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The lichen genus *Schistophoron* Stirt.
(Ascomycetes, Graphidaceae) in Brazil
with a world key to the species

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The lichen genus *Schistophoron* Stirt. (Ascomycetes, Graphidaceae) in Brazil with a world key to the species

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ABSTRACT

KEY WORDS

Lirellae,
mazaedium,
new records,
tropics,
Chaco.

The genus *Schistophoron* Stirt. is reported for the first time from Brazil, based on collections from Mato Grosso do Sul State. Two species, *S. indicum* Kr.P.Singh & Swarnalatha, and *S. tenue* Stirt., were found, both of which are described and illustrated. In addition, a brief characterization of the other known species, with their geographic distribution, a comparative table and a world key are provided to facilitate their identification.

RÉSUMÉ

Les lichens du genre Schistophoron Stirt. (Ascomycetes, Graphidaceae) au Brésil avec une clé mondiale des espèces.

MOTS CLÉS
Lirellae,
mazaedium,
nouveaux signalements,
tropiques,
Chaco.

Le genre *Schistophoron* Stirt. est signalé pour la première fois au Brésil, sur la base de collections de l'État du Mato Grosso do Sul. Deux espèces, *S. indicum* Kr.P.Singh & Swarnalatha, et *S. tenue* Stirt., ont été trouvées, et toutes deux décrites et illustrées. De plus, une brève caractérisation des autres espèces connues du genre, avec leur répartition géographique, un tableau comparatif et une clé mondiale sont fournis pour faciliter leur identification.

INTRODUCTION

The genus *Schistophoron* Stirt. was first described by Stirton (1876), based on a collection from the Bonny river, Niger (currently Nigeria), West Africa, made by Mr Grant. It is similar to *Tylophoron* Nylander by its apothecia with lecanorine margins and a mazaedium, but differs by the elongated apothecia (lirellae) and different ascospores. Stirton (1876) recognized only one species, *Schistophoron tenue* Stirt., which is thus the type species of the genus. It is also the most widely distributed species in the genus.

A century later, Weber (1976) made the second report of *S. tenue*, this time from the Galápagos Islands. Tibell (1981), in a study on Caliciales, expanded the known geographical distribution of *S. tenue* to Ivory Coast and Cameroon. After a study of specimens from Costa Rica, Tibell (1982) described a second species of the genus, *S. variabile* Tibell, and reported *S. tenue* for the first time from Venezuela and Peru. On the Asian continent, *S. tenue* was first reported from India by Awasthi (1991). Finally, Tibell (1996), in his monograph on neotropical species of Caliciales, reported *S. tenue* for the first time from Guatemala and French Guiana, and *S. variabile* from the Galápagos Islands.

Recently, three species were added to genus: *S. aurantiacum* Aptroot & Sipman (Aptroot & Sipman 2007), *S. indicum* Kr.P.Singh & Swarnalatha (Singh & Swarnalatha 2011) and *S. muriforme* Weerakoon & Aptroot (Weerakoon & Aptroot 2016). Thus, five species are currently known in the genus. The genus appears to be restricted to tropical lowlands, between 28°06'N and 28°30'S (Fig. 1), and between 05–1100 m elevation, where it grows preferably on tree trunks in forest.

Schistophoron was considered as belonging to the family Cypheliaceae, order Caliciales, by Zahlbruckner (1926). Tibell (1984) excluded it from Caliciales. Aptroot & Sipman (2007) discussed the affinity of *Schistophoron* with the family Graphidaceae, based on the structure of the filaments of the hymenium (free in the upper part, not branched and septate), the lirelliform shape of the apothecia, the I-negative hymenium and the clavate shape of the asci with thick apices. Tehler *et al.* (2009) used molecular data and reinforced the idea of this genus belonging to Graphidaceae. Eventually, Rivas-Plata *et al.* (2012) confirmed the monophyly of Graphidaceae, which includes *Schistophoron*. Currently, *Schistophoron* belongs to the subfamily Graphidoideae, family Graphidaceae and order Ostropales (Lücking *et al.* 2017).

The genus *Schistophoron* is characterized by its lirelliform, mazaediate ascomata (Fig. 2E), with partially disintegrated hymenium at maturity, a non-carbonized brown excipulum, the transversely septate to submuriform dark brown ascospores and *Trentepohlia* Mart. as photobiont (Singh & Swarnalatha 2011).

Based on specimens from Mato Grosso do Sul, Brazil, we provide here detailed descriptions of *S. tenue* and *S. indicum*, with illustrations and comparative comments. We also present brief characterizations of the other species described in the genus, together with an identification key, a comparative table of characters of taxonomic importance and maps of the known geographic distribution of all the species.

MATERIAL AND METHODS

The specimens were collected during lichenological expeditions undertaken by A. A. Spielmann in the municipalities of Porto Murtinho and Jardim. The collected specimens (CGMS) were studied morphologically and anatomically. Chromatographic profiles were made following Huneck & Yoshimura (1996) and Orange *et al.* (2010). Results were also confirmed through Microcrystallization and Mass Spectrometry. The thalli photographs were taken under Stereo Microscope Zeiss Discovery V20, and mazaedium and ascospores under scanning electron microscope JOEL JSM-6380LV at 10 kV.

The identification key for *Schistophoron* species is based on the descriptions provided here for *S. indicum* and *S. tenue* and on the descriptions found in the literature for *S. variabile*, *S. aurantiacum* and *S. muriforme*. Some characters of taxonomic importance are presented in the Table 1. The descriptions were standardized so as to be easily compared.

Distribution maps were prepared using the software QGIS® 2.14.0.

RESULTS

The genus *Schistophoron* is reported for the first time from Brazil comprising *S. tenue* and *S. indicum* collected from the municipalities of Jardim and Porto Murtinho respectively in the Mato Grosso Sul State. The species *S. indicum* is a new record for the American continent.

THE *SCHISTOPHORON* SPECIES

Order OSTROPALES Nannf.
Family GRAPHIDACEAE Dumort.
Genus *Schistophoron* Stirt.

Schistophoron aurantiacum Aptroot & Sipman

Bibliotheca Lichenologica 96: 22 (2007). — Type: Costa Rica. Puntarenas: Parque Nacional Carara (Area de Conservación Pacífico Central), 60 km WSW of San Jose on road from Orotina to Quepos, trail from visitor's center to Quebrada Bonita, 9°47'N, 84°35'W, 100 m elev., lowland moist forest zone: partly disturbed primary forest along stream with dense *Erythrochiton gymnanthus* understory, on bark (stem) in clearing, 18.VII.2002, H. Sipman 48386d (holo-, B[B]; iso-, INBio[INBio]), fide Aptroot & Sipman (2007).

KNOWN DISTRIBUTION. — Only known from Costa Rica (Aptroot & Sipman 2007).

NOTES

This species is characterized by the white thallus with an orange hue, orange-brown prothallus, sessile and elliptical to shortly lirelliform, partially orange pruinose ascomata with carbonized wall, and grey to blackish-brown, uniseptate and ellipsoid (10–12 × 5–7 µm) ascospores (Aptroot & Sipman 2007).

Schistophoron aurantiacum has lichexanthone in the thallus, being UV+ deep yellow and an orange, K+ deep violet red anthraquinone in the ascoma wall, thallus and especially the prothallus

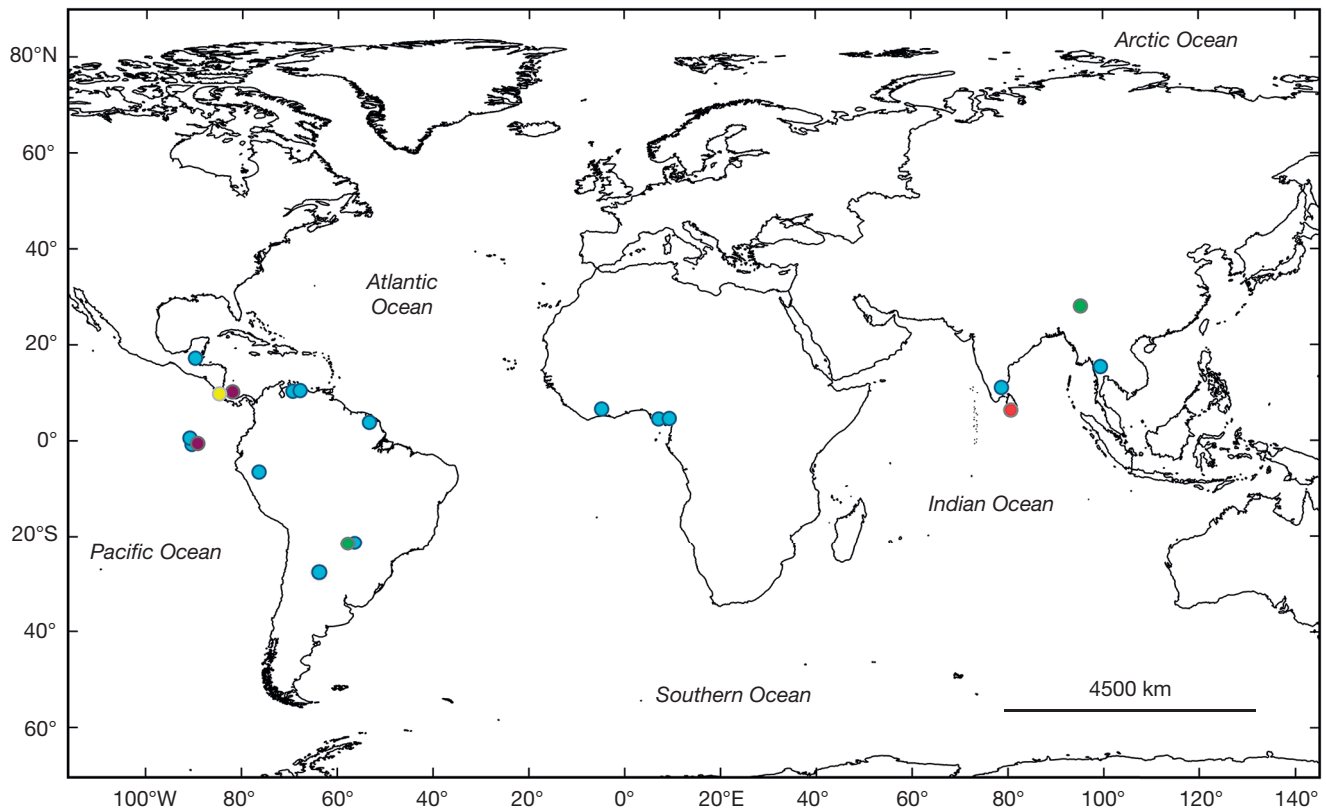


FIG. 1. — Geographic distribution of *Schistophoron* Stirt. species. The yellow dot ● corresponds to *S. aurantiacum* Aptroot & Sipman; the green dots ● to *S. indicum* Kr.P.Singh & Swarnalatha; the blue dots ● to *S. tenue* Stirt.; the red dot ● to *S. muriforme* Weerakoon & Aptroot; the violet dots ● to *S. variabile* Tibell.

(Aptroot & Sipman 2007). This is the only known species in the genus with lichexanthone, and the only one with an anthraquinone.

Schistophoron indicum Kr.P.Singh & Swarnalatha

Lichenologist 43 (3): 209 (2011). — Type: India. Arunachal Pradesh: East Siang district, Gette Basti, alt. c. 500–700 m, 8.I.1983, K.P. Singh 2858 (holo-, BSA[BSA]; iso-, ASSAM [ASSAM]), fide Singh & Swarnalatha (2011).

SPECIMEN EXAMINED. — **Brazil.** Mato Grosso Do Sul: Porto Murinho, Fazenda Paleati, 21°34'56.02"S, 57°46'44.93"W, 95 m elev., corticolous, on tree trunk, footpath edge, open forest, slightly shaded, 21.IX.2011, A.A. Spielmann *et al.* 9546 (CGMS).

KNOWN DISTRIBUTION. — Previously reported from East India (Singh & Swarnalatha 2011). Is the first report from Brazil.

MORPHOLOGY

Thallus

Crustose, greyish, rimose, strongly farinose, ecorticate, lacking prothallus; photobiont *Trentepohlia*.

Ascomata

Elliptical to lirelliform, sessile, not constricted at the base, concolorous with the thallus to pale yellow, unbranched to very occasionally furcate, curved to flexuous when lirelliform, 0.5–2.0 mm long, 0.3–0.6 mm wide, 0.25–0.4 mm high; with obtuse ends.

Disc

Slit-like, sometimes narrowly open, black due to the accumulation of ascospores in the upper part of hymenium.

Excipulum

Well developed, non-carbonized, orange, dark brown laterally towards inner side, 50–80 µm thick at base, 80–110 µm thick laterally.

Labia

Convergent, entire, covered by thalline margin.

Hymenium

Hyaline, not interspersed, I-, 50–70 µm high; paraphyses and asci disintegrating with age and only an ascospore mass remain in the upper part of the hymenium.

Subhymenium

Hyaline to yellowish, 12–20 µm high.

Paraphyses

Unbranched, not capitate, with 6–8 septa, c. 2.0 µm wide.

Asci

Clavate.

Ascospores

Eight per ascus, uniseriate, brown to dark brown, bilocular to tetralocular-submuriform, distoseptate, with 1 transverse

TABLE 1.— Characters of taxonomic importance in the *Schistophoron* Stirt. species.

Character	<i>S. aurantiacum</i>	<i>S. indicum</i>	<i>S. muriforme</i>	<i>S. tenue</i>	<i>S. variabile</i>
Thallus	White with orange hue	White or gray	Pale yellowish white	White	White
Prothallus	Orange-brown	Absent	Diffuse, brown	Marrom	Marrom
Ascomata	Elliptical to shortly lirelliform, not constricted at base, with orange pruina	Elliptical to lirelliform, not constricted at base, without pruina	Elliptical or lirelliform or branched, without pruina	Elliptical to shortly lirelliform, constricted at base, without pruina	Sub-circular to elliptical, not constricted at base, without pruina
Ascospores	Ellipsoid. Transversely septate (1 septum), 10.0-12.0 × 5.0-7.0 µm	Ellipsoid to subglobose. Transversely septate (1 septum) to submuriform (1 × 1 septate), (6.0-7.0-9.0-(10.0) × 6.0-8.0 µm	Globose to ellipsoid. Muriform (3-7 × 2-4-septate), 15.0-30.0 × 15.0-18.0 µm	Ellipsoid to occasionally subglobose. Submuriform (3 × 1 septate), (11.0-)12.0-15.0 × 6.0-8.0 µm	Ellipsoid. Transversely septate (2-3 septa), 11.0-14.0 × 6.0-7.0 µm
Chemistry	Lichexanthone and anthraquinones	Norstictic and Stictic acid (major)	Psoromic acid	Norstictic and Stictic acid (major)	No secondary substances were identified

and 1 longitudinal incomplete to complete septum, ellipsoid when bilocular and subglobose when tri- or tetralocular-submuriform, I-, (6-)7-9(-10) × 6-8 µm, walls *c.* 1.0 µm thick, smooth, with lenticular to spherical lumina.

Pycnidia
Absent.

CHEMISTRY

Thallus K+ yellow, C-, KC-, P+ strong yellow, UV-. Ascomata K+ yellow, C-, KC-, P+ orange, UV-. Norstictic stictic and peristictic acids (major); hypoconstictic and/or cryptostictic and substictic acids (minor).

NOTES

Schistophoron indicum has a white or grey thallus, sessile and elliptical to lirelliform ascomata (Fig. 2A), and small, dark brown, ellipsoid to subglobose, bilocular to tetralocular-submuriform (1 transverse and 1 longitudinal incomplete to complete septum) ascospores (Fig. 2B).

In morphological and chemical characters *S. indicum* closely resembles *S. tenue* which has smaller (0.4-0.9 mm long × 0.3-0.5 mm wide) ascomata with constricted base (Fig. 2C); larger (11.0-15.0 × 6.0-8.0 µm) submuriform (2-3 transverse and 1-2 longitudinal septa) ascospores (Fig. 2D) with reticulate ornamentation on their walls at maturity (Singh & Swarnalatha 2011).

Schistophoron muriforme Weerakoon & Aptroot

Phytotaxa 280 (2): 158 (2016). — Type: Sri Lanka. Morningside: on bark of tree, 24.IV.2015, *G. Weerakoon Mo12A* (holo-, PD[PD]; iso-, F[F]), fide Weerakoon & Aptroot (2016).

NOTES

Schistophoron muriforme has a pale yellowish to white thallus with a diffuse brown prothallus, sessile, elliptical or lirelliform or branched ascomata, globose to ellipsoid, large (15.0-30.0 ×

15.0-18.0 µm) muriform (3-7 × 2-4 septate) ascospores, and contains psoromic acid (Weerakoon & Aptroot 2016).

Schistophoron muriforme is the only known species in the genus that produces psoromic acid and has muriform ascospores. Known distribution: Only known from Sri Lanka (Weerakoon & Aptroot 2016).

Schistophoron tenue Stirt.

Report and Transactions of the Glasgow Society of Field Naturalists 4: 165 (1876). — Type: West Africa. Bonny River: *Grant s.n.*, fide Tibell (1996).

SPECIMEN EXAMINED. — **Brazil.** Mato Grosso Do Sul: Jardim, Camping Seu Assis, 21°25'14.2"S, 56°23'16.7"W, 230 m elev., corticolous, in riparian forest, Prata river, more or less shaded, 04.VI.2010. *A.A. Spielmann et al.* 5368 (CGMS).

KNOWN DISTRIBUTION. — Previously reported in Africa from Cameroon [wrongly reported as Nigeria by Tibell (1981)], Ivory Coast (Tibell 1981) and Nigeria (Stirton 1876), in America from the Galápagos Islands (Weber 1976, 1981, 1986; Elix & McCarthy 1998), French Guiana, Guatemala (Tibell 1996), Argentina (Ferraro & Michlig 2011), Peru and Venezuela (Tibell 1982), and in Asia from India (Awasthi 1991). It is the first report from Brazil.

MORPHOLOGY

Thallus

Crustose, white, rimose, slightly farinose, ecorticate with brown prothallus, photobiont *Trentepohlia*.

Ascomata

Elliptical to shortly lirelliform, sessile, constricted at the base, concolorous with the thallus to yellow pale, simple to occasionally furcate, curved to flexuous when shortly lirelliform, 0.4-0.9 mm long, 0.3-0.5 mm wide, 0.3-0.6 mm high, with obtuse ends.

Disc

Slit-like, sometimes narrowly open, black due to the accumulation of ascospores in the upper part of hymenium.

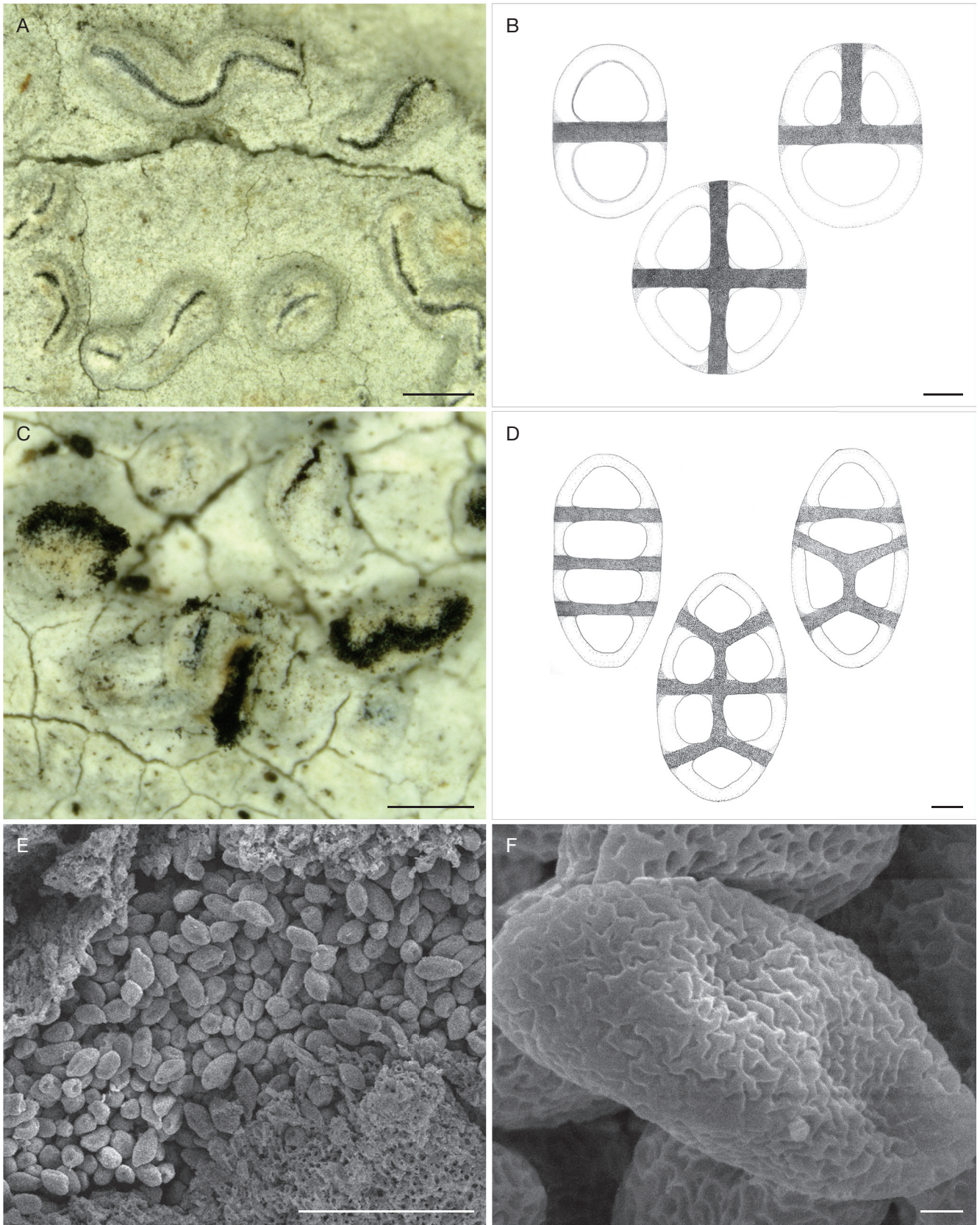


FIG. 2. — **A, B**, *Schistophoron indicum* Kr.P.Singh & Swarnalatha (Spielmann *et al.* 9546): **A**, ascomata; **B**, ascospores, shape and septation. **C-F**, *Schistophoron tenue* Stirt. (Spielmann *et al.* 5368): **C**, ascomata; **D**, ascospores, shape and septation; **E**, scanning electronic photo of a mazedium; **F**, scanning electronic photo of ornamented ascospore. Scale bars: A-C, 0.5 mm; B-D, 2 μ m; E, 50 μ m; F, 1 μ m.

Excipulum

Well developed, non-carbonized, yellow, dark brown laterally towards inner side, 100-125 µm thick at base, 80-110 µm thick laterally.

Labia

Convergent, entire, covered by thalline margin.

Hymenium

Hyaline, not interspersed, I-, 60-75 µm high; paraphyses and asci disintegrating with age and only a mass of ascospores remain in the upper part of hymenium.

Subhymenium

Hyaline to pale yellow, 20-25 µm high.

Paraphyses

Unbranched, not capitate, septate, *c.* 2.0 µm thick.

Asci

Narrowly clavate.

Ascospores

Eight per ascus, uniseriate, brown to dark brown, submuriform, with 3 transverse and 1 longitudinal incomplete to complete septum, ellipsoid to occasionally subglobose, I-, (11-)12-15 × 6-8 µm, walls *c.* 1.0 µm thick reticulately ornamented at maturity, with lenticular to spherical lumina.

Pycnidia

Absent.

CHEMISTRY

Thallus K+ yellow, C-, KC-, P+ strong yellow, UV-. Ascomata K+ yellow, C-, KC-, P+ orange, UV-. Norstictic stictic; hypoconstictic and/or cryptostictic, and peristictic acids (major); hyposalazinic, connorstictic and menegaz-
ziaic acids (minor).

NOTES

Schistophoron tenue has a white thallus, sessile and elliptical to shortly lirelliform ascomata constricted at the base and ellipsoid to occasionally subglobose and submuriform (3 transverse and 1 longitudinal incomplete to complete septa) ascospores with ornamented walls (SEM) (Fig. 2F).

A closely allied species, *S. variabile* differs from *S. tenue* in having less elevated ascomata (0.15-0.25 mm), lacking constriction at the base and smaller ascospores (11.0-14.0 × 6.0-7.0 µm) with 2-3 transverse septa and smooth walls (Tibell 1982, 1996).

Schistophoron variabile Tibell

Lichenologist 14 (4): 242 (1982). — Type: Costa Rica. Prov. Limón: 1 km north-west of Pto. Limón, 10°00'N, 83°02'W, on coconut palms in rather open stand close to the shore, 1979, *Tibell 8514* (holo-, UPS[UPS]), fide Tibell (1982).

KNOWN DISTRIBUTION. — Reported from Costa Rica and the Galapagos Islands (Tibell 1982, 1996).

NOTES

Schistophoron variabile has a white thallus with brown prothallus, sessile and subcircular to elliptical ascomata, ellipsoid, 2-3 transversely septate ascospores with smooth walls and absence of secondary substances (Tibell 1982, 1996).

DISCUSSION

This study shows the need for more lichenological exploration in Brazil. Until now, the genus *Schistophoron* was unknown in the country, although it was found in several Neotropical countries. Here we are reporting two species from Mato Grosso do Sul State alone. Consequently, the genus can be expected in other Brazilian states. The discovery of *S. indicum* in Brazil is particularly surprising because this species was previously known only from India.

KEY TO THE SPECIES OF SCHISTOPHORON

1. Ascospores muriform, ≥15.0 µm long; psoromic acid present *S. muriforme* Weerakoon & Aptroot
— Ascospores transversely septate or submuriform, ≤15.0 µm long; psoromic acid absent 2
2. Ascospores transversely septate; lichexanthone present or secondary substances absent 3
— Ascospores transversely septate to submuriform; stictic and norstictic acid present 4
3. Ascospores transversally 1-septate; lichexanthone present; ascomata orange pruinose; prothallus orange-brown *S. aurantiacum* Aptroot & Sipman
— Ascospores transversally 2-3 septate; secondary substances absent; ascomata epruinose; prothallus brown
..... *S. variabile* Tibell
4. Ascomata constricted at the base, 0.4-0.9 mm long, 0.3-0.6 mm high; ascospores 11-15 × 6-8 µm, submuriform (2-3 transverse and 1 longitudinal septa) *S. tenue* Stirt.
— Ascomata not constricted at the base, 0.5-2.0 mm long, 0.25-0.4 mm high; ascospores submuriform (1 transverse and 1 longitudinal septum), (6-)7-9(-10) × 6-8 µm *S. indicum* Kr.P.Singh & Swarnalatha

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