



## Gasteroid fungi (Basidiomycota) from two protected natural areas in Rio Grande do Norte State, Brazil

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### Abstract

In this study, a total of 13 species of gasteroid fungi belonging to six genera in five families collected from ‘Área de Proteção Ambiental Piquiri-Una’ and the ‘Parque Estadual Mata da Pipa’ are discussed, described and illustrated. *Clathrus columnatus* and *Geastrum pusillipilosum* are reported for the first time from Rio Grande do Norte State. In addition, a checklist of gasteroid fungi of Rio Grande do Norte is provided. A total of 50 species belonging to 18 genera are reported from Rio Grande do Norte State.

**Key words** – *Agaricomycetes* – Atlantic rainforest – Biodiversity – gasteromycetes – taxonomy

### Introduction

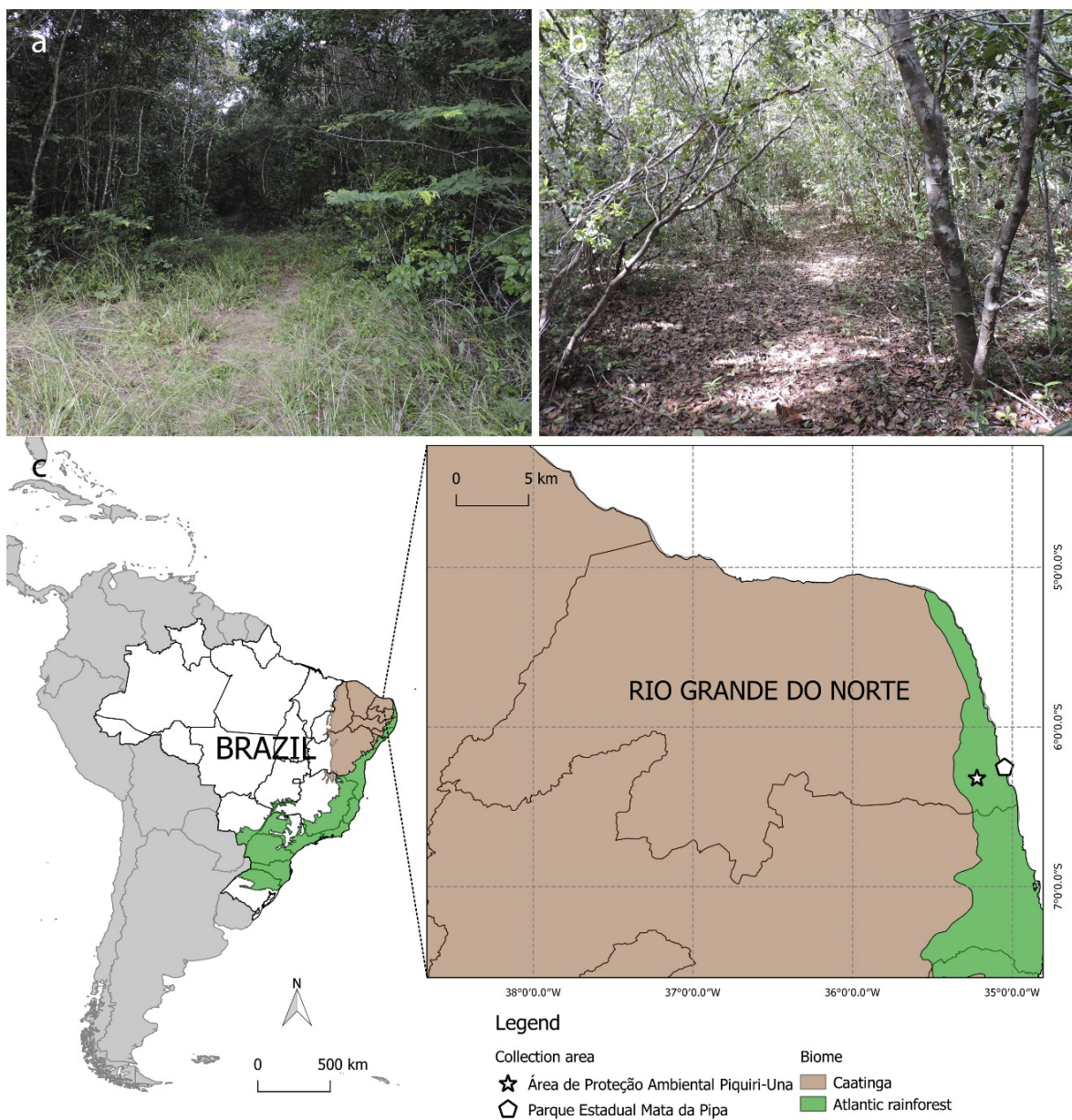
Brazil has continental dimensions with contrasts in climates and ecosystems. Rio Grande do Norte State is one of the 27 federal units of Brazil and covers a total area of 52,811,107 km<sup>2</sup> (IBGE 2018), with equivalent dimensions to the Republic of Bosnia, which covers 51,197 km<sup>2</sup>. It is located in the eastern segment of the Brazilian northeast, between parallels 4°49'53"S–6°58'57"S and meridians 34°58'06"W–38°34'54"W, and the altitude ranges from 0–830 m above mean sea level (Neves et al. 2010). In reference to the configuration of its vegetation, the Brazilian northeast is a very particular case within the country, presenting several ecosystems in its territory (Santos & Miranda de Melo 2010). In particular, Rio Grande do Norte is covered by the vegetation of the Caatinga, an exclusively Brazilian biome, and of the Atlantic rainforest, classified as one of the 25 global biodiversity hotspots (Myers et al. 2000). Although they are areas of extreme biological importance, both are in under threat of destruction due to anthropic action, and they are the most degraded Brazilian ecosystems (Cunha & Guedes 2003, Leal et al. 2005).

Both the Caatinga and the Atlantic rainforest of Rio Grande do Norte have a rich mycobiota and Maia et al. (2015) reported 202 fungal species for the state. The study of the diversity of gasteroid fungi in the State began in the 21st century with the discovery of the new taxon *Abrachium floriforme* (= *Aseroë floriformis*) recorded by Baseia & Calonge (2005) for the ‘Parque Estadual Dunas do Natal’ (PEDN), in the city of Natal. Since then, Rio Grande do Norte has had continuous studies on fungi with researchers exploring several protected areas from the State for more than a decade. Trierveiler-Pereira & Baseia (2009) provided the last checklist of gasteroid

fungi for Brazil, recording 14 species for the state. However, despite the efforts of mycologists in recent years, knowledge about the gasteroid mycobiota in Rio Grande do Norte is asymmetric, since studies concentrated on just a few areas. In this context, it was proposed that the diversity of gasteroid fungi should be investigated in two areas of Atlantic rainforest in Rio Grande do Norte which still lack inventories, contributing to fill gaps in the knowledge about gasteroid mycobiota in still unexplored areas in the state. In addition, an up-to-date checklist of gasteroid fungi in Rio Grande do Norte State is provided.

### Materials & Methods

Field trips were carried out in the rainy season from May–September 2016 and from March–July 2017 in the ‘Área de Proteção Ambiental Piquiri-Una’ – APAPU (May–June 2016) and in the ‘Parque Estadual Mata da Pipa’ – PEMP (August–September 2016, March–July 2017) (Fig. 1). The basidiomata were obtained from preexisting trails, growing on some substrates such as soil, litter and decaying wood. Following Baseia et al. (2014) the basidiomata were photographed in the field. Data such as the date of collection, geolocation, substrate and habit of specimens were registered.



**Fig. 1** – Collection site. a ‘Área de Proteção Ambiental Piquiri-Una’. b ‘Parque Estadual Mata da Pipa’. c Map of Rio Grande do Norte State and collection site.

The studies of the specimens were carried out at the Laboratory of Fungus Biology in the Department of Botany and Zoology, of the Biosciences Center at the Federal University of Rio Grande do Norte (UFRN), in Natal/RN. The collected samples were herborized in an electric dehydrator with temperature between 35–40°C for a period of 24 hours, depending on the dimensions of the basidiomata, until completely dry. Subsequently they were stored in duly identified plastic bags. The specimens were analyzed macroscopically with the unaided eye or with the aid of a Leica EZ4 stereomicroscope. Measurements of the basidiomata were verified using a pachymeter, and the colours were determined following a colour guide by Küppers (2002). For measurement of structures smaller than 3 mm a Nikon SMZ 1500 stereomicroscope was used.

Slides were assembled with 5% KOH and observed on Nikon Eclipse NiU optical microscope (LM) with a Nikon DS-R1 camera coupled. Dyes such as Cotton Blue, Congo Red and Melzer reagent were used to visualize specific structures such as rhizomorph crystals and connection clamps (Miller & Miller 1988). Under the 100× objective, measurements were made using the Nikon NIS-Elements AR software v.4.51.00. Thirty measurements (basidiospores – including ornamentation) and twenty measurements for other microstructures (capillitium, peridium hyphae and rhizomorphs) and extreme values were recorded. Spore statistics (Qm) followed Bates (2004), where: height(min) – height(max) × width(min) – width(max) [x= height(mean) ± standard deviation × width(mean) ± standard deviation, Qm= mean of the quotient of basidiospores' width and length, n= number of randomly measured basidiospores].

The identification of specimens was carried out with specialized literature (Ponce de Leon 1968, Brodie 1975, Dring 1980, Miller & Miller 1988, Sunhede 1989, Bates et al. 2009, Cabral et al. 2012, 2014b, Crous et al. 2016a, b). Fungal terminology was based on the nomenclature adopted by Kirk et al. (2008). The specimens were deposited in the Fungi Collection of the University of Rio Grande do Norte (UFRN), Natal, Brazil.

The checklist on gasteroid fungi of Rio Grande do Norte was prepared based on valid reports published up until 31 December, 2017. The Index Fungorum website ([www.indexfungorum.org](http://www.indexfungorum.org)) was consulted to verify the currently accepted name and nomenclature. The species names, as reported in the cited publications are replaced by currently accepted names. The checklist is arranged alphabetically by family and species.

## Results & Discussion

### Taxonomy

#### Agaricaceae Chevall.

*Cyathus earlei* Lloyd, Mycol. Writ. (7): 26 (1906)

Fig. 2a–c

Description – Peridium infundibuliform, 6–7.5 mm high, 4.5–5.5 mm wide at the upper opening, not expanded at the mouth, not tapering at the base. Emplacement 1.9–4.4 mm in diam., glabrous, conspicuous, dark brown (N<sub>80</sub>Y<sub>99</sub>M<sub>80</sub>). Exoperidium woolly, light brown (N<sub>60</sub>Y<sub>99</sub>M<sub>60</sub>), with tomentum 0.3–0.6 mm, arranged in irregular and flexible tufts, smooth to inconspicuously plicate, with 0.5–0.6 mm between folds. Mouth finely fimbriate, 0.4 mm high, continuous, light brown (N<sub>60</sub>Y<sub>99</sub>M<sub>60</sub>). Endoperidium light brown (N<sub>60</sub>Y<sub>60</sub>M<sub>40</sub>), smooth to inconspicuously plicate, with 0.4–0.6 mm between folds, perceptibly bright, contrasting with the exterior. Stipe 1.2 mm, light brown (N<sub>60</sub>Y<sub>60</sub>M<sub>40</sub>). Epiphragm not observed. Peridioles 1.7–2.1 mm × 1.1–2 mm, blackish brown (N<sub>50</sub>Y<sub>70</sub>M<sub>40</sub>), smooth, circular to angular. Tunic indistinct. Cortex double-layered, exocortex reddish brown (N<sub>80</sub>Y<sub>99</sub>M<sub>80</sub>), mesocortex silver gray (N<sub>10</sub>Y<sub>00</sub>M<sub>00</sub>) with compacted hyphae, endocortex black. Basidiospores 11.8–19 × 8.8–14.2 µm (x= 16.1 ± 1.4 × 11.4 ± 1.2, Qm= 1.43, n= 30), smooth, ellipsoid, hyaline in 5% KOH, walls 0.8–2.7 µm, apicule present in some spores.

Habitat – Gregarious, growing on decaying wood in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'46.52"S, 35°3'18.20"W, 20 m, on decaying wood, 14 Apr 2017, A.A. Lima, AAL 31 (UFRN–Fungos 2904).

Notes – *Cyathus earlei* is characterized by a smooth to inconspicuously plicate peridium, and perceptibly bright and double layered cortex. This species belongs to the group I – *olla*, proposed by Brodie (1975). It can easily be confused with *C. gracilis*, but can be distinguished by the basidiomata with a distinct pedicel at the base in the latter. Despite all the similar characteristics, the specimens analyzed in this work and the materials described for Brazil (Cruz et al. 2012, 2014) present a particularity: the cortex is double-layered and well delimited in Brazilian material, different from the type species, which presents a simple subhomogeneous cortex at the base and top, only double at the edges. This species is recurrent in Atlantic rainforest areas of Northeastern Brazil.

***Cyathus gracilis*** H.J. Brodie, Can. J. Bot. 51(7): 1393 (1973)

Fig. 2d–f

Description – Peridium infundibuliform, 6.4–8.4 mm high, 4.1–5.9 mm wide at the upper opening, expanded or not at the mouth, tapering at the base. Emplacement 1.1–2.1 mm in diam., glabrous, inconspicuous, reddish brown (N<sub>80</sub>Y<sub>90</sub>M<sub>60</sub> to N<sub>80</sub>Y<sub>99</sub>M<sub>60</sub>). Exoperidium hirsute, reddish brown (N<sub>80</sub>Y<sub>90</sub>M<sub>60</sub> to N<sub>80</sub>Y<sub>99</sub>M<sub>60</sub>), with tomentum 0.4–0.6 mm, arranged in irregular and flexible tufts, smooth to inconspicuously plicate, with 0.4–0.5 mm between folds. Mouth finely fimbriate, 0.4 mm high, continuous, grayish brown (N<sub>70</sub>Y<sub>50</sub>M<sub>40</sub>). Endoperidium grayish brown (N<sub>70</sub>Y<sub>50</sub>M<sub>40</sub>), smooth to inconspicuously plicate, with 0.4–0.5 mm between folds, slightly bright, not contrasting with the exterior. Stipe absent. Epiphragm not observed. Peridioles 2.1–2.6 × 2.1–2.4 mm, blackish (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>), smooth, circular to angular. Tunic indistinct. Cortex double-layered, exocortex blackish (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>), mesocortex silver gray (N<sub>10</sub>Y<sub>00</sub>M<sub>00</sub>) with compacted hyphae, endocortex black. Basidiospores 15.8–18.2 × 10.1–12.9 μm (x= 17.3 ± 0.7 × 11.5 ± 0.7, Qm= 1.51, n= 30), smooth, ellipsoid to elongated, hyaline in 5% KOH, walls 1.5–2.3 μm, apicule absent.

Habitat – Gregarious, growing on decaying wood and leaves in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.99"S, 35°3'19.49"W, 15 m, on decaying wood and leaves, 22 Aug 2016, A.A. Lima, AAL 24 (UFRN–Fungos 2901).

Notes – *Cyathus gracilis* is mainly characterized by the basidiomata tapering at the base, a smooth to inconspicuously plicate peridium, hirsute exoperidium, peridioles measuring up to 2 mm, a double-layered cortex and ellipsoid basidiospores. This species belongs to group IV – *gracilis* (Brodie 1975). It can be confused with *C. earlei* as they have basidiomata with similar sizes, a smooth to inconspicuously plicate peridium and finely fimbriate mouth. However, *C. earlei* differs because it is perceptibly bright, contrasting with the exterior, and absence of a pedicel. As for the size and shape of the spores, Brodie (1975) compares *C. gracilis* with *C. intermedius*, but the latter differs in that it has a simple-layered cortex and setose mouth. The specimens analyzed in this study had peridioles with up to 2.4 mm in diameter. However, after a reviewing the genus *Cyathus* in the herbaria of northeastern Brazil, Cruz et al. (2014) recorded materials with peridioles up to 2.5 mm in diam.

***Cyathus limbatus*** Tul. & C. Tul., Anns Sci. Nat., Bot., sér. 3 1: 78 (1844)

Fig. 2g–i

Description – Peridium infundibuliform, 5.6–8.3 mm high, 4.9–7.2 mm wide at the upper opening, expanded or not at the mouth, not tapering at the base. Emplacement 1.6–3.9 mm diam., glabrous, conspicuous, reddish brown (N<sub>80</sub>Y<sub>90</sub>M<sub>60</sub> to N<sub>80</sub>Y<sub>99</sub>M<sub>60</sub>). Exoperidium woolly to hirsute, reddish brown (N<sub>80</sub>Y<sub>90</sub>M<sub>60</sub> to N<sub>80</sub>Y<sub>99</sub>M<sub>60</sub>), with tomentum 0.3–0.6 mm, arranged in irregular and flexible tufts, smooth to inconspicuously plicate, with 0.5–0.8 mm between folds. Mouth finely to distinctly fimbriate, 0.3–0.7 mm high, continuous, dark brown (N<sub>90</sub>Y<sub>99</sub>M<sub>80</sub>). Endoperidium grayish brown (N<sub>70</sub>Y<sub>50</sub>M<sub>40</sub>), inconspicuously to conspicuously plicate, with 0.4–0.8 mm between folds, slightly bright, contrasting with the exterior. Stipe 0.3–0.5 mm, reddish brown (N<sub>80</sub>Y<sub>99</sub>M<sub>60</sub>). Epiphragm not observed. Peridioles 1.7–2.2 × 1.5–2 mm, blackish (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>),

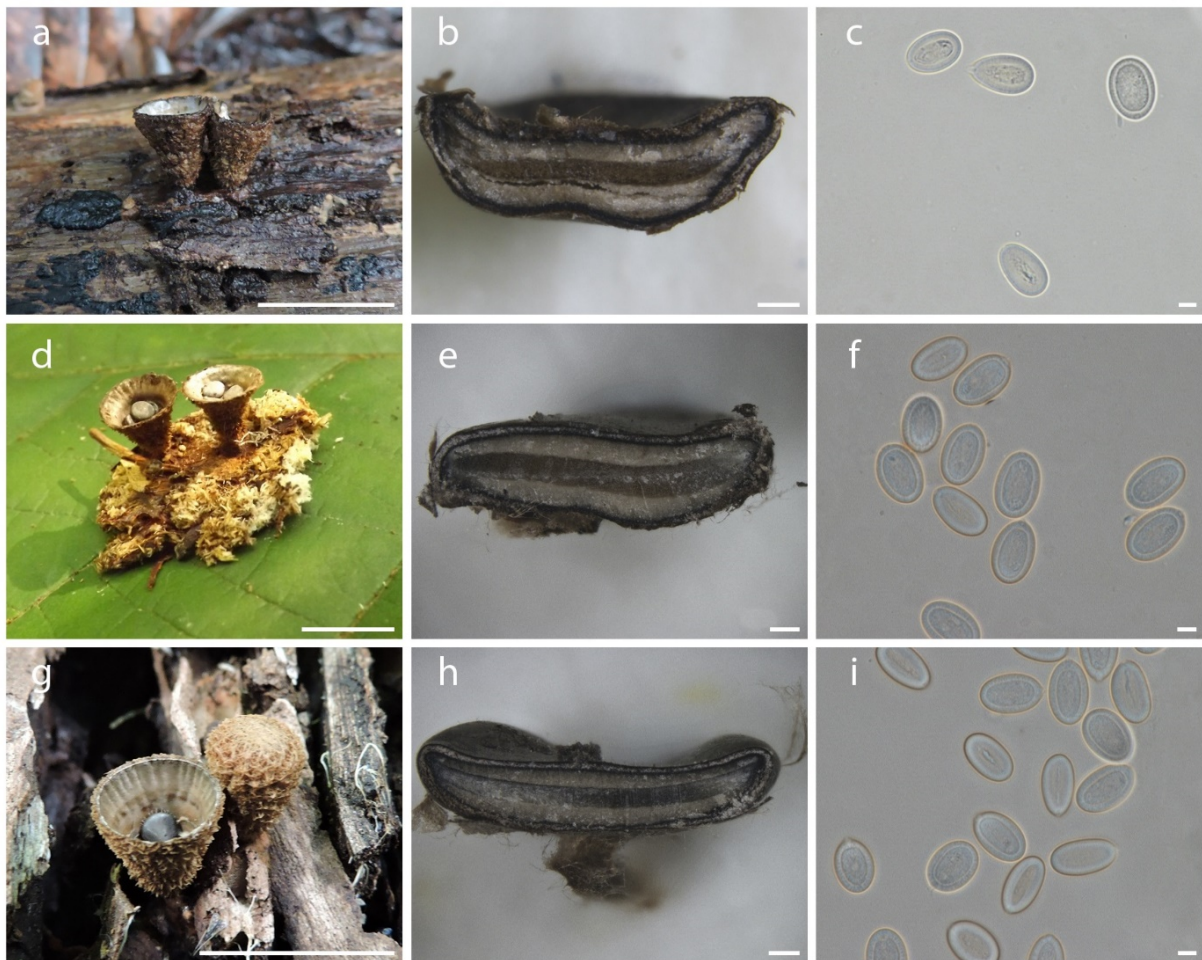


smooth, circular to angular. Tunic indistinct. Cortex double-layered, exocortex brown (N<sub>80</sub>Y<sub>50</sub>M<sub>50</sub>) to blackish (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>), mesocortex silver gray (N<sub>10</sub>Y<sub>00</sub>M<sub>00</sub>) to yellowish gray (N<sub>50</sub>Y<sub>10</sub>M<sub>00</sub>) with compacted hyphae, endocortex black. Basidiospores 13.2–19.3(21.8) × 9.4–14.6(15.2) μm ( $\bar{x}$  = 16.9 ± 1.2 × 11.6 ± 0.5, Qm = 1.48, n = 30), smooth, ellipsoid to elongated, hyaline in 5% KOH, walls 1.4–3.5 μm, apicule absent.

Habitat – Gregarious, growing on decaying wood and leaves in low light environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'30.8"S, 35°12'53.0"W, 67 m, on decaying wood, 16 Jun 2016, A.A. Lima, D.O. Andrade, AAL 17 (UFRN–Fungos 2897). Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'29.20"S, 35°12'59.72"W, 69 m, on decaying wood, 16 Jun 2016, A.A. Lima, D.O. Andrade, AAL 22 (UFRN–Fungos 2899). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'38.37"S, 35°3'20.35"W, 12 m, on decaying leaves, 12 Sep 2016, A.A. Lima, AAL 27 (UFRN–Fungos 2902).

Notes – *Cyathus limbatus* can be recognized by having a hirsute peridium, inconspicuously to conspicuously plicate, dark to black peridioles, lacking a tunic, a double-layered cortex, and large ellipsoid basidiospores. It may be confused with *C. poeppigii*. However, the latter has larger basidiospores (> 30 μm). It resembles *C. striatus*, due to the fact that both have a conspicuous base and similar sized basidiospores, but the latter differs because it has perceptible brightness, and tunic is present. According to Brodie (1975), this species is included in group VI – *poeppigii*. The material analyzed in this study has slightly larger basidiospores than the type collections.



**Fig. 2** – *Cyathus earlei*. a Basidiomata *in situ*. b Sectioned peridiole (double-layered cortex). c Basidiospores. *Cyathus gracilis*. d Basidiomata *in situ*. e Sectioned peridiole (double-layered cortex). f Basidiospores. *Cyathus limbatus*. g Basidiomata *in situ*. h Sectioned peridiole (double-layered cortex). i Basidiospores. – Bars: a, d, g = 10 mm, b, e, h = 0.2 mm, c, f, i = 5 μm.

## Clathraceae Chevall.

*Abrachium floriforme* (Baseia & Calonge) Baseia & T.S. Cabral, Myc. 119: 424 (2012) Fig. 3a–c

Description – Immature basidiomata not observed. Expanded basidiomata fresh 28 mm high. Receptacle 25 mm diam., orange (Y<sub>90</sub>M<sub>60</sub>C<sub>00</sub>), flattened, flower-shaped, without arms, with a perforated central disc, 11 mm diam., reddish pink (Y<sub>80</sub>M<sub>80</sub>C<sub>20</sub>), reticulate, covered with gleba. Pseudostipe 23 mm high × 8 mm wide, yellowish pink (N<sub>00</sub>Y<sub>40</sub>M<sub>50</sub>), cylindrical, spongy, hollow. Volva 15 mm high × 10 mm wide, white (N<sub>00</sub>Y<sub>00</sub>M<sub>00</sub>) to brownish (N<sub>30</sub>Y<sub>60</sub>M<sub>30</sub>), subglobose, smooth surface, papery. Rhizomorph up to 60 mm adhered to the base of volva. Gleba olive (N<sub>90</sub>C<sub>00</sub>Y<sub>99</sub>), mucilaginous, fetid. Basidiospores 3.8–4.9 × 1.2–1.8 μm (x= 4.4 ± 0.3 × 1.5 ± 0.1, Qm= 3.03, n= 30), cylindrical to bacilliform, hyaline in 5% KOH, smooth. Receptacle composed of pseudoparenchymatous hyphae, 18.4–40.5 × 14.9–30 μm, globose to ovoid, hyaline. Pseudostipe composed of pseudoparenchymatous hyphae, 16.3–41.7 × 11–39 μm, subglobose to ovoid, hyaline, thin walls (<1μm). Volva composed of filamentous hyphae, 3.2–8.3 μm, straight, with inflated parts, subglobose to irregular, hyaline, thin walls (<1μm), ramifications and frequent septa, presenting connection clamps. Rhizomorph composed of filamentous hyphae, 3.3–9.1 μm, hyaline, thin walls (<1 μm), with inflated tips connected by pores, ramifications and rare septa.

Habitat – Solitary, growing on sandy soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.52"S, 35°3'18.92"W, 19 m, on sandy soil covered with litter, 08 Jul 2017, A.A. Lima, A.A. Lima, AAL 48 (UFRN–Fungos 2917).

Notes – *Abrachium floriforme* is segregated by sunflower-shaped receptacle without arms, the center of the receptacle having a central disc covered by gelatinous gleba and cylindrical to bacilliform basidiospores (Cabral et al. 2012). Based on molecular studies and receptacle shape, Cabral et al. (2012) segregated this taxon into a distinct genus. Originally, *Abrachium floriforme* was proposed as *Aseröe floriformis* by Baseia & Calonge (2005) for the Atlantic rainforest of Rio Grande do Norte, based only on morphological characters. However, the species of *Aseröe* Labill. differs from *Abrachium floriforme* by a receptacle with an apical disc from which long, acute arms arise marginally and become free at maturity (Pegler et al. 1995), unlike *Abrachium* where the arms are absent. Currently, this genus is monospecific and is reported only for Brazil.

*Clathrus columnatus* Bosc, Mag. Gesell. naturf. Freunde, Berlin 5: 85 (1811) Fig. 3d–f

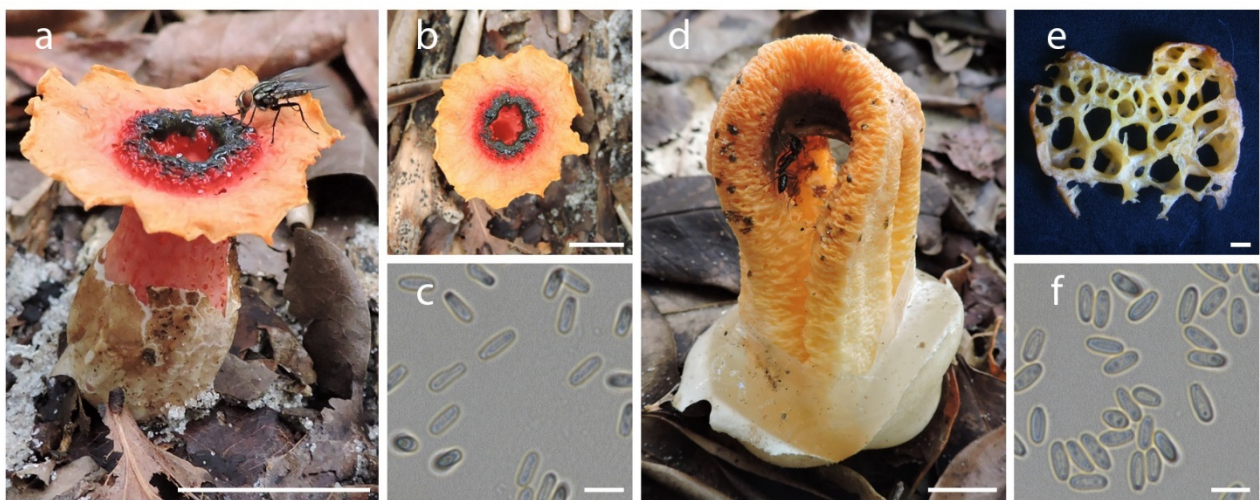
Description – Immature basidiomata 20–27 mm high × 23–31 mm diam., subglobose, epigeous, white (N<sub>00</sub>Y<sub>00</sub>M<sub>00</sub>), surface glabrous, not encrusted. Expanded basidiomata fresh with up to 90 mm high. Receptacle 70–84 mm high × 18–43 mm wide, whitish yellow (Y<sub>20</sub>M<sub>00</sub>C<sub>00</sub>) at the base, orange (N<sub>00</sub>Y<sub>80</sub>M<sub>50</sub>) at the apex, formed by 3–4 columnar arms, wide, spongy, with grooves on the outer surface, free at the base, tapering and fusing at the apex, with numerous and irregular tubes. Volva 30–35 mm high × 30–42 wide, white (N<sub>00</sub>Y<sub>00</sub>M<sub>00</sub>), subglobose, glabrous to cracked in the apical portion, papery. Rhizomorph up to 107 mm, adhered at the base of the volva. Gleba arranged at the apex of the receptacle, olive green (N<sub>90</sub>C<sub>10</sub>Y<sub>99</sub>), mucilaginous, fetid. Basidiospores 3.7–5 × 1.3–2 μm (x= 4.4 ± 0.4 × 1.6 ± 0.2, Qm= 2.74, n= 30), cylindrical to bacilliform, hyaline in 5% KOH, smooth. Receptacle composed of pseudoparenchymatous hyphae, 16.7–42.6 × 16.4–38.6 μm, globose, subglobose to ovoid, hyaline, thin walls (<1μm). Volva composed of two layers: external layer composed of filamentous hyphae, 2.2–7.2 μm, straight, with inflated parts, irregular, hyaline, thin walls (<1μm), with septa and branches; gelatinous internal layer, composed of filamentous hyphae, 1.4–3.2 μm, straight, with inflated tips, hyaline, thin walls (<1μm), with septa and ramifications. Rhizomorph composed of filamentous hyphae, 2–8.2 μm, hyaline, thin walls (<1μm), with inflated tips connected by pores.

Habitat – Solitary, growing on sandy soil covered with litter in low light environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.68"S, 35°3'18.67"W, 19 m, on sandy soil covered with litter, 02 Jul 2017, A.A. Lima, AAL 42 (UFRN–Fungos 2912). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP,

6°15'40.00"S, 35°3'18.57"W, 26 m, on sandy soil covered with litter, 08 Jul 2017, A.A. Lima, A.A. Lima, AAL 49 (UFRN–Fungos 2918). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.16"S, 35°3'19.06"W, 24 m, on sandy soil covered with litter, 08 Jul 2017, A.A. Lima, A.A. Lima, AAL 50 (UFRN–Fungos 2919).

Notes – This species is recognized by 3–4 columns, spongy, reddish orange, free at the base and fused at the apex, gleba spread on the inside of the columns, not confined in a glebifer (Sandoval-Leiva et al. 2014). It can be confused with *Laternea triscapa*, although the latter has smaller basidiomata (up to 70 mm) and the gleba are confined in a glebifer at the apex of the columns. According to Cunningham (1944), Dring (1980), this species may exhibit a variety of colours, number and shape of the columns and the receptacle. *Clathrus columnatus* has a wide geographical distribution and is treated in the literature under different generic names, for example, *Colonnaria* Rafinesque-Schmaltz, *Laternea* Turpin, *Linderia* G. Cunningham and *Linderiella* G. Cunningham. Therefore, in this work Dring (1980) was followed. This is the first record for Rio Grande do Norte State.



**Fig. 3** – *Abrachium floriforme*. a Basidioma *in situ*. b Flower-shaped receptacle. c Basidiospores. *Clathrus columnatus*. d Basidioma *in situ*. e Sectioned arm (tubes). f Basidiospores. Scale Bars: a, b, d = 10 mm, c, f = 5  $\mu$ m, e = 1 mm.

### Geastraceae Corda

***Geastrum entomophilum*** Fazolino, Calonge & Baseia, Mycotaxon 104: 450 (2008) Fig. 4a–e

Description – Immature basidiomata epigeous, white (N<sub>00</sub>Y<sub>00</sub>M<sub>00</sub>) to yellowish (N<sub>00</sub>Y<sub>30</sub>M<sub>00</sub>), subglobose, 15–19 mm high  $\times$  12–18 mm wide, rounded apex, surface encrusted with sand and litter, papery to cottonous. Expanded basidiomata arched, 25–43 mm high (including peristome)  $\times$  40–63 mm wide. Exoperidium open forming 5–7 rays, flat to arched, non-hygroscopic. Mycelial layer double-layered: outer portion yellowish (N<sub>00</sub>Y<sub>30</sub>M<sub>00</sub>), cottonous; inner portion white (N<sub>00</sub>Y<sub>00</sub>M<sub>00</sub>), papery, encrusted with sediment, peeling-off in irregular patches. Fibrous layer yellowish white (N<sub>00</sub>Y<sub>10</sub>M<sub>00</sub> to N<sub>00</sub>Y<sub>40</sub>M<sub>00</sub>), papery. Pseudoparenchymatous layer dark brown (N<sub>99</sub>Y<sub>70</sub>M<sub>70</sub>), persistent, rimose. Endoperidial body grayish brown (N<sub>70</sub>Y<sub>30</sub>M<sub>20</sub>), globose to subglobose, 9–20 mm high (including peristome)  $\times$  19–23 mm wide, sessile, surface with protruding hyphae. Peristome fibrillose to lacerate, not delimited, concolor with endoperidium, conical. Gleba blackish gray (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>). Basidiospores brownish in 5% KOH, globose to subglobose, 4.3–5.2  $\times$  3–5  $\mu$ m ( $x = 4.7 \pm 0.2 \times 4.5 \pm 0.3 \mu$ m, Qm = 1.05, n = 30), ornamentation evident under LM, verrucose. Capillitium brownish, 2.9–6.1  $\mu$ m diam., thin walls (<1  $\mu$ m), encrusted, evident lumen, not branched. Mycelial layer composed of hyaline hyphae, 1.5–2.1  $\mu$ m diam., sinuous and thin walls (<1  $\mu$ m), non-encrusted, non-evident lumen, not branched. Fibrous



layer formed by yellowish hyphae, 2.3–4 µm diam., sinuous and thin walls (<1 µm), non-encrusted, evident lumen. Pseudoparenchymatous layer formed by hyaline to yellowish hyphae, 29.3–63.8 µm high × 20.3–46 µm diam., thin walls (<1 µm), subglobose to elongated.

Habitat – Gregarious, growing on soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'22.83"S, 35°12'58.05"W, 60 m, on soil covered with litter, 06 Jun 2016, A.A. Lima, D.O. Andrade, AAL 09 (UFRN–Fungos 2891). Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'30.18"S, 32°12'56.31"W, 69 m, on soil covered with litter, 16 Jun 2016, A.A. Lima, D.O. Andrade, AAL 18 (UFRN–Fungos 2898). Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'29.25"S, 35°12'58.31"W, 69 m, on soil covered with litter, 16 Jun 2016, A.A. Lima, D.O. Andrade, AAL 19 (UFRN–Fungos 2920).

Notes – *Geastrum entomophilum* is characterized by arched basidiomata, a sessile endoperidial body, blackish, with protruding vermiform hyphae forming fascicles and fibrillose peristome without delimitation. It can be initially confused with *G. setiferum* by its arched basidiomata and ornamented endoperidial body, but the latter can be differentiated by having a sulcate peristome and cymbiform protruding hyphae (Baseia & Milanez 2002). *Geastrum rufescens* also has protruding hyphae in the endoperidial body and a non-delimited fibrillose peristome, but it is distinguished by a clearer endoperidial body, stalk and non-vermiform hyphae (Sunhede 1989, Bates 2004). According to Zamora et al. (2014), *G. entomophilum* is similar to *G. hieronymi*, but it composes an unsupported clade, and can be differentiated morphologically by *Geastrum hieronymi*, showing clearly stained, endoperidial body stalked, non-vermiform hyphae and larger basidiospores (5–7 µm diam.).

***Geastrum lloydianum*** Rick, Brotéria, Rev. scienc. nat. Colleg. S. Fiel 5: 27 (1906) Fig. 4f–j

Description – Immature basidiomata not observed. Expanded basidiomata arched, 13–16 mm high (including peristome) × 33–44 mm wide. Exoperidium open forming 5–6 rays, arched, non-hygroscopic. Mycelial layer yellow-orange (N<sub>00</sub>Y<sub>60</sub>M<sub>30</sub>), papery to fluffy, encrusted with litter, persistent or peeling-off in irregular patches with age. Fibrous layer grayish orange (N<sub>10</sub>Y<sub>50</sub>M<sub>20</sub>), papery. Pseudoparenchymatous layer dark brown (N<sub>99</sub>Y<sub>80</sub>M<sub>80</sub>), persistent or peeling-off in irregular patches. Endoperidial body dark brown (N<sub>99</sub>Y<sub>50</sub>M<sub>70</sub>), subglobose to depressed globose, 9–14 mm high (including peristome) × 11–20 mm wide, surface with protruding hyphae. Apophysis prominent, clearer than endoperidium, glabrous. Stalk short (up to 3 mm high), clearer than endoperidium. Peristome regularly plicate, 13–18 folds, weakly delimited, darker than endoperidium, conical (up to 4 mm high). Gleba grayish brown (N<sub>80</sub>Y<sub>30</sub>M<sub>40</sub>). Basidiospores brownish in 5% KOH, globose to subglobose, 4–5 × 3.9–4.7 µm (x = 4.6 ± 0.2 × 4.4 ± 0.2 µm, Qm = 1.04, n = 30), ornamentation evident under LM, verrucose. Capillitium brownish, 2.8–5.4 µm diam., thin walls (<1 µm), encrusted, verrucose, evident lumen, not branched. Gleba with bi-pyramidal crystals. Mycelial layer composed of hyaline to yellowish hyphae, 1.1–1.8 µm diam., sinuous and thin walls (<1 µm), non-encrusted, non-evident lumen, not branched. Fibrous layer formed by yellowish hyphae, 3.2–6 µm diam., sinuous and thick walls (>1 µm), non-encrusted, evident lumen. Pseudoparenchymatous layer formed by yellowish hyphae, 26.5–79.3 µm high × 17.2–58.3 µm diam., thin walls (<1 µm), subglobose, elongated to oval.

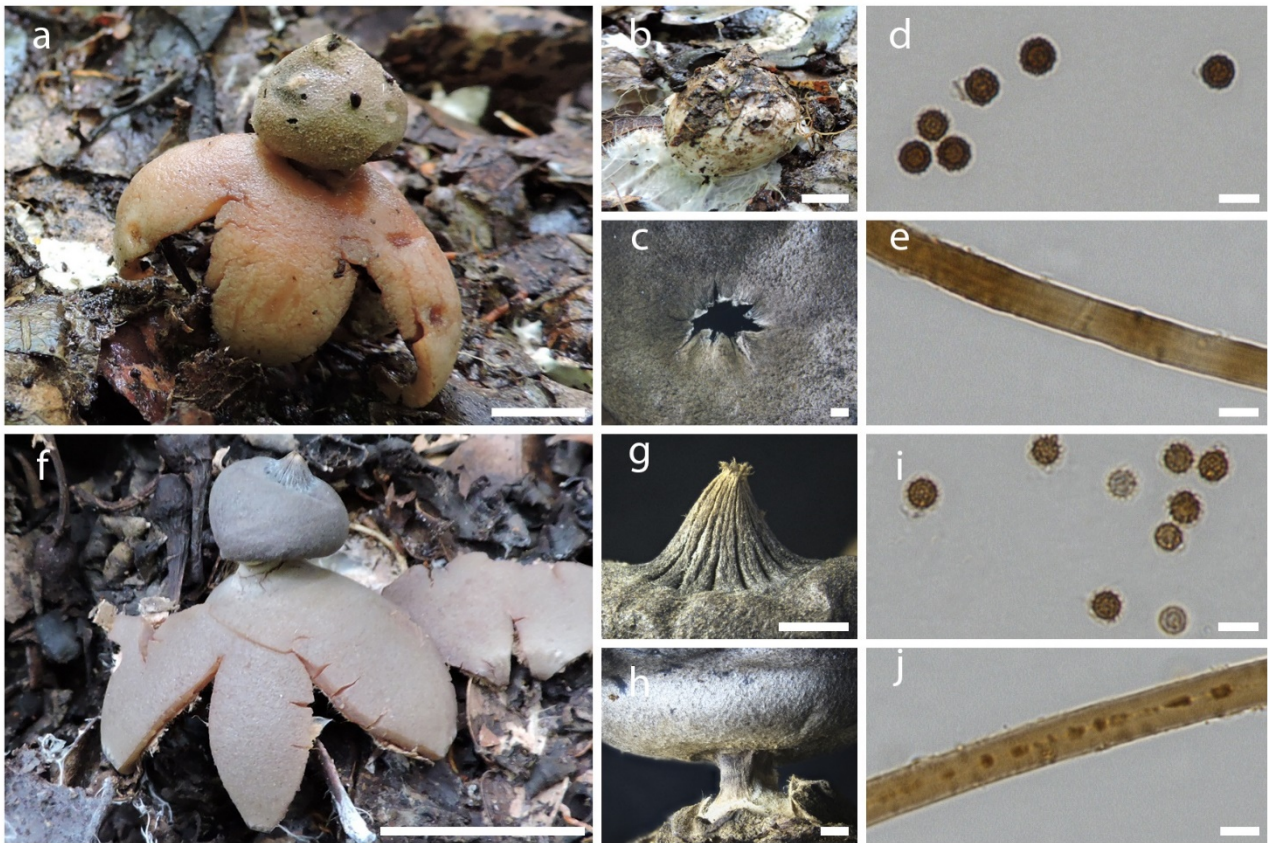
Habitat – Gregarious, growing on soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'25.37"S, 35°12'51.83"W, 59 m, on soil covered with litter, 26 May 2016, A.A. Lima, D.O. Andrade, AAL 09 (UFRN–Fungos 2890).

Notes – *Geastrum lloydianum* is characterized by arched expanded basidiomata, an asperulate dark endoperidial body, stalked, presence of apophysis, glabrous, conical peristome, and being regularly sulcate. It resembles *G. entomophilum* because it has arched expanded basidiomata and a dark endoperidial body, but differs from the latter that has a sessile endoperidial body with vermiform hyphae and a fibrillose peristome. *Geastrum elegans*, *G. pectinatum* and *G. kotlabae* also have regularly sulcate peristomes; however, they not have a dark endoperidial body. *Geastrum*



*elegans* has a sessile endoperidial body and larger basidiospores (up to 4.5–7 µm diam.), *G. pectinatum* has a long peristome and striate apophysis and *G. elegans* has a verrucose endoperidial body and strongly hygroscopic rays (Sunhede 1989, Pegler et al. 1995). When reviewing the type collections, Ponce de Leon (1968) considered *G. lloydianum* and *G. hariotii* Lloyd as synonyms; however, Trierveiler-Pereira & Silveira (2012) separate these two species mainly by the size of the basidiospores: 5–6 µm in *G. lloydianum* and 3–4 µm in *G. hariotii*. Also, Trierveiler-Pereira & Silveira (2017) reconsidered *G. reinkingii* Lloyd basically by the size of the basidiospores (3.5–4.5 µm diam). Thus, this species needs a molecular morphological and phylogenetic revision with the type specimens. Therefore, it was considered in the present work, as *Geastrum lloydianum*, following Ponce de Leon (1968).



**Fig. 4** – *Geastrum entomophilum*. a Expanded basidioma *in situ*. b Immature basidioma. c Peristome. d Basidiospores. e Capillitium. *Geastrum lloydianum*. f Expanded basidioma *in situ*. g Peristome. h Apophysis and stalk. i Basidiospores. j Capillitium. Scale Bars: a, b, f = 10 mm, c, g, h = 1 mm, d, e, i, j = 5 µm.

***Geastrum pusillipilosum*** J.O. Sousa, Alfredo, R.J. Ferreira, M.P. Martín & Baseia, *Persoonia* 37: 235 (2016) Fig. 5a–e

Description – Immature basidiomata epigeous, light yellow blond (N<sub>10</sub>Y<sub>70</sub>M<sub>30</sub>), globose, 5–7 mm high × 5–6 mm wide, rounded apex, encrusted surface, hirsute, with long and flexible hair. Expanded basidiomata saccate, 2–4 mm high (including peristome) × 6–8 mm wide. Exoperidium open, forming 5–6 rays, revolute, non-hygroscopic. Mycelial layer light yellow blond (N<sub>10</sub>Y<sub>70</sub>M<sub>80</sub>), encrusted surface, hirsute, persistent. Fibrous layer whitish yellow (N<sub>00</sub>Y<sub>40</sub>M<sub>10</sub>), papery. Pseudoparenchymatous layer light brown (N<sub>40</sub>Y<sub>40</sub>M<sub>30</sub> to N<sub>60</sub>Y<sub>60</sub>M<sub>50</sub>), persistent. Endoperidial body light brown (N<sub>40</sub>Y<sub>40</sub>M<sub>40</sub>), subglobose, 3–4 mm high (including peristome) × 2–4 mm wide, sessile, glabrous. Peristome finely fibrillose, clearer than endoperidium, delimited, mammiform (<1 mm). Gleba grayish brown (N<sub>80</sub>Y<sub>00</sub>M<sub>20</sub>). Basidiospores brownish in 5% KOH, globose to subglobose, 4.4–6 × 4.3–5.9 µm (x = 5.2 ± 0.5 × 5 ± 0.5 µm, Qm = 1.03, n = 30), inconspicuous ornamentation

under LM, verrucose. Capillitium yellowish, 1.2–2.3  $\mu\text{m}$  diam., straight, thin walls ( $<1 \mu\text{m}$ ), encrusted, evident lumen, not branched. Mycelial layer composed of hyaline to yellowish hyphae, 1.3–3.4  $\mu\text{m}$  diam., sinuous and thin walls ( $<1 \mu\text{m}$ ), non-encrusted, non-evident lumen, not branched. Fibrous layer formed by hyaline hyphae, 1.1–2.3  $\mu\text{m}$  diam., sinuous and thin walls ( $<1 \mu\text{m}$ ), non-encrusted, evident lumen. Pseudoparenchymatous layer formed by hyaline hyphae, 16.7–38.7  $\mu\text{m}$  in high  $\times$  13.6–30.4  $\mu\text{m}$  diam, thin walls ( $<1 \mu\text{m}$ ), subglobose to ellipsoid.

Habitat – Gregarious, growing on sandy soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.86"S, 35°3'11.15"W, 2 m, on sandy soil covered with litter, 03 Jul 2017, A.A. Lima, AAL 46 (UFRN–Fungos 2915).

Notes – *Geastrum pusillipilosum* is characterized by small basidiomata (up to 17 mm wide), a hirsute exoperidium, fibrillose peristome, delimited, and 5–6.8  $\mu\text{m}$  diam basidiospores. It resembles *Geastrum hirsutum*, but the latter is distinguished by larger basidiomata (15–20 mm wide), a subicular base and smaller basidiospores (2.5–3  $\mu\text{m}$ ) (Baseia & Calonge 2006). *Geastrum albonigrum* and *G. inpaense* also have an external hirsute portion of the exoperidium. However, these species differs because they have larger basidiomata (40 mm wide) and the rhizomorph adheres to the base; the former has a non-delimited peristome, and ephemeral mycelial layer, blackish endoperidium and pseudoparenchymatous layer; the latter has a fibrillose peristome and irregularly sulcate and smaller basidiospores (2.6–3.8  $\mu\text{m}$ ) (Calonge & Mata 2004, Cabral et al. 2014a).

***Geastrum rusticum*** Baseia, B.D.B. Silva & T.S. Cabral, Nova Hed. 98(1-2): 265 (2014) Fig. 5f–j

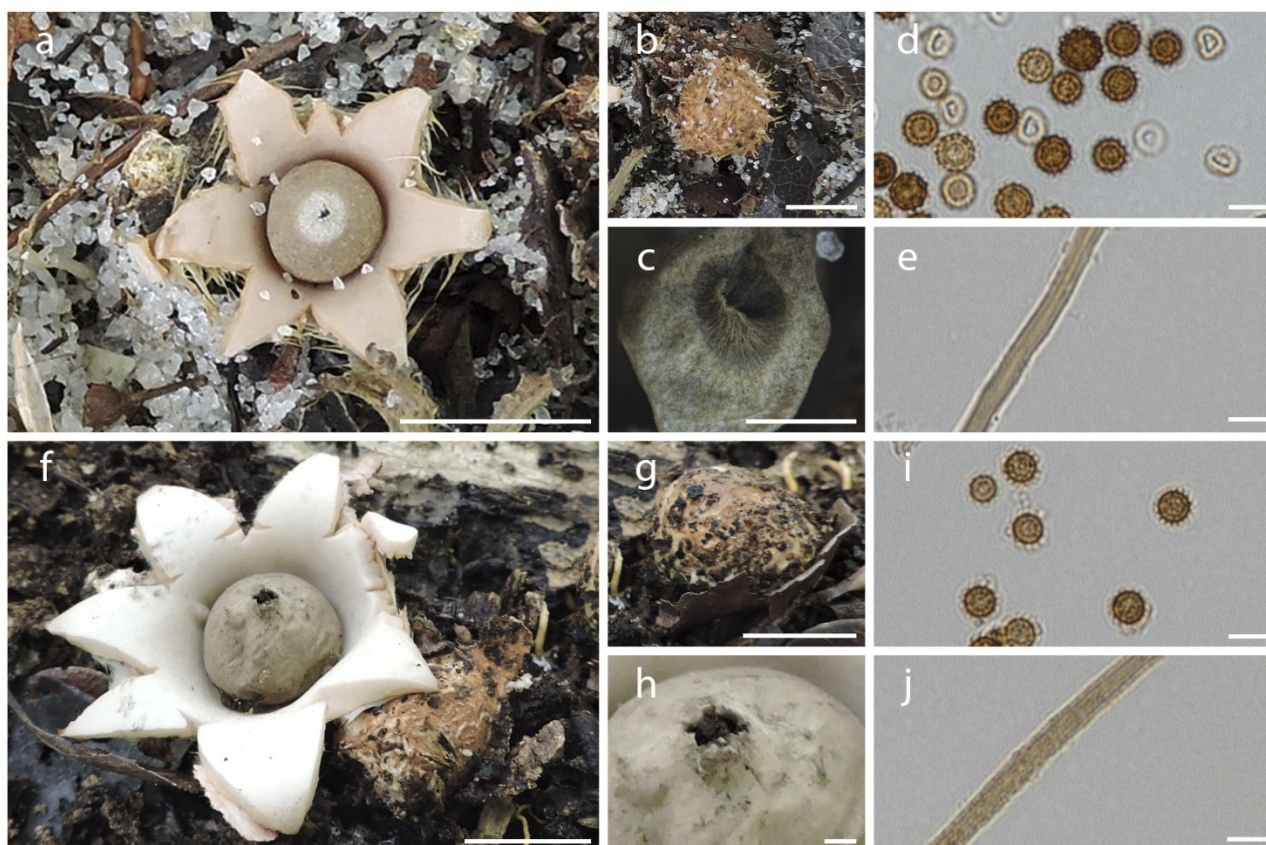
Description – Immature basidiomata semi-hypogeous, grayish yellow (N<sub>40</sub>Y<sub>50</sub>M<sub>30</sub>), subglobose to depressed globose, 10–13 mm high  $\times$  15–19 mm wide, rounded apex, encrusted with sediment, papery, subiculum present. Expanded basidiomata saccate, 12–15 mm high (including peristome)  $\times$  28–37 mm wide. Exoperidium open forming 5–6 rays, revolute, non-hygroscopic. Mycelial layer grayish yellow (N<sub>40</sub>Y<sub>50</sub>M<sub>30</sub>), encrusted, persistent, papery to cottony, peeling-off in irregular patches. Fibrous layer whitish yellow (N<sub>00</sub>Y<sub>30</sub>M<sub>10</sub>), coriaceous. Pseudoparenchymatous layer brownish gray (N<sub>10</sub>Y<sub>20</sub>M<sub>10</sub> to N<sub>30</sub>Y<sub>50</sub>M<sub>30</sub>), persistent. Endoperidial body grayish light brown (N<sub>50</sub>Y<sub>40</sub>M<sub>20</sub>), subglobose, 13 mm high (including peristome)  $\times$  14 mm wide, sessile, glabrous. Peristome fimbriate to fibrillose, concolor with endoperidium, not delimited, mammiform ( $<1 \text{mm}$ ). Gleba brownish gray (N<sub>99</sub>Y<sub>10</sub>M<sub>20</sub>). Basidiospores yellowish to brownish in 5% KOH, globose, 4.2–5.4  $\times$  4.1–5.2  $\mu\text{m}$  ( $\bar{x}$  = 4.9  $\pm$  0.3  $\times$  4.7  $\pm$  0.3  $\mu\text{m}$ , Qm = 1.03, n = 30), inconspicuous ornamentation under LM, verrucose. Capillitium yellowish, 1.5–3.3  $\mu\text{m}$  diam., straight, thin walls ( $<1 \mu\text{m}$ ), encrusted, verrucose, evident lumen, branched. Mycelial layer composed of hyaline to yellowish hyphae, 0.6–1.6  $\mu\text{m}$  diam., sinuous, thin walls ( $<1 \mu\text{m}$ ), encrusted, non-evident lumen, not branched. Fibrous layer formed by hyaline hyphae, 1.1–2.5  $\mu\text{m}$  diam., sinuous, thin walls ( $<1 \mu\text{m}$ ), encrusted, evident lumen. Pseudoparenchymatous layer formed by hyaline hyphae, 24–47  $\mu\text{m}$  high  $\times$  18.1–36  $\mu\text{m}$  diam., thin walls ( $<1 \mu\text{m}$ ), subglobose to ellipsoid.

Habitat – Gregarious, growing on decaying wood in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'40.11"S, 35°3'17.31"W, 23 m, on decaying wood, 03 Jul 2017, A.A. Lima, AAL 47 (UFRN–Fungos 2916).

Notes – *Geastrum rusticum* is characterized by a mycelial layer encrusted with decaying wood fragments, semi-hypogeous immature basidiomata, and basidiospores with short warts. It resembles *G. fimbriatum*, but the latter differs by the endoperidial body surface and warts of basidiospores (Sunhede 1989, Cabral et al. 2014b). *Geastrum hieronymi* also has immature semi-hypogeous basidiomata, a mycelial layer encrusted with debris and fibrillose peristome. However, it differs from *G. rusticum* because it has an stalked endoperidial body with basilar apophysis and protruding hyphae (Cabral et al. 2014b). In a molecular analysis, *G. rusticum* grouped in a clade with *G. floriforme* Vittad., but the latter differs by the ephemeral mycelial layer, furfuraceous endoperidial body and larger basidiospores (5–7  $\mu\text{m}$ ) (Cabral et al. 2014b).





**Fig. 5** – *Geastrum pusillipilosum*. a Expanded basidioma *in situ*. b Immature basidioma. c Peristome. d Basidiospores. e Capillitium. *Geastrum rusticum*. f Expanded basidioma *in situ*. g Immature basidioma. h Peristome. i Basidiospores. j Capillitium. Scale Bars: a, b = 5 mm, c, h = 1 mm, d, e, i, j = 5  $\mu$ m, f, g = 10 mm.

***Geastrum schweinitzii*** (Berk. & M.A. Curtis) Zeller, Mycologia 40(6): 649 (1948) Fig. 6a–e

Description – Immature basidiomata epigeous, yellowish white (N<sub>00</sub>Y<sub>30</sub>M<sub>10</sub>) to brownish yellow (N<sub>20</sub>Y<sub>50</sub>M<sub>30</sub>), subglobose to napiform, 4–10 mm high  $\times$  4–8 mm wide, umbonate apex, non-encrusted surface, tomentose, growing on whitish subiculum (N<sub>00</sub>Y<sub>30</sub>M<sub>10</sub>), rhizomorph adhered, up to 18 mm length, non-encrusted. Expanded basidiomata saccate, 3–7.5 mm high (including peristome)  $\times$  7–15 mm wide. Exoperidium open forming 5–9 rays, revolute, non-hygroscopic. Mycelial layer yellowish white (N<sub>00</sub>Y<sub>50</sub>M<sub>10</sub>) to yellowish brown (N<sub>20</sub>Y<sub>60</sub>M<sub>30</sub>), non-encrusted, tomentose, persistent. Fibrous layer yellowish white (N<sub>00</sub>Y<sub>30</sub>M<sub>10</sub>), papery. Pseudoparenchymatous layer yellowish brown (N<sub>50</sub>Y<sub>60</sub>M<sub>40</sub>), persistent to non-persistent, peeling-off in irregular patches. Endoperidial body beige (N<sub>10</sub>Y<sub>30</sub>M<sub>10</sub>) to grayish brown (N<sub>60</sub>Y<sub>30</sub>M<sub>20</sub>), globose to subglobose, 2–5 mm high (including peristome)  $\times$  3–6 mm wide, sessile, glabrous, pruinose. Peristome finely fimbriate, whitish gray (N<sub>10</sub>Y<sub>10</sub>M<sub>00</sub>), delimited, clearer than endoperidium, mammiform (<1 mm). Gleba blackish gray (N<sub>99</sub>Y<sub>00</sub>M<sub>00</sub>). Basidiospores brownish in 5% KOH, globose to subglobose, 3.7–4.8  $\times$  3.5–4.8  $\mu$ m ( $x = 4.3 \pm 0.3 \times 4.2 \pm 0.3 \mu\text{m}$ , Q<sub>m</sub> = 1.03, n = 30), inconspicuous ornamentation under LM, verrucose. Capillitium brownish, 1.7–4.4  $\mu$ m diam., straight, thin walls (<1  $\mu$ m), encrusted, evident lumen, not branched. Mycelial layer composed of hyaline hyphae, 1.2–4.2  $\mu$ m diam., sinuous, thin walls (<1  $\mu$ m), non-encrusted, evident lumen, not branched. Fibrous layer formed by hyaline hyphae, 1–3.4  $\mu$ m diam., sinuous, thin walls (<1  $\mu$ m), non-encrusted, non-evident lumen. Pseudoparenchymatous layer consisting of hyaline to yellowish hyphae, 16.4–47  $\mu$ m high  $\times$  10.7–35.8  $\mu$ m diam., thin walls (<1  $\mu$ m), subglobose to elongated. Rhizomorph composed of hyaline hyphae, thin (<1  $\mu$ m), presenting crystals of the bi-pyramidal type, prisms grouped and oblique prisms non-grouped.

Habitat – Caespitose, growing on decaying wood and termite nest in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'27.04"S, 35°12'58.28"W, 54 m, on decaying wood, 06 Jun 2016, A.A. Lima, D.O. Andrade, AAL 14 (UFRN–Fungos 2894). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'39.40"S, 35°3'16.16"W, 49 m, on termite nest, 03 Jul 2017, A.A. Lima, AAL 44 (UFRN–Fungos 2913).

Notes – *Geastrum schweinitzii* is characterized by being lignic, having a cespitose habit, growing on yellowish white subiculum, saccate basidiomata, a sessile endoperidial body and fibrillose delimited peristome (Sousa et al. 2014b). It resembles *G. pusillipilosum*, but the latter differs its hirsute mycelial layer and larger basidiospores (5–6.8 µm) (Crous et al. 2016b). *Geastrum hirsutum*, *G. lilloi*, *G. subiculosum* and *G. pleosporum* has a subiculum and saccate basidiomata. However, *G. hirsutum* has a hirsute mycelial layer and smaller basidiospores (2.5–3 µm) (Baseia & Calonge 2006); *G. lilloi* has a hygroscopic exoperidium and the presence of mycosclereids in the gleba (Leite et al. 2011); *G. subiculosum* has a smooth mycelial layer and smaller basidiospores (2.4–3.3 µm); *G. pleosporum* has a mycelial layer that separates easily from the fibrous layer and smooth to sub-smooth basidiospores (Douanla-Meli 2005). This species is usually found growing on wood; however, some samples of this study occurred in a decomposing termite nest, in which the specimens showed a differentiation mainly in the colour of the exoperidium, with darker shades when compared with specimens that grow on decaying wood.

***Geastrum triplex*** Jungh., Tijdschr. Nat. Gesch. Physiol. 7: 287 (1840)

Fig. 6f–j

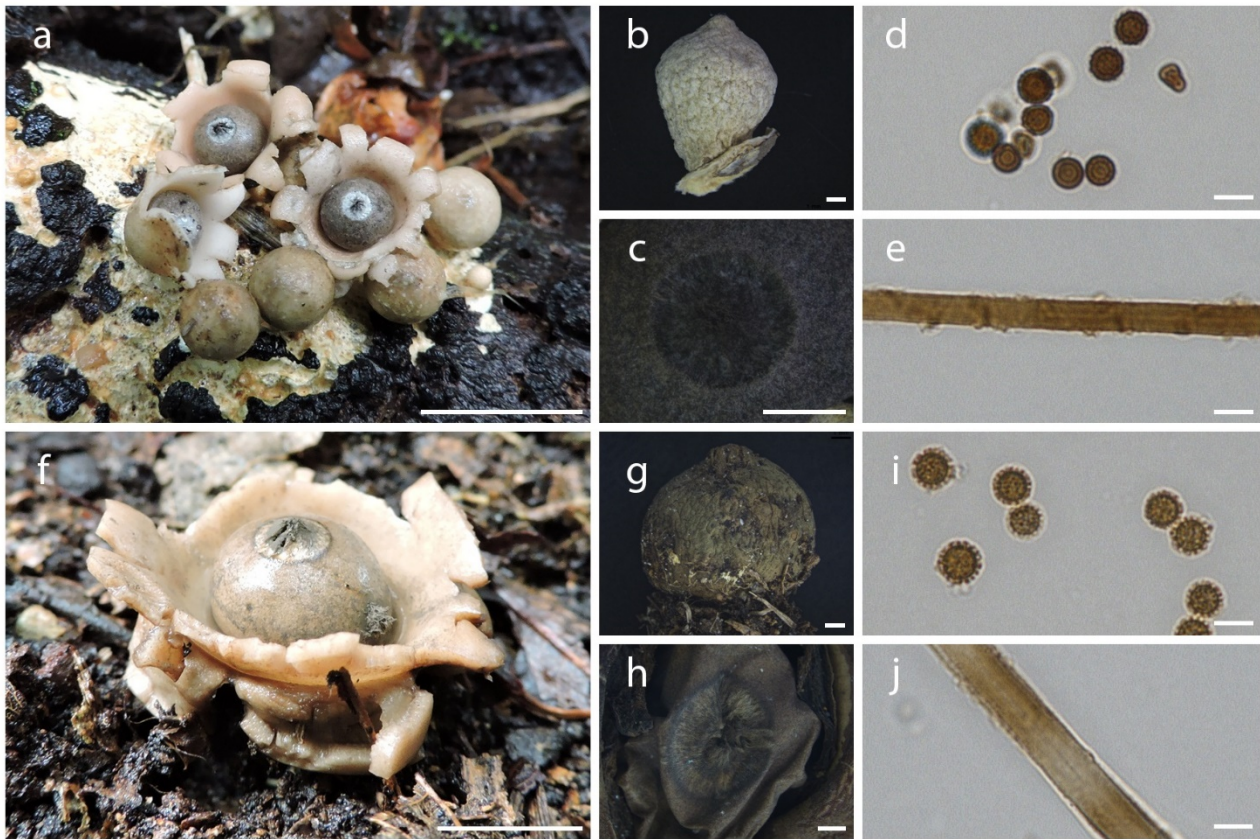
Description – Immature basidiomata epigeous, greenish yellow (Y<sub>90</sub>M<sub>70</sub>C<sub>70</sub>), subglobose, 6–8 mm high × 5.5–9 mm wide, umbonate apex, papery, non-encrusted, rhizomorph adhered at the base. Expanded basidiomata saccate to arched, 8 mm high (including peristome) × 26 mm wide. Exoperidium open forming 5 rays, revolute, non-hygroscopic. Mycelial layer greenish yellow (Y<sub>90</sub>M<sub>70</sub>C<sub>70</sub>), papery, non-encrusted, persistent or peeling-off in irregular patches. Fibrous layer beige (Y<sub>30</sub>M<sub>10</sub>C<sub>00</sub>), papery. Pseudoparenchymatous layer brown (N<sub>60</sub>Y<sub>80</sub>M<sub>50</sub>), forming prominent collar, persistent. Endoperidial body grayish brown (N<sub>70</sub>Y<sub>60</sub>M<sub>40</sub>), subglobose, 9 mm high (including peristome) × 13 mm wide, sessile, glabrous. Peristome finely fimbriate, darker than the endoperidium, delimited, delimitation darker than endoperidium, mammiform (<1 mm). Gleba gray (N<sub>80</sub>Y<sub>20</sub>M<sub>00</sub>). Basidiospores brownish in 5% KOH, globose to subglobose, 4.8–6 × 4.6–5.8 µm (x= 5.4 ± 0.3 × 5.2 ± 0.3 µm, Qm= 1.03, n= 30), verrucose. Capillitium brownish, 3.1–6.2 µm diam., straight, thin walls (<1 µm), encrusted, verrucose, not branched, evident lumen. Mycelial layer composed of hyaline to yellowish hyphae, 4.8–6.6 µm diam., sinuous, thin walls (<1 µm), non-encrusted, non-evident lumen, branched, septate with connection clamps. Fibrous layer constituted by hyaline hyphae, 2.2–5.3 µm diam., sinuous, thin walls (<1 µm), non-encrusted, evident lumen, branched. Pseudoparenchymatous layer formed by hyaline hyaline to yellowish, 19–63 µm high × 13.1–33.3 µm diam., thin walls (<1 µm), subglobose to elongated-ovoid.

Habitat – Solitary, growing on soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'12.71"S, 35°12'59.41"W, 93 m, on soil covered with litter, 06 Jun 2016, A.A. Lima, D.O. Andrade, AAL 11 (UFRN–Fungos 2893).

Notes – *Geastrum triplex* can be recognized by the pseudoparenchymatous layer forming a collar around the base of the endoperidial body, delimited fibrillose peristome, squamous mycelial layer formed by branched hyphae and connection clamps (Soto & Wright 2000). *Geastrum melanocephalum* also has a squamous mycelial layer and collar around the endoperidial body, as it is phylogenetically close to *Geastrum triplex*, but differs in that it has a ephemeral endoperidial body and stalk (Kasuya et al. 2012). The collar around the endoperidial body can also occur in *G. fimbriatum* and *G. morganii*. The former differs in that it has an encrusted mycelial layer and a non-delimited peristome, while the latter has a non-delimited sulcate peristome. *Geastrum saccatum* can also be confused with *G. triplex*; however, *G. saccatum* does not have a collar formed by the pseudoparenchymatous layer (Sunhede 1989).





**Fig. 6** – *Geastrum schweinitzii*. a Expanded basidiomata *in situ*. b Immature basidioma. c Peristome. d Basidiospores. e Capillitium. *Geastrum triplex*. f Expanded basidioma *in situ*. g Immature basidioma. h Peristome. i Basidiospores. j Capillitium. Scale Bars: a, f = 10 mm, b, c, g, h = 1 mm, d, e, i, j = 5  $\mu$ m.

## Phallaceae Corda

*Phallus indusiatus* Vent., Mém. Inst. nat. Sci. Arts 1: 520 (1798)

Fig. 7a–c

Description – Immature basidiomata not observed. Expanded basidiomata fresh with 150–180 mm high. Receptacle 27–36 mm high  $\times$  22–34 mm wide, white (N<sub>00</sub>M<sub>00</sub>C<sub>00</sub>) to pinkish yellow (Y<sub>10</sub>M<sub>10</sub>C<sub>00</sub>), campanulate, reticulate surface, apical pore 3–6 mm diam. Pseudostipe 125–150 mm high  $\times$  12–16 mm wide, white (N<sub>00</sub>M<sub>00</sub>C<sub>00</sub>), cylindrical, spongy, hollow. Indusium in development with up to  $\frac{3}{4}$  length of the pseudostipe to well-developed extending to the ground, white (N<sub>00</sub>M<sub>00</sub>C<sub>00</sub>), polygonal meshes, joined to the apex of the pseudostipe. Volva 26–35 mm high  $\times$  21–35 wide, white (N<sub>00</sub>M<sub>00</sub>C<sub>00</sub>), with pink pigments (N<sub>00</sub>M<sub>10</sub>C<sub>00</sub>), globose, smooth surface, papery. Rhizomorph up to 150 mm, white (N<sub>00</sub>M<sub>00</sub>C<sub>00</sub>), adhered to the base of volva. Gleba olive green (N<sub>90</sub>C<sub>00</sub>Y<sub>99</sub>), mucilaginous, fetid. Basidiospores 2.8–4  $\times$  1.1–1.8  $\mu$ m ( $x = 3.3 \pm 0.1 \times 1.5 \pm 0.2$ , Qm = 2.26, n = 30), elongated to cylindrical, hyaline in 5% KOH, smooth, thin walls (<1 $\mu$ m). Pseudostipe composed of pseudoparenchymatous hyphae, 19.8–46.8  $\times$  18.5–44.8  $\mu$ m, globose to elongated-ovoid, hyaline, thin walls (<1 $\mu$ m). Indusium composed of pseudoparenchymatous hyphae, 20.7–38.5  $\times$  18–31  $\mu$ m, globose to elongated-ovoid, hyaline, thin walls (<1 $\mu$ m). Volva composed of three layers: outer layer composed of filamentous hyphae, 1.7–7  $\mu$ m, straight, with inflated parts, hyaline, thin walls (<1 $\mu$ m), branched, septate, with connection clamps; intermediate layer gelatinous, composed of thin hyphae (1.4–2.4  $\mu$ m wide), straight, hyaline, branched, septate, with connection clamps; internal layer composed of filamentous hyphae, 2.3–10  $\mu$ m, straight, with inflated parts, hyaline, thin walls (<1 $\mu$ m), branched, septate and connection clamps. Rhizomorph composed of filamentous hyphae, 7.1–16  $\mu$ m, hyaline, thin walls (<1 $\mu$ m), with inflated tips connected by pores.

Habitat – Gregarious, growing on decaying wood, sandy soil and litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'18.0"S, 35°13'11.0"W, 130 m, on decaying wood and litter, 12 May 2016, A.A. Lima, H.P. Lima, AAL 01 (UFRN–Fungos 2887). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'37.71"S, 35°3'20.20"W, 10 m, on sandy soil covered with litter, 03 Jul 2017, A.A. Lima, AAL 38 (UFRN–Fungos 2911).

Notes – *Phallus indusiatus* is considered a common species in the tropics (Baseia et al. 2006) and is characterized by the presence of a reticulate receptacle, indusium generally white, long, reaching the base, volva with pink pigmentation and rhizomorphs (Magnago et al. 2013). It resembles *Phallus impudicus* but differs by the absence of indusium in the latter. Other species of *Phallus* that have indusia are mainly differentiated, by the coloration of the indusium and volva, and surface of the receptacle, such as *Phallus atrovolvatus*, which can be recognized by the white indusium, rugular receptacle and black volva (Calonge et al. 2005); *Phallus cinnabarinus* with an orange to reddish indusium and pale yellow to brown volva (Cabral et al. 2015); *Phallus duplicatus*, that has a rudimentary indusium, yellowish white and reddish white to pale red volva (Cortez et al. 2011); *Phallus luteus* with yellow indusium and pale pink to reddish purple volva (Kasuya 2008); *Phallus merulinus* with white indusium, smooth receptacle and white volva (Cheypte 2010); *Phallus multicolor* which has an orange indusium and white volva, and *Phallus rubrovolvatus* which be recognized by the red volva (Cheypte 2010). Some specimens analyzed in this work have an indusium in development up to  $\frac{3}{4}$  of their length, besides a receptacle with shallow reticles and squamous volva.

## Sclerodermataceae Corda

*Scleroderma dunense* B.D.B. Silva, Sulzbacher, Grebenc, Baseia & M.P. Martín, Persoonia 36: 415 (2016) Fig. 7d–f

Description – Basidiomata epigeous, subglobose to depressed-subglobose, 6–14 mm high × 9–20 mm diam., sessile, base attached to the substrate by a tuft of mycelium and rhizomorphs. Peridium composed of two layers, thin, <1 mm thick, pale yellow (N<sub>10</sub>Y<sub>70</sub>M<sub>20</sub> to N<sub>30</sub>Y<sub>70</sub>M<sub>40</sub>), papery, coriaceous, partially smooth at the base and cracked at the top, with small thin scales, light brown (N<sub>30</sub>Y<sub>70</sub>M<sub>30</sub>) to brown (N<sub>90</sub>Y<sub>50</sub>M<sub>50</sub>). Dehiscence by an irregular and lacerated apical pore. Gleba compact when young, becoming powdery at maturity, greenish gray (Y<sub>90</sub>M<sub>90</sub>C<sub>80</sub>). Basidiospores 7.9–11.2 × 7.9–11 µm (x = 9.5 ± 0.7 × 9.2 ± 0.8, Qm = 1.03, n = 30), globose to subglobose, equinulate, dark brown in 5% KOH. Exoperidium composed of interwoven hyphae, hyaline to yellowish, 2.5–5.3 µm diam., thin walls (<1 µm), branched, septate. Endoperidium composed of interwoven hyphae, hyaline, 3–7.4 µm diam., thin walls (<1 µm), septate.

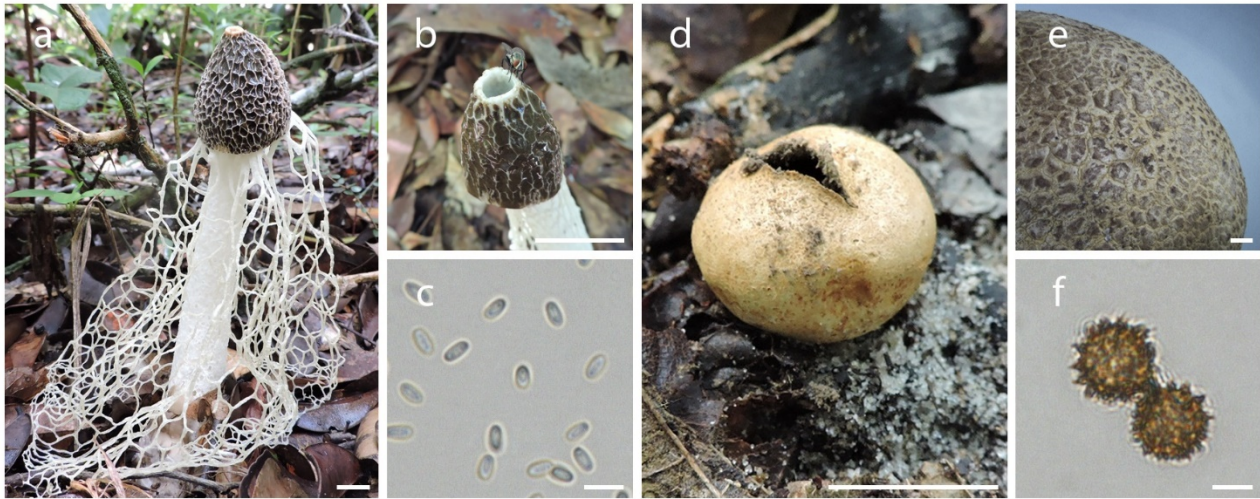
Habitat – Solitary or gregarious, growing on sandy soil covered with litter in shaded environment.

Material examined – Brazil, Rio Grande do Norte, Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'24.78"S, 35°12'50.67"W, 61 m, on sandy soil covered with litter, 26 May 2016, A.A. Lima, D.O. Andrade, AAL 02 (UFRN–Fungos 2888). Goianinha, APA Piquiri-Una – APAPU, Trilha Catu, 6°21'30.80"S, 35°12'53.03"W, 67 m, on sandy soil covered with litter, 16 Jun 2016, A.A. Lima, D.O. Andrade, AAL 16 (UFRN–Fungos 2896). Tibau do Sul, Parque Estadual Mata da Pipa – PEMP, 6°15'41.36"S, 35°3'17.37"W, 19 m, on sandy soil covered with litter, 05 May 2017, A.A. Lima, AAL 35 (UFRN–Fungos 2908).

Notes – This species is characterized by 12–17 mm diam. basidiomata, small and fine scales covering the exoperidium, dehiscence from an irregular to lacerate apical pore and equinulate 8–10.8 µm diam. basidiospores (Crous et al. 2016a). It usually grows in sand dunes near *Coccoloba* spp. Morphologically this species resembles *S. areolatum*, *S. nitidum* and *S. verrucosum* due to the fact that it has irregular dehiscence and equinulate basidiospores, but differ basically in the size of the basidiomata (15–30 mm diam, 20–25 mm diam, 25–30 mm diam, respectively) and



basidiospores with 10–15  $\mu\text{m}$ , 7–11  $\mu\text{m}$ , 9–12  $\mu\text{m}$ , respectively (Guzmán et al. 2013). Despite the fact that has morphological similarities with *S. areolatum*, *S. nitidum* and *S. verrucosum*, phylogenetic studies based on molecular data show a greater similarity with *S. capeverdeanum* (Crous et al. 2016a). In previous studies, Gurgel et al. (2008), Sulzbacher et al. (2013) reported this species as *Scleroderma nitidum*.



**Fig. 7** – *Phallus indusiatus*. a Basidioma *in situ*. b Apical pore. c Basidiospores. *Scleroderma dunense*. d Basidioma *in situ*. e Scales of peridium. f Basidiospores. – Bars: a, b, d = 10 mm, c, f = 5  $\mu\text{m}$ , e = 1 mm.

### Checklist

A total of 50 species of gasteroid fungi belonging to 18 genera, seven families and four orders (Agaricales, Boletales, Geastrales and Phallales) are reported in Rio Grande do Norte (Table 1). The genera *Geastrum* (18 spp.) and *Cyathus* (9 spp.) are the most representative. These two genera are considered cosmopolitan and adapted to different habitats (Brodie 1975, Sousa et al. 2014b).

**Table 1** Checklist of species of gasteroid fungi occurring in Rio Grande do Norte State.

Taxa	Distribution	Collection area	Substrate	Reference
<b>Agaricaceae Chevall.</b>				
<i>Calvatia cyathiformis</i> (Bosc) Morgan	João Câmara	<sup>1</sup> Cauaçu	sandy soil	Baseia et al. 2014
<i>Calvatia fragilis</i> (Vittad.) Morgan	João Câmara	<sup>1</sup> Cauaçu	sandy soil	Baseia et al. 2014
<i>Calvatia sculpta</i> (Harkn.) Lloyd	Natal	<sup>2</sup> PEDN	sandy soil	Baseia & Calonge 2008
* <i>Cyathus apiculatus</i> M.M.B. Barbosa & Baseia	Natal	<sup>2</sup> PEDN	decaying wood	Da Silva et al. 2016
* <i>Cyathus aurantogriseocarpus</i> R. Cruz, J.S. Góis, M.P. Martín, K. Hosaka & Baseia	Natal	<sup>2</sup> Pitimbu	decaying wood	Crous et al. 2017a
<i>Cyathus badius</i> Kobayasi	Natal	<sup>2</sup> PEDN	decaying wood	Cruz et al. 2012
* <i>Cyathus batistae</i> M.M.B. Barbosa & Baseia	Baía Formosa	<sup>2</sup> RPPN ME	decaying wood	Da Silva et al. 2016
<i>Cyathus earlei</i> Lloyd	Natal	<sup>2</sup> PEDN	decaying seed	Cruz et al. 2012
	Natal	<sup>2</sup> PEDN	decaying wood, branch or seed	Cruz et al. 2014
<i>Cyathus gracilis</i> H.J. Brodie	Tibau do Sul	<sup>2</sup> PEMP	decaying wood	Present study
	Natal	<sup>2</sup> PEDN	decaying wood or litter	Cruz et al. 2014

**Table 1** Continued.

Taxa	Distribution	Collection area	Substrate	Reference
	Tibau do Sul	<sup>2</sup> PEMP	decaying wood, litter	Present study
<i>Cyathus limbatus</i> Tul. & C. Tul.	Natal	<sup>2</sup> PEDN	litter	Cruz et al. 2014
	Baia	<sup>2</sup> RPPN ME	litter	Cruz et al. 2014
	Formosa			
	Goianinha	APAPU	decaying wood, litter	Present study
	Tibau do Sul	<sup>2</sup> PEMP	decaying wood, litter	Present study
<i>Cyathus pallidus</i> Berk. & M.A. Curtis	Baia	<sup>2</sup> RPPN ME	decaying wood, litter	Cruz et al. 2014
<i>Cyathus setosus</i> H.J. Brodie	Natal	<sup>2</sup> PEDN	decaying wood or soil	Cruz et al. 2014
<i>Disciseda candida</i> (Schwein) Lloyd	Caicó	<sup>1</sup> Caicó	Soil with grass	Silva & Baseia 2014
<i>Disciseda verrucosa</i> G. Cunn.	Jucurutu	<sup>1</sup> Jucurutu	rocky soil	Silva & Baseia 2014
* <i>Lycoperdon arenicola</i> (Alfredo & Baseia) Baseia, Alfredo & M.P. Martín	Natal	<sup>2</sup> PEDN	sandy soil	Alfredo et al. 2014 as <i>Morganella arenicola</i> Alfredo & Baseia
	Natal	<sup>2</sup> PEDN	sandy soil	Barbosa et al. 2011 as <i>Morganella compacta</i> (G. Cunn.) Kreisel & Dring
* <i>Lycoperdon demoulinii</i> Baseia, Alfredo & M.P. Martín	Natal	<sup>2</sup> PEDN	sandy soil	Crous et al. 2017b
<i>Lycoperdon fuliginum</i> Berk. & M. Curtis	Baia	<sup>2</sup> RPPN ME	decaying wood	Alfredo et al. 2017
<i>Podaxis pistillaris</i> (L.) Fr.	Apodi	<sup>1</sup> Chapada do Apodi	rocky soil	Baseia et al. 2014
	Baraúna	<sup>1</sup> PARNA FF	rocky soil	Baseia et al. 2014
<i>Tulostoma cyclophorum</i> Lloyd	Baia	<sup>2</sup> RPPN ME	humose soil	Silva et al. 2007
	Formosa			
<i>Tulostoma fimbriatum</i> Fr.	Baia	<sup>2</sup> RPPN ME	humose soil	Silva et al. 2007
	Formosa			
<b>Clathraceae Chevall.</b>				
* <i>Abrachium floriforme</i> (Baseia & Calonge) Baseia & T.S. Cabral	Natal	<sup>2</sup> PEDN	sandy soil	Baseia & Calonge 2005, Baseia et al. 2006 and Leite et al. 2007a as <i>Aseroë floriformis</i> Baseia & Calonge
	Baia	<sup>2</sup> RPPN ME	sandy soil	Baseia & Calonge 2005 and Leite et al. 2007a as <i>Aseroë floriformis</i> Baseia & Calonge
	Formosa			
<i>Clathrus columnatus</i> Bosc	Tibau do sul	<sup>2</sup> PEMP	sandy soil, litter	Present study
<i>Ileodictyon cibarium</i> Tul. ex M. Raoul	Tibau do sul	<sup>2</sup> PEMP	sandy soil, litter	Present study
	Natal	<sup>2</sup> PEDN	sandy soil	Baseia et al. 2006, Leite et al. 2007a
<i>Laternea triscapa</i> Turpin	Natal	<sup>2</sup> PEDN	humose soil	Baseia et al. 2006, Leite et al. 2007a
<b>Geastraceae Corda</b>				
<i>Geastrum albonigrum</i> Calonge & M. Mata	Baia	<sup>2</sup> RPPN ME	sandy soil, litter, decaying wood	Sousa et al. 2014a
	Formosa			



**Table 1** Continued.

Taxa	Distribution	Collection area	Substrate	Reference
<i>*Geastrum entomophilum</i> Fazolino, Calonge & Baseia	Natal	<sup>2</sup> PEDN	litter	Fazolino et al. 2008
<i>Geastrum fimbriatum</i> Fr.	Goianinha Baia	<sup>2</sup> APAPU <sup>2</sup> RPPN ME	sandy soil, litter sandy soil	Present study Sousa et al. 2014b
<i>Geastrum javanicum</i> Lév.	Formosa Baia	<sup>2</sup> RPPN ME	sandy soil	Sousa et al. 2014b
<i>Geastrum lageniforme</i> Vittad.	Formosa Baia	<sup>2</sup> RPPN ME	sandy soil	Sousa et al. 2014b
<i>Geastrum lloydianum</i> Rick	Formosa Baia	<sup>2</sup> RPPN ME	sandy soil	Sousa et al. 2014b
<i>Geastrum minimum</i> Schwein.	Formosa Natal Goianinha	<sup>2</sup> PEDN <sup>2</sup> APAPU <sup>2</sup> RPPN ME	sandy soil sandy soil, litter sandy soil	Sousa et al. 2014b Present study Sousa et al. 2014b
<i>Geastrum morganii</i> Lloyd	Formosa Natal Baia	<sup>2</sup> PEDN <sup>2</sup> RPPN ME	sandy soil sandy soil, litter	Sousa et al. 2014b Sousa et al. 2014a
<i>Geastrum ovalisporum</i> Calonge & Mor.-Arr.	Serra Negra do Norte Natal	<sup>1</sup> ESEC <sup>2</sup> PEDN	sandy soil, litter decaying wood	Sousa et al. 2014a Leite et al. 2007b
<i>Geastrum pectinatum</i> Pers.	Baia Formosa	<sup>2</sup> RPPN ME	sandy soil	Sousa et al. 2014b
<i>Geastrum pusillipilosum</i> J.O. Sousa, Alfredo, R.J. Ferreira, M.P Martín & Baseia	Natal Tibau do sul	<sup>2</sup> PEDN <sup>2</sup> PEMP	sandy soil sandy soil, litter	Sousa et al. 2014b Present study
<i>Geastrum quadrifidum</i> Pers.	Natal	<sup>2</sup> PEDN	sandy soil	Sousa et al. 2014a
<i>*Geastrum rusticum</i> Baseia, B.D.B. Silva & T.S. Cabral	Baia Formosa Tibau do sul	<sup>2</sup> RPPN ME <sup>2</sup> PEMP	decaying wood decaying wood	Cabral et al. 2014b Present study
<i>Geastrum saccatum</i> Fr.	Natal	<sup>2</sup> PEDN	sandy soil	Leite & Baseia 2007
<i>Geastrum schweinitzii</i> (Berk. & M.A. Curtis) Zeller	Natal	<sup>2</sup> PEDN	decaying wood	Sousa et al 2014b
<i>Geastrum setiferum</i> Baseia	Goianinha Tibau do sul Baia	<sup>2</sup> APAPU <sup>2</sup> PEMP <sup>2</sup> RPPN ME	decaying wood termite nest sandy soil	Present study Present study Sousa et al. 2014b
<i>Geastrum triplex</i> Jungh.	Formosa Natal Goianinha	<sup>2</sup> PEDN <sup>2</sup> APAPU	litter sandy soil, litter	Leite & Baseia 2007 Present study
<i>Geastrum xerophilum</i> Long ex Desjardin	Caicó	<sup>1</sup> Caicó	sandy soil	Silva et al. 2011
<i>*Myriostoma calongei</i> Baseia, J.O. Sousa & M.P. Martín	Baia Formosa	<sup>2</sup> RPPN ME	sandy soil, litter	Sousa et al. 2014b as <i>Myriostoma coliforme</i> (Dicks.) Corda and Sousa et al. 2017
<b>Phallaceae Corda</b>				
<i>Itajahya rosea</i> Delile	Serra Negra do Norte	<sup>1</sup> ESEC	rocky soil	Otoni et al. 2010 as <i>Phallus roseus</i> Delile
<i>Mutinus caninus</i> (Huds.) Fr.	Natal	<sup>2</sup> PEDN	sandy soil, litter	Baseia et al. 2006
<i>*Mutinus verrucosus</i> T.S. Cabral, B.D.B. Silva, K. Hosaka, M.P. Martín & Baseia	Baia Formosa	<sup>2</sup> RPPN ME	soil	Crous et al. 2017b
<i>Phallus indusiatius</i> Vent.	Baia Formosa	<sup>2</sup> RPPN ME	sandy soil, litter	Baseia et al. 2006

**Table 1** Continued.

Taxa	Distribution	Collection area	Substrate	Reference
	Natal	<sup>2</sup> PEDN	sandy soil, litter	Baseia et al. 2006
	Goianinha	<sup>2</sup> APAPU	decaying wood, litter	Present study
	Tibau do sul	<sup>2</sup> PEMP	sandy soil, litter	Present study
<i>Staheliomyces cinctus</i> E. Fisch.	Natal	<sup>2</sup> PEDN	sandy soil, litter	Baseia et al. 2006, Leite et al. 2007a
<b>Sclerodermataceae Corda</b>				
* <i>Scleroderma dunense</i> B.D.B. Silva, Sulzbacher, Grebenc, Baseia & M.P. Martín	Natal	<sup>2</sup> PEDN	sandy soil	Crous et al. 2016a (originally published as " <i>dunensis</i> "), Sulzbacher et al. 2013, Gurgel et al. 2008 as <i>Scleroderma nitidum</i> Berk
	Goianinha	<sup>2</sup> APAPU	sandy soil, litter	Present study
	Tibau do sul	<sup>2</sup> PEMP	sandy soil, litter	Present study
<b>Trappeaceae P.M. Kirk</b>				
* <i>Restingomyces reticulatus</i> Sulzbacher, B.T. Goto & Baseia	Natal	<sup>2</sup> PEDN	sandy soil (hypogeous)	Sulzbacher et al. 2016

\* new species for science. <sup>1</sup> Caatinga areas. <sup>2</sup> Atlantic rainforest areas. APAPU – ‘Área de Preservação Ambiental Piquiri-Una. ESEC – ‘Estação Ecológica do Seridó’. PARNA FF – ‘Parque Nacional da Furna Feia’. PEDN – ‘Parque Estadual Dunas do Natal’. PEMP – ‘Parque Estadual Mata da Pipa’. RPPN ME – ‘Reserva do Patrimônio Particular Natural Mata Estrela’.

In relation to the biome, 84% of the species (43 spp.) are reported in Atlantic rainforest areas, while 16% (7 spp.) are reported for the Caatinga. The studies are concentrated in the ‘Parque Estadual Dunas do Natal’ and the ‘Reserva Particular do Patrimônio Natural Mata Estrela’. Sandy soil and decaying wood are the most reported habitats for the gasteroid fungi. Like other macro fungi, these fungi have important ecological function, mainly decomposition of dead wood and leaf litter (Gogoi & Vipin 2015).

The present study contributes to the knowledge of gasteroid fungi in potentially rich areas for their development, although not yet investigated. However, these data are still far from complete. Hawksworth & Lücking (2017) reported the importance of studies of fungi in tropical areas. In addition, Baseia et al. (2016) emphasized the urgency of inventory studies, especially in areas most threatened by human activities, where species may be at risk of extinction before being described and named. Therefore, new studies are needed to increase the knowledge about the gasteroid fungi in the studied areas, as well as in other areas of the state, in order to mitigate gaps in the knowledge of these organisms of great ecological and economic importance.

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