

First record of *Sphaerobolus stellatus* Tode (Basidiomycota, Geastraceae) from the Amazon, Brazil

Marcos Diones Ferreira Santana ^{a*}, Sheyla Regina Marques Couceiro ^b

^a Programa de Pós-Graduação em Biodiversidade e Biotecnologia, Universidade Federal do Pará, Belém, 66077-830, Pará, Brasil.
* santana.mdf@gmail.com

^b Programa de Pós-Graduação em Biodiversidade e Biotecnologia, Universidade Federal do Oeste do Pará, Santarém, 68040-470, Pará, Brasil.

Received: July 19, 2022 / Accepted: March 14, 2023 / Published online: June 6, 2023

Abstract

Sphaerobolus stellatus Tode is a fascinating gasteroid fungus that is distinguished from other fungi by the diminutive morphology of the starry basidiome when mature and its peculiar strategy of spore's dispersion. This taxon ejects the gleba for a considerable distance as if it was cannon, and therefore is popularly known as artillery fungus. Although the species is cosmopolitan, records are seldom in regions such as South America, and many of them require greater attention due to the absence of important morphological characters. In Brazil, the South American country with most records, the distribution was restricted to a few sites, none of them in the Amazon. This study describes the occurrence of *S. stellatus* from the Amazon, contributing to the understanding of its geographical distribution and making the material available for future diversity studies.

Keywords: Gasteromycetes, artillery fungus, geographic distribution, new occurrence.

Primeiro registro de *Sphaerobolus stellatus* Tode (Basidiomycota, Geastraceae) na Amazônia, Brasil

Resumo

Sphaerobolus stellatus Tode é um fungo gasteroide fascinante que se distingue dos outros fungos pela morfologia diminuta do basidioma estrelado quando maturo e sua peculiar estratégia de dispersar esporos. Esse táxon ejeta a gleba por uma distância considerável assim como um canhão, e por isso são popularmente conhecidos como fungo de artilharia. Embora a espécie seja cosmopolita, regiões como a América do Sul apresentam raros registros, muitos dos quais, devido à ausência de caracteres morfológicos importantes, necessitam de maior atenção. No Brasil, país com a maioria das amostras, a distribuição estava restrita a poucas localidades, nenhuma delas na Amazônia. O presente estudo descreve a ocorrência de *S. stellatus* para a Amazônia, contribuindo com a compreensão de sua distribuição geográfica e disponibilizando o material para futuros estudos de diversidade.

Palavras-chave: Gasteromycetes, fungo de artilharia, distribuição geográfica, nova ocorrência.

The genus *Sphaerobolus* Tode (Geastraceae) was described almost 300 years ago by Micheli (1729), who at the time named it *Carpobolus*. However, the currently accepted name was coined by Tode (1970) when he adequately described the type species. The generic name is derived from the Greek words "sphaer" meaning "sphere" and "obolus" meaning "to throw", i.e. ball-throwing fungus or artillery fungus due to its peculiar ability to eject its gleba at a considerable distance to disperse its spores (Walker, 1927; Bottomley, 1948; Geml, Davis & Geiser, 2005a; Brantley, Davis & Kuhns, 2001).

The genus diversity is a source of great discussion in the scientific community and the information available is divergent. In the fungal database Index Fungorum (Cabi, 2021) there are 35 taxon, from which only four species are recognized

(*S. brunneocarneus* Rick, *S. stellatus* Tode, *S. ingoldii* Geml, D.D. Davis & Geiser e *S. minimus* Sacc.). The others are synonymized with *S. stellatus*, the type species, not validated or transferred to other genera. On the other hand, Geml, Davis & Geiser (2005a, b), based on morphological data, molecular analyses and characteristics of mycelial cultures, recognized only three species (*S. iowensis* L.B. Walker, *S. ingoldii* e *S. stellatus*), even though their study was concentrated in materials from the northern hemisphere, despite its cosmopolitan nature (Geml, Davis & Geiser, 2005b).

The species *S. stellatus* is the best supported in the clade, present in all continents, except for Antarctica (Geml, Davis & Geiser, 2005b). In South America, information is scarce

and part of the few existing records require review and molecular studies for elucidation as documented by Hosaka et al. (2020), mainly for the material lacking essential morphological characters in integrative taxonomy.

In Brazil, where the most extensive tropical forests in the world are home to great biological diversity (Lewinsohn & Prado, 2005), about 50% of samples (n=34) were not identified at the species level and the remaining samples were divided between *S. stellatus* (88%) and *S. stellatus* var. *brasiliensis* Viégas & C.G. Teixeira (12%) (Cria 2021), even though the latter was synonymized with the first (Cabi, 2021). The literature on gasteroid fungi in the country reports *S. brunneocarneus* and *S. stellatus* (Rick, 1961; Trieverler-Pereira et al., 2009), but if you consider the study of Geml, Davis & Geiser (2005b), only the latter would be documented.

The scenario is even more concerning in the Amazon, where the richness of fauna and flora stands out, but little is known about funga (only 1050 species were known until 2015 according to Maia et al. 2015). Even though the number of fungal species has increased in recent years, studies on gasteroid mycobiota are still emerging. Thus, in order to contribute for the knowledge on the diversity of Amazonian fungi, we describe the first record of *S. stellatus* from the Amazon; expanding and improving the understanding of its distribution and contributing for future diversity studies.

The collections were carried out in 2018 in a fragment of the Amazon forest in western Pará, Brazil (2°48'41.9"S, 54°18'11.8"W), near the Silvio Pinto (Curuá-Una) Hydroelectric power plant. The forest fragment is about 30,000 ha large and is mostly a plateau area (with little altitudinal variation) covered by high-canopy forest and its understory dominated by natural regeneration, herbaceous and shrubby plants, palm trees and shrubs.

The specimens were collected with a pocket knife and packed in a plastic box compartmentalized for transport. Taxonomic identification was performed based on macro and micromorphological characterization, using stereomicroscope and optical microscope (OM). Color identifications were based on Kornerup and Wanscher (1978). The nomenclature followed the database of Index Fungorum (Cabi 2021) and The International Plant Names Index (Ipini, 2021) and the voucher was deposited in the collection of fungi from the HSTM herbarium of the Universidade Federal do Oeste do Pará, Brazil (<http://hstm.jbrj.gov.br/>).

Data on *S. stellatus* occurrence from South America were compiled based on research of literature records and online databases, such as Gbif (Gbif, 2021), Species Link (Cria, 2021) and Flora do Brasil (Flora, 2021). Only the records identified at the species level were considered for creation of the distribution map.

Taxonomy: *Sphaerobolus stellatus* Tode, Fungi Mecklenburgenses Selecti 1: 43 (1790; Figura. 1).

Epigeous and gregarious basidiomes, measuring between 2.5–3.0 mm high × 2.0–2.5 mm in diameter when mature, star-like with 5–6 rays. White mycelial layer (1A4), wooly and evanescent. Yellow, papyraceous, fragile, strongly encrusted exoperidium (1A4). Dark gray endoperidium (1F1). Dark gray peridiole (1F1) with 1.1 mm diameter × 2.55 mm in length.

Missing subgleba and rhizomorphs. Peridiole composed of basidiospores and trachea hyphae. Hyaline basidiospores in KOH 5%, dextrinoid, cyanophilic ellipsoids, smooth under optical microscope, 8.8–10.5 µm × 4.5–6.0 µm in diameter (n = 40). Brown trachea hyphae in KOH 5% non-dextrinoid measuring 3.1–5.0 µm, septate, with connecting clamps. Unobserved basidia. Brown globe yolks in KOH 5%, non-dextrinoids, observed crystals and absent rhizomorphs.

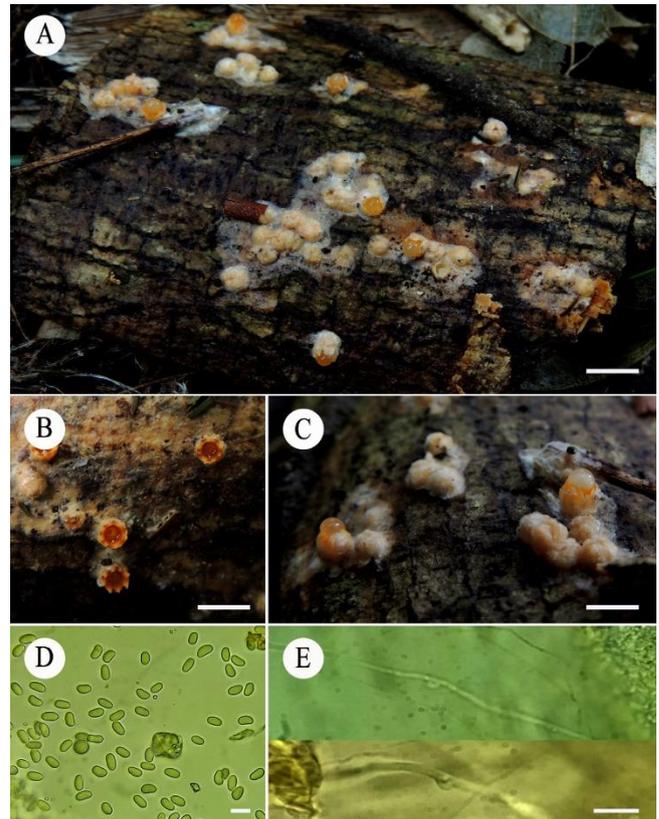


Figure 1. *Sphaerobolus stellatus*. A) Basidiomes growing on decomposing tree trunk, B) Basidiomes without gleba, C) Basidiomes with gleba, D) Basidiospores, E) Connection clamp. Bars: A-C) 5 mm; D) 10 µm; E) 20 µm.

Examined material: Brazil. Pará: Santarém, forest fragment near the Silvio Pinto (Curuá-Una) hydroelectric power plant, in decomposing tree trunk fallen to the ground, 2°48'41.9"S, 54°18'11.8"W, 27 April 2018, Santana, MDF 569, HSTM Fungi 014712.

Reference: Bottomley (1948), Geml, Davis & Geiser (2005a, b) and Walker (1927) and Viégas and Teixeira (1945) were referred for species description.

Distribution: Cosmopolitan species (Geml, Davis & Geiser, 2005b). In South America it is recorded from Chile, Argentina, Uruguay, Venezuela and Brazil (Caffot et al., 2015; Cria, 2021; Gbif, 2021). In Brazil, records indicate a range comprising the Pampa (Rick, 1961; Trieverler-Pereira, Honaiser & Silveira, 2018; Flora, 2021; Cria, 2021), Cerrado (Bononi, Trufem & Grandi, 1981; Flora, 2021; Cria, 2021), Caatinga (Oliveira, 2019; Cria, 2021), Atlantic Forest (Trieverler-Pereira & Baseia 2009; Flora, 2021; Cria, 2021) and Amazon (this study) (Figure 2) biomes.

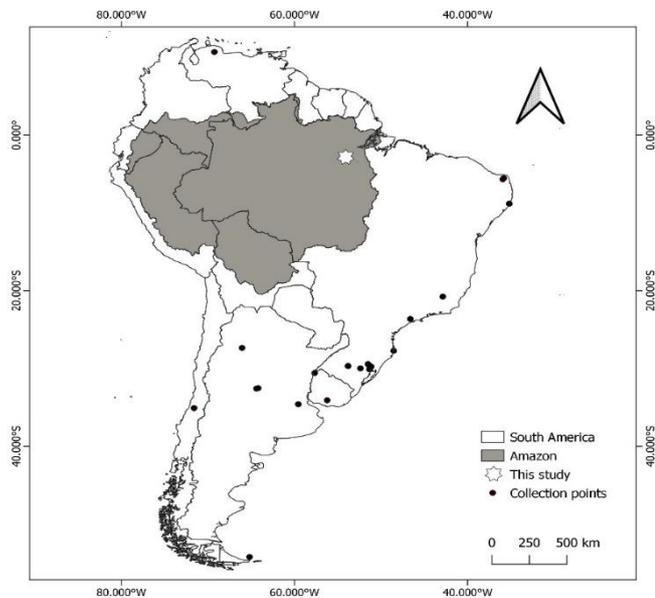


Figure 2. Distribution of *Sphaerobolus stellatus* in South America, Amazon in grey.

Notes: *Sphaerobolus stellatus* presents miniature and star-like basidiome with 5 to 6 rays when mature, with a peculiar way of dispersing its spores like a cannon, an artillery fungus. Microscopically the peridiole presents gems and the basidiospores are ellipsoids and smooth. This species can be confused with *S. ingoldii* and *S. iowensis*, although *S. stellatus* presents larger basidiome and peridiole, slightly smaller basidiospores and gems are present, differentiating from *S. ingoldii*, absence of basidial chambers in immature glebas and gelatinous layer differing from *S. iowensis* (Geml, Davis & Geiser, 2005a, b).

The current distribution of *S. stellatus* in South America is still restricted to a few localities and although in Brazil there are the highest number of records, the distribution was known only in the states of Rio Grande do Sul (Rick, 1961; Treiveiler-Pereira et al., 2009; Treiveiler-Pereira, 2018), São Paulo (Bononi, Trufem & Grandi, 1981; Treiveiler-Pereira et al., 2009), Rio Grande do Norte (Oliveira, 2019), Pernambuco and Santa Catarina (Cria, 2021). This is the first record from the Brazilian Amazon, as well as from the state of Pará.

Many samples deposited in South American scientific collections require greater attention to verify species identification. In part, due to the lack of materials with important characteristics normally necessary to describe a gasteroid fungus, such as *Sphaerobolus*, which gleba and basidiospores are important morphological characters for the genus. However, these characters can be difficult to observe depending on the basidiome's degree of maturation, when found. Thus, especially in these cases, molecular studies are necessary in view of the divergence regarding genus diversity, as highlighted by Hosaka et al. (2020), and it is possible that the diversity of the taxon is greater than that recorded so far.

This is the first record of *S. stellatus* from the Brazilian Amazon and in light of your example, it is necessary to assess areas little or not at all explored in the Amazon, where there is

great fungal diversity. However, the difficult access to some sites, and the decharacterization of the forest by deforestation, concern scientific and conservation efforts and are obstacles to research involving large-scale mycology. Thus, this study increases the geographical distribution of *S. stellatus* to the Amazon and contributes to minimize the knowledge gap on fungal diversity in this worldwide important area.

Acknowledgements

The authors thank Pró-reitoria de Pesquisa, Pós-graduação e Inovação Tecnológica (PROPPIT) of Universidade Federal do Oeste do Pará (UFOPA), for the logistical support, especially for field trips.

References

- Bononi V. L. R., Trufem S. F. B. & Grandi R. A. (1981). Fungos macroscópicos do Parque Estadual das Fontes do Ipiranga, São Paulo (SP), Brasil, depositados no Herbário do Instituto de Botânica. *Rickia*, 9: 37–53.
- BottoMley A. M. (1948). Gasteromycetes of South Africa. *Bothalia*, 4: 473–810.
- Brantley E. A., Davis D. D. & Kuhns L. 2001. Biological control of the artillery fungus, *Sphaerobolus stellatus*, with *Trichoderma harzianum* and *Bacillus subtilis*. *Journal of Environmental Horticulture*, 19: 21–23. doi: <https://doi.org/10.24266/0738-2898-19.1.21>
- Cabi (Bioscience). (2021). The CABI Bioscience and CBS Database of Fungal Names. <http://www.indexfungorum.org/Names/Names.asp/26Jul.2021>.
- Caffot1 M. L. H., Broiero X. A., Fernández M. E., Ruiz L. S., Crespo E. M. & Nuhra E. R. (2015). Gasteroid mycobiota (Agaricales, Geastrales, and Phallales) from Espinal forests in Argentina. *Mycotaxon*, 130: 1213.
- Cria (Species Link). (2021). <http://splink.cria.org.br/> 27Jul.2021.
- Flora (Flora do Brasil 2020). (2021). <http://floradobrasil.jbrj.gov.br/25Jul.2021>.
- Gbif - Global Biodiversity Information Facility. (2021).
- Geml J., Davis D. D. & Geiser D. M. (2005a). Systematics of the genus *Sphaerobolus* based on molecular and morphological data, with the description of *Sphaerobolus ingoldii* sp. nov. *Mycologia*, 97: 680–694. doi: <https://doi.org/10.1080/15572536.2006.11832798>
- Geml J., Davis D. D. & Geiser D. M. (2005b). Phylogenetic analyses reveal deeply divergent species lineages in the genus *Sphaerobolus* (Phallales: Basidiomycota). *Molecular Phylogenetics and Evolution*, 35: 313–322. doi: <https://doi.org/10.1016/j.ympev.2005.01.014>
- Hosaka K., Nam K., Linn W. W. & Aung M. M. (2020). First Record of a species in the genus *Sphaerobolus* (Geastrales) from Myanmar. *Bulletin of the National Museum of Nature and Science, Series B*, 46: 101–106.
- Ipini (International Plant Name Index). (2021). (<https://www.ipni.org/>). Accessed on 25 Jul 2021.
- Kornerup A. & Wanscher J. H. (1978). *Methuen Handbook of Colours*. 3rd edition. London, Eyre Methuen.
- Lewinsohn T. M. & Prado P. I. (2005). How Many Species Are There in Brazil? *Conservation Biology*, 19: 619–24. doi: <https://doi.org/10.1111/j.1523-1739.2005.00680.x>
- Maia L. C., Júnior A. A. C., Cavalcanti L. H. & Gugliotta A. M et al. (2015). Diversity of Brazilian Fungi. *Rodriguésia*, 66: 1033–1045. doi: <https://doi.org/10.1590/2175-7860201566407>
- Micheli P. A. (1729). *Nova Plantarum Genera*. Florence, Italy.
- Oliveira R. L. 2019. Taxonomia de fungos gasteroides (Basidiomycota) em áreas de Caatinga do Rio Grande do Norte e Paraíba, Brasil. Repository of Universidade Federal do Rio Grande do Norte, Brasil – Tesis.
- Rick J. (1961). Basidiomycetes Eubasidii in Rio Grande do Sul, Brasilia. *Iheringia, Série Botânica*, 9: 455–479.
- Tode H. J. (1790). *Fungi Mecklenburgenses selecti* (Lüneburg). 1: 43.
- Treiveiler-Pereira L., Honaiser L. P. & Silveira R. M. B. 2018. Diversity of gasteroid fungi (Agaricomycetes, Basidiomycota) from the Brazilian Pampa Biome. *Nova Hedwigia*, 106: 305–324. doi: https://doi.org/10.1127/nova_hedwigia/2017/0438
- Treiveiler-Pereira L., Silva G. & Baseia I. G. 2009. Notes on gasteroide

fungi of the Brazilian Amazon rainforest. *Mycotaxon*, 110: 73–80. doi:
<https://doi.org/10.5248/110.73>

Viégas A. P. (1945). Alguns fungos do Brasil. *Bragantia*, 5: 584–595.

Walker L. (1927). Development and mechanism of discharge in *Sphaerobolus iowensis* and *S. stellatus* Tode. *Journal of the Elisha Mitchell Scientific Society*, 42: 151–178

License: Creative Commons CC BY NC 4.0

This article was published with open access for distribution under the terms of the Creative Commons Attribution License, which allows unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.