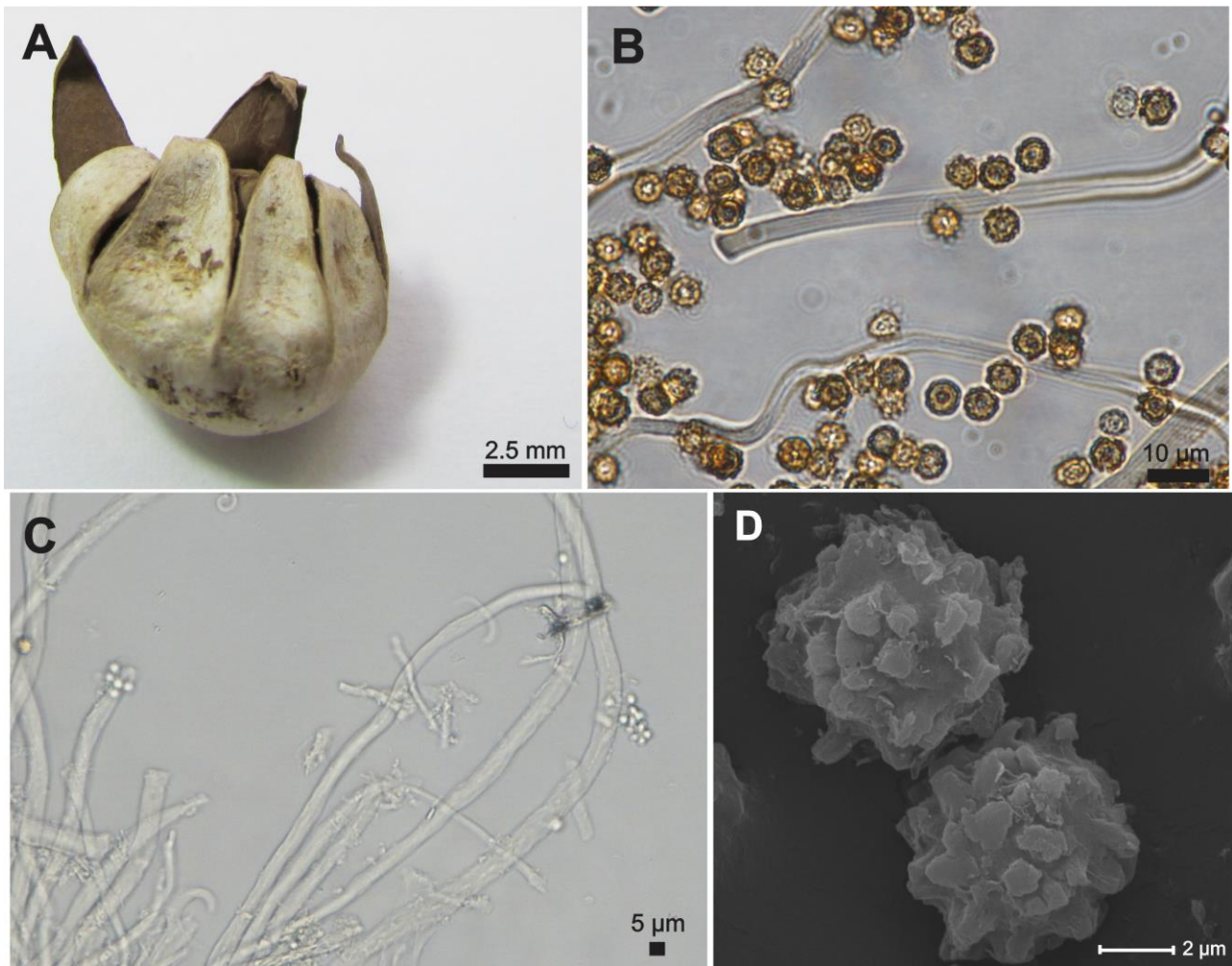


Plate 1 – *Geastrum floriforme*. A Expanded basidioma. B Basidiospores and capillitium under LM. C Hyphae from fibrous layer under LM. D Basidiospores under SEM.

often slightly stipitate. Exoperidium splitting into 6–9 rays, revolute, rolling up under basidioma, non-hygroscopic. Mycelial layer dark purple (14F4) to greyish magenta (13E4), papery to felted, surface not encrusted, with longitudinal cracks. Fibrous layer yellowish white (4A2), papery. Pseudoparenchymatous layer greyish ruby (12D5) when fresh, greyish magenta (13E5) to dark magenta (13F4) when dry, glabrous, often forming a collar-like structure surrounding the endoperidium. Endoperidium subglobose to pyriform, 5–17 mm high × 5–12 mm wide, sessile, surface glabrous, violet brown (10F8) when fresh, greyish brown (10F3) when dry. Apophysis and stalk absent. Peristome irregularly plicate, becoming fibrillose to lacerate with age, not delimited, conic (up to 2 mm high), 4–9 folds, lighter than the endoperidium. Gleba brownish grey (5C2).

Basidiospores globose, $2.9\text{--}3.1 \times 2.7\text{--}3.0 \mu\text{m}$ [$x = 3.1 \pm 0.2 \times 3.0 \pm 0.2$, $Q_m = 1.02$, $n = 30$], brownish, warts inconspicuous under LM. Finely verrucose under SEM; warts short with rounded tips; apiculus evident, surrounded by short processes. Capillitium $4.6\text{--}7.1 \mu\text{m}$ diam., walls straight, thick ($>1 \mu\text{m}$ diam.), surface light encrusted, glabrous, lumen evident, not branched, brownish. Mycelial layer composed of sinuous thin-walled hyphae ($<1 \mu\text{m}$), $2.9\text{--}4.6 \mu\text{m}$ diam., surface not encrusted, lumen pinkish, branched, hyaline. Fibrous layer composed of sinuous hyphae, $3.7\text{--}5.2 \mu\text{m}$ diam., surface light encrusted, lumen not evident, hyaline. Pseudoparenchymatous layer composed of thick-walled ($<1 \mu\text{m}$) hyphal cells, globose, subglobose, pyriform to oval, $47\text{--}82 \mu\text{m}$ in length × $7.4\text{--}57 \mu\text{m}$ in wide, hyaline with pinkish granules.

Known distribution – South America: Brazil, Rio Grande do Sul state (Rick 1961, Trierveiler-Pereira & Silveira 2012); Argentina (Kuhar & Pappinuti 2009).

Material examined – Brazil, Paraíba, Areia, Parque Estadual Mata do Pau Ferro, growing on litter, 15 Jul 2013, J.O. Sousa, D.S. Alfredo & R.A. Lima, JM31, UFRN Fungos – 2117,

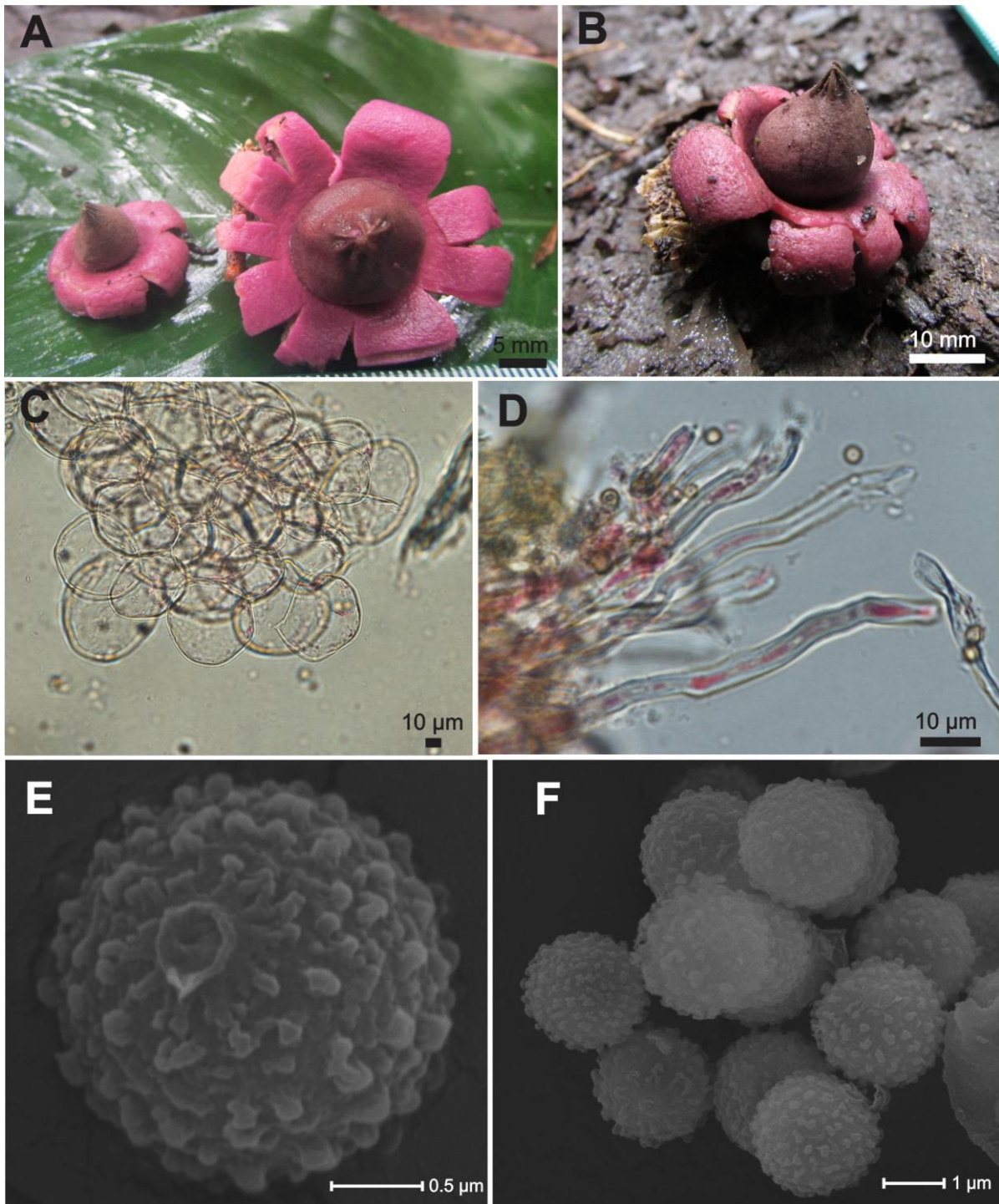


Plate 2 – *Geastrum violaceum*. A, B Expanded basidiomata. C Hyphal cells from pseudoparenchymatous layer under LM (with pinkish granules and thick-walled). D Hyphae from mycelial layer under LM. E, F Basidiospores SEM.

Geastrum xerophilum Long ex Desjardin, Pacific Science 65:493 (2011) Plate 3, Figure 1C
 Expanded basidiomata saccate to arched, 5–19 mm high × 5–24 mm wide. Exoperidium splitting into 6–11 rays, arched to involute, rolling up under endoperidial body, some rays broken off, semi hygroscopic. Mycelial layer brown (6E5) to grayish orange (5B3, 5B4), papery to felted, surface totally encrusted with sand, persistent. Fibrous layers orange white (5A2) brownish orange (5C5), papery. Pseudoparenchymatous layer brown (6E6) to dark brown (6F4, 6F6), surface

rimose, persistent. Endoperidium depressed globose to subglobose, 2–11 mm high \times 4–12 mm wide, stalked, surface furfuraceous, becoming glabrous with age, pale orange (5A3), orange gray (5B2) or brownish gray (6D3, 6D6, 6E3). Apophysis reduced, concolorous with the endoperidium. Stalk reduced (up to 1 mm high), lighter than endoperidium. Peristome plicate, becoming lacerated with age, not delimited, conic (up to 2.5 mm high), 14–35 folds, concolorous or darker than endoperidium. Gleba grayish brown (5F3) to yellowish brown (5E5).

Basidiospores globose to subglobose, $4.4\text{--}6.3 \times 4.1\text{--}6.3 \mu\text{m}$ [$x = 5.4 \pm 0.5 \times 5.3 \pm 0.4$, $Q_m = 1.02$, $n = 30$], yellowish, warts evident under LM. Densely verrucose under SEM; warts long, triangular, often with truncate tips, apiculus not seen. Capillitium 3–5 μm diam., walls sinuous, thick ($>1 \mu\text{m}$ diam.), surface not encrusted, glabrous, lumen not evident, not branched, yellowish. Mycelial layer composed of sinuous thin-walled hyphae ($<1 \mu\text{m}$), 2–4.5 μm diam., surface not encrusted, lumen not evident, branched, hyaline to yellowish. Fibrous layer composed of sinuous to straight thick-walled hyphae ($>1 \mu\text{m}$), 2–6.1 μm diam., surface not encrusted, lumen often evident, hyaline to brownish. Pseudoparenchymatous layer composed of thin-walled ($<1 \mu\text{m}$) hyphal cells, elongate to oval, 12.9–47.9 in length \times 9–28 μm in wide, hyaline to yellowish.

Known distribution – North America: United States (Ponce de Leon 1968, Bates 2004); Mexico (Esqueda et al. 1995, 2009, Moreno et al. 2010); South America: Brazil, Rio Grande do Norte state (Silva et al. 2011); Europe: Spanish (Jeppson et al. 2013); Hawaii (Smith & Ponce de Leon 1982, Gilbertson et al. 2001, Hemmes & Desjardin 2011).

Material examined – Brazil, Pernambuco, Buíque, Parque Nacional Vale do Catimbau, growing on soil, 21 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 334, 21 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 1273, $08^{\circ}30'21''\text{S}$, $37^{\circ}17'22''\text{W}$, 21 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 1275, 22 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 944, $08^{\circ}30'34''\text{S}$, $37^{\circ}16'50''\text{W}$, 23 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 943; 23 Jul 2007, T. B. S. Ottoni, UFRN Fungos – 1279.

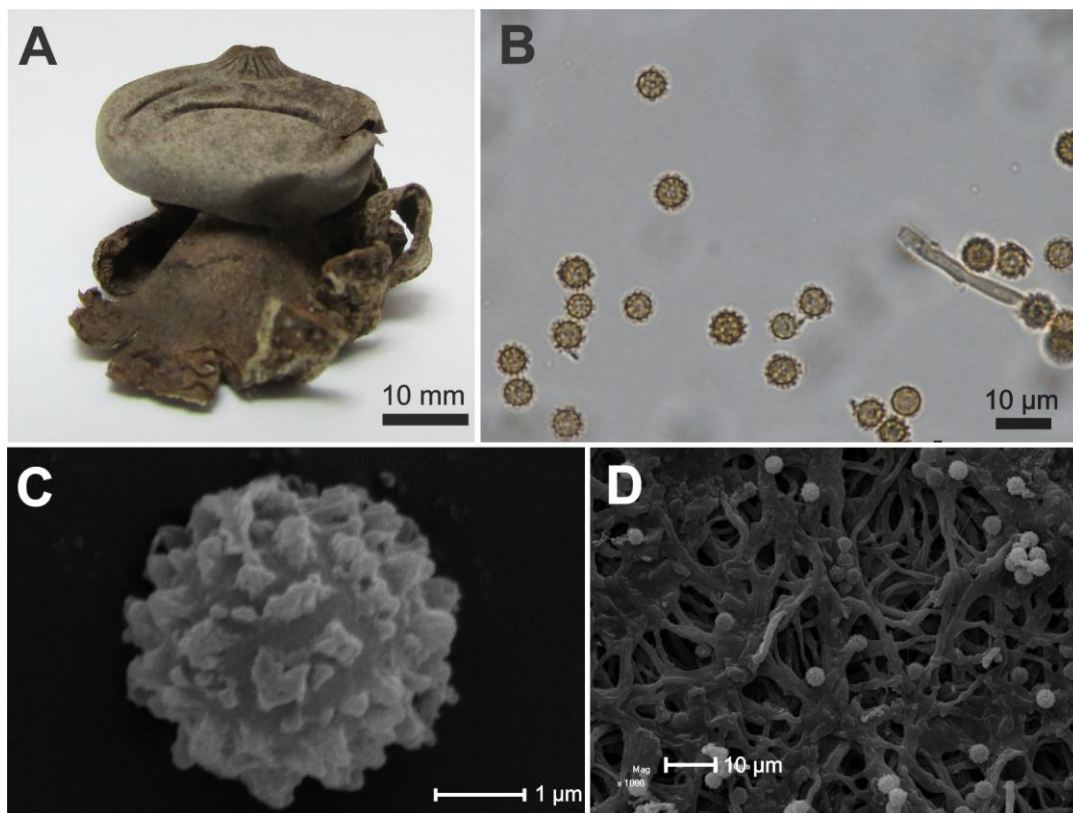
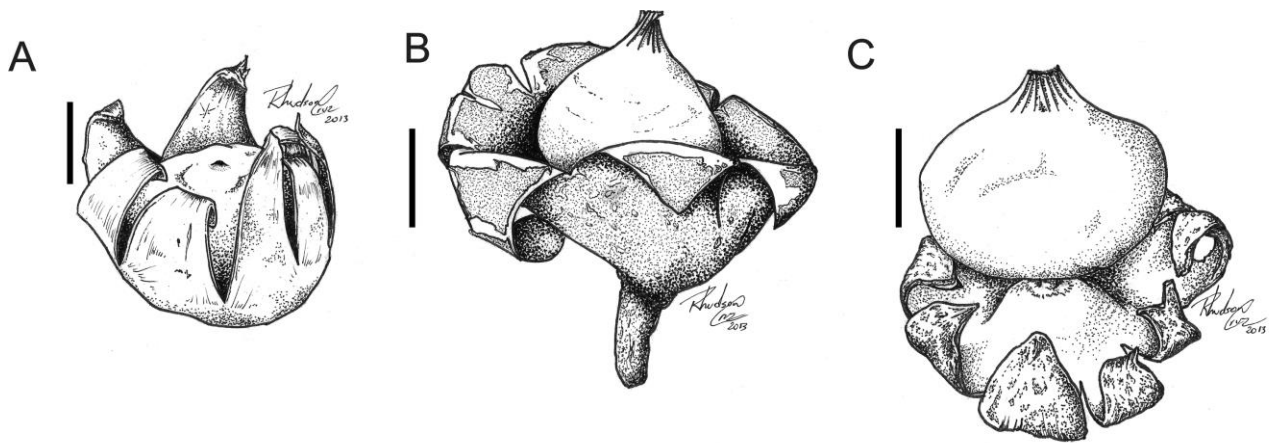


Plate 3 – *Geastrum xerophilum*. A Expanded basidioma. B Basidiospores under LM. C Basidiospore under SEM. D Surface of endoperidium under SEM.



Figures 1 – Schematic drawing of expanded basidiomata. A *Geastrum floriforme*. B *G. violaceum*. C *G. xerophilum*. Scale bars = 5 mm.

Discussion

Geastrum floriforme is truly hygroscopic species, with rays entirely covering the endoperidial body. It also characterized by fibrillose peristome, undelimited and endoperidium sessile furfuraceous, in addition, mycelial layer is often absent on expanded specimens (Sunhede 1989, Bates 2004, Hemmes & Desjardin 2011). Although *Geastrum hungaricum* Hollós exhibits morphology similar to *G. floriforme* in the presence of hygroscopic rays, a fibrillose peristome and a mycelial layer encrusted with sediment, it differs in its distinctly delimited peristome, pruinose endoperidium and smaller basidiomata (Sunhede 1989). *Geastrum corollinum* (Batsch) Hollós and *Geastrum kotlabae* V.J. Staněk also exhibit strongly hygroscopic rays, a trait observed in species occurring in dry environments (Jeppson et al. 2013). However, *Geastrum corollinum* differs from *G. floriforme* by its distinctly delimited peristome, mycelial layer free of encrustations, and smaller basidiospores (up to 5 μm in diameter). *Geastrum kotlabae* can be segregated due to its plicate peristome and verrucose endoperidium (Sunhede 1989, Pegler et al. 1995, Calonge 1998, Bates 2004). *Geastrum floriforme* is widely distributed, and this is the first record for Brazil.

Geastrum violaceum displays distinct coloring, differing from the color pattern of other species of *Geastrum*, ranging from black to reddish. It can clearly be distinguished from the other species, as it exhibits a pinkish to reddish exoperidium and endoperidium, undelimited peristome, irregularly plicate and small basidiospores measuring up to 3.2 μm (Lloyd 1907, Kuhar & Papinutii 2009, Trierweiler-Pereira & Silveira 2012). Another peculiarity of *G. violaceum* is the presence of a small stipe, under the basidioma, a trait observed in few species of the genus, such as *Geastrum schweinitzii* var. *stipitatum* (Solms) P. Ponce de León, which differs from *G. violaceum* in its distinctly delimited fibrillose peristome and presence of subiculum (Ponce de León 1968, Sunhede 1989). According to Rick (1961), *G. violaceum* differs from *Geastrum saccatum* Fr. only in the pinkish color of the exoperidium. However, *G. saccatum* can be also distinguished by its delimited fibrillose peristome and larger basidiospores (4.5–6 μm) (Sunhede 1989, Kuhar & Papinutii 2009). *Geastrum morgani* Lloyd and *G. violaceum* are very similar species morphologically, both with basidiomata saccate, peristome irregularly plicate, not delimited, mycelial layer free of encrustations and endoperidium sessile (Kuhar & Papinutii 2009, Zamora et al. 2013), but *G. morgani* can be easily distinguished by its brownish exoperidium and larger basidiospores (4.5–6 μm) (Sunhede 1989). To date the occurrence of this species has been restricted to subtropical ecosystems, this being the first record of *Geastrum violaceum* for the tropics and the first for the semi-arid region of Brazil.

Geastrum xerophilum is not truly hygroscopic species, with rays rolling up under endoperidial body. Other main characteristics are plicate peristome, undelimited, endoperidium pedicellate with surface furfuraceous and basidiospores densely verrucose. This species has hypogeous habit when unexpanded, hence it has mycelial layer strongly encrusted with sediment on expanded specimens.

Morphologically, this species is similar to *Geastrum campestre* Morgan and *G. kotlabae*, both exhibiting a plicate peristome, hypogeous basidiomata and exoperidium encrusted with sediment. On the other hand, *G. campestre* and *G. kotlabae* differ from *G. xerophilum* in their strongly hygroscopic rays and verrucose exoperidium. One peculiarity of *Geastrum xerophilum* is its occurrence strictly in dry environments (Silva et al. 2011, Jeppson et al. 2013), this being the first record for the semi-arid region of Pernambuco state and the second record of the species for the Neotropics.

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