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Taxonomy and systematics

New records of *Tulostoma* (Agaricales: Agaricaceae) from Mexico

Nuevos registros de Tulostoma *(Agaricales: Agaricaceae) de México*

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Abstract

Tulostoma australianum is reported for the first time from the Mexican mycobiota, while *T. dumeticola*, *T. macrocephalum* and *T. wrightii* are recorded for the second time from Mexico. All of the studied species are poorly known worldwide, and more knowledge about their morphological variability and distribution is required. Species descriptions, photographs of basidiomes, as well as micrographs of spores and capillitium are presented. *Tulostoma exitum*, *T. operculatum*, and *T. puncticulosum* are discarded from Mexican mycobiota because these species are synonyms.

Keywords: Chorology; Gasteroid fungi; Taxonomy

Resumen

Tulostoma australianum se registra por primera vez para la micobiota mexicana, mientras que *T. dumeticola*, *T. macrocephalum* y *T. wrightii* se documentan por segunda vez para México. Las especies estudiadas se conocen poco en el mundo y requieren un mejor conocimiento sobre su variabilidad morfológica y distribución. Se presenta la descripción de las especies, fotografías de basidiomas, así como microfotografías de esporas y capilicio. *Tulostoma exitum*, *T. operculatum* y *T. puncticulosum* se descartan para México por ser especies sinónimas.

Palabras clave: Corología; Hongos gasteroides; Taxonomía

Introduction

Sonora ranks fifth of 32 states of the Mexican Republic in fungal diversity with 618 species (Aguirre-Acosta, Ulloa, Aguilar, Cifuentes, & Valenzuela, 2014), of which about 210 belong to gasteroid and secotiod fungi; being the genus *Tulostoma* Pers. the most diverse and representative (Esqueda et al., 2010). Currently, 26 species and a variety of this genus have been reported from Sonora. Some of them are very common worldwide (e.g. *T. fimbriatum* Fr.); others are mainly distributed in arid zones (e.g. *T. xerophilum* Long, *T. albicans* V.S. White, *T. obesum* Cooke & Ellis). Some species are rare in Mexico, found only in Sonora (e.g. *T. cyclophorum* Lloyd, *T. longii* Lloyd, *T. membranaceum* Long & Ahmad); while others, such as *T. gracilipes* J. E. Wright and *T. portoricense* J. E. Wright, are found only in their holotype localities and in Sonora (Esqueda, Pérez-Silva, Herrera, Altés, & Moreno, 1998; Esqueda, Moreno, Pérez-Silva, Sánchez, & Altés, 2004; Hernández-Navarro, Gutiérrez, Barredo-Pool, & Esqueda, 2015; Piña-Páez, Esqueda, Altés, & Gutiérrez, 2010).

As part of a major research, we studied all *Tulostoma* collections from Sonora deposited in the macromycetes collection of Universidad Estatal de Sonora. Doing so, we found some unidentified specimens, some mixed collections and some specimens that did not match the original description, resulting in new records for the Sonoran and Mexican mycobiota.

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Materials and methods

Specimens were collected in 8 localities and 5 vegetation types from Sonora, Mexico (Table 1). The studied material is preserved in the collection of macromycetes of Universidad Estatal de Sonora, Unidad Hermosillo, Mexico (UES). Basidiomes were characterized and conserved following conventional mycological techniques. Keys in parentheses after colours in basidiomata descriptions follow the Methuen Handbook of Colour (Kornerup & Wanscher, 1978). Microscopic features were measured mounting gleba sections in temporary preparations with KOH 10% solution using an OLYMPUS BX-51 Light microscope (LM). One hundred spores including ornamentation, capillitia and septa were randomly measured from different basidiomes per species, and the mean and standard deviation were calculated. All the measurements were taken with the software INFINITY Analyzer. Scanning electron microscope (SEM) micrographs were produced with a JEOL-JSM 600LB microscope, using the critical point drying, and sputtered with gold–palladium.

Descriptions

Tulostoma australianum *Lloyd, Mycol. Writ. (7): 20 (1906)*
Figures 1–3

Spore sac robust, globose-depressed, variable in size from 13 up to 25.5 mm, average 18 mm diam. Exoperidium membranous, partially covered by a layer of soil, falling off in scales, persistent in the base. Endoperidium subsmooth, yellowish white to ochraceous (3A2–5A4). Mouth fibrillose with a simple torn aperture. Socket conspicuous in most of the specimens, but partially to fully appressed in a few of them, 5–8 mm diam, but up to 12 mm in the larger basidiomes, deep, quite separated from the endoperidium, with an entire or lacerated membrane. Gleba ferruginous to light brown (7E5–7E8). Stem straight to slightly curved, attenuating at the base, 16–45 mm length and 4–7.6 mm wide, brown to reddish (7F8–8F8), ending basally in a volvoid structure. The stipe seems to be easily separated from the stem and missing in some of our collections. Spores yellowish, globose, wall thickness 0.60 ± 0.03 μm, asperulate to verrucose under LM, (3.3) 4.2–4.9 (5.8) μm diam [$x = 4.7 \pm 0.4 \times 4.6 \pm 0.4$ μm, $Q_m = 0.99$ ($n = 100$)]; under SEM, the ornamentation appears as small, low, dense and appressed warts. Capillitium hyaline, septate, thick-walled 1.56 ± 0.16 μm, lumen visible to almost solid, 3–5.6 μm diam [$x = 3.9 \pm 0.8$ μm]. Septa somewhat swollen of 4–8.3 μm diam [$x = 5.1 \pm 1.3$ μm].

Taxonomic summary

The Mexican material consists of 10 basidiomes. Mexico, Sonora, Municipality of Pitiquito, km 158 Road 36 north to Puerto Libertad, August-29-1998, A. Núñez & M. Esqueda (UES 4485). Mexico, Sonora, Municipality of Gral. Plutarco Elías Calles, El Papalote, April-26-2004, I. Encinas & J. Miranda (UES 5156); October-29-2011, M. Esqueda, M. Coronado, & M. Lizárraga (UES 10289); km 4.2 Crater El Colorado-Biological Station road, October-28-2011, M. Esqueda, M. Coronado, & M. Lizárraga (UES 10276).

Distribution. Australia, Ecuador, United States, South Africa, Mexico.

Remarks

According to Wright (1987), this is an ill-defined species due to the doubtful nature of the mouth, but also considered that the spore ornamentation and larger basidiome are diagnostic characters of the species. We consider it is a distinctive species by the combination of the following characteristics: large basidiome, fibrillose to undefined mouth, membranous exoperidium and warty spores. It might be confused with *T. obesum*, but the latter has ochraceous capillitium and entirely smooth dark spores. It can also be confused with *T. macrocephalum* Long (see discussion below). This is a new record for Mexico. It was collected in 3 different municipalities and types of vegetation, including mezquital, microphyllous desert scrub, and sandy desert vegetation. The latter from El Pinacate and Gran Desierto de Altar biosphere reserve, where larger and gregarious basidiomes were collected. Specimens from United States were annotated as doubtful, and their revision is needed.

Tulostoma dumeticola *Long, Lloydia 10: 117 (1947)*
Figures 4–6

Spore sac subglobose to globose-depressed, 4–8.2 mm diam. Exoperidium conformed by a thin layer of hyphae intertwined with debris and forming small dark brown patches similar to verrucae, not visible to the naked eye, falling off in the upper portion of spore-sac. Endoperidium subsmooth, velvety, tan to dark brown (6F4–6F7). Mouth circular, 1–1.5 mm diam, hardly projecting < 0.5 mm. Socket inconspicuous of 1.5–2.6 mm diam, with a membrane irregularly dentate. Gleba light ferruginous (6B6). Stem not entirely straight, reddish to dark brown (8F8–6F7), striate, up to 50 mm length but more commonly 10–20 mm, 1.2–1.6 mm wide, with a volvoid structure, strongly mixed with debris. Exoperidium and endoperidium presenting fascicles of hyphae resembling mycosclereids, thick-walled >1 μm and dark coloured, variable in shape and size, some slightly branched. Spores globose, yellowish to ochraceous, wall thickness 0.64 ± 0.07 μm, conspicuously spiny, some anastomosed under LM; under SEM, the spines are straight to slightly curved or digitiform, irregularly anastomosed to subreticulated, 4.5–6.4 μm diam [$x = 5.2 \pm 0.5 \times 5.2 \pm 0.4$ μm, $Q_m = 1$ ($n = 100$)]. Capillitium hyaline to slightly coloured, 3.6–5.4(8) μm diam [$x = 4.2 \pm 1.2$ μm], branched, septate, wall thickness 0.86 ± 0.14 μm, lumen visible to solid, sometimes lacunar, swollen at the more pigmented septa of 4–6.2 μm diam [$x = 4.6 \pm 0.8$ μm].

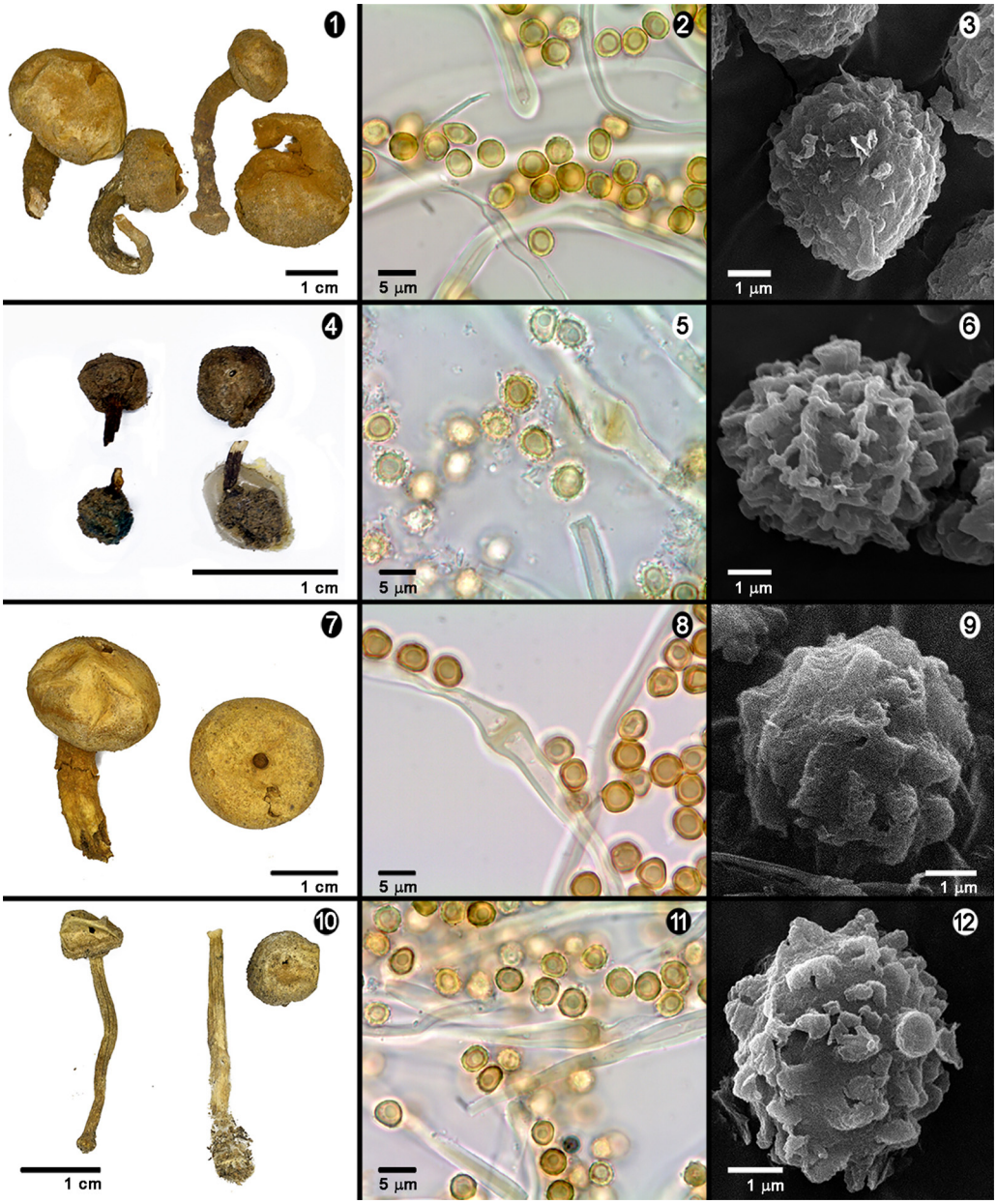
Taxonomic summary

The Sonoran material consisted of 4 complete basidiomes. Mexico, Sonora, Municipality of Álamos, El Encinal, September-14-1997, M. Esqueda (UES 3384). Mexico, Sonora, Municipality of San Javier, km 151 Hermosillo to Yécora road, August-25-1998, A. Armenta & M. Esqueda (UES 4253); km

Table 1
Studied localities and vegetation type.

Locality	N	W	Vegetation	Elevation (m asl)
1. Municipality of Pitiquito, km 158 Road 36 north to Puerto Libertad, Sonora, Mexico	29°52′45.00″	112°38′14.00″	MDS	28
2. Municipality of General Plutarco Elías Calles, El Papalote, Sonora, Mexico	31°55′48.00″	113°01′48.00″	M	318
3. Municipality of Álamos, El Encinal, Sonora, Mexico	26°58′10.00″	108°59′00.00″	OF	1,492
4. Municipality of San Javier, km 151 Hermosillo to Yécora road, Sonora, Mexico	28°34′32.98″	109°40′55.00″	TDF	715
5. Municipality of San Javier, km 137 Hermosillo to Yécora road, Sonora, Mexico	28°34′34.00″	109°46′42.00″	TDF	498
6. Municipality of Hermosillo, El Crucero, Sonora, Mexico	28°49′50.62″	111°42′55.01″	M	21
7. Municipality of Cumpas, El Mezquital, Sonora, Mexico	29°57′26.64″	109°38′23.36″	M	819
8. Municipality of General Plutarco Elías Calles, km 4.2 Crater El Colorado-Biological Station road, Sonora, Mexico	31°53′31.40″	113°17′39.01″	SDV	200

Type of vegetation: tropical deciduous forest (TDF); microphyllous desert scrub (MDS); mezquital (M); oak forest (OF); sandy desert vegetation (SDV).



Figures 1–12. 1–3: *Tulostoma australianum* (UES 10276). 1, Basidiocarps; 2, capillitium and spores under LM; 3, spores by SEM. 4–6: *Tulostoma dumeticola* (UES 4275); 4, basidiocarps; 5, capillitium and spores under LM; 6, spores by SEM; 7–9, *Tulostoma macrocephalum* (UES 1612b): 7, basidiocarps; 8, capillitium and spores under LM; 9, spores by SEM. 10–12, *Tulostoma wrightii* (UES 5608): 10, basidiocarps; 11, capillitium and spores under LM; 12, spores by SEM.

137 Hermosillo to Yécora road, August-25-1998, A. Armenta & M. Esqueda (UES 4275).

Distribution. Brazil, Uruguay, Argentina, Costa Rica, Mexico (Baja California, Sonora).

Remarks

This species is characterized by its brown endoperidium, circular stoma, warty exoperidium, and digitiform spines on spores, which can coalesce. The presence of mycosclereids is not a common feature in the genus; some other species also presenting them are: *T. squamosum* (J. F. Gmel.) Pers., that differs by a larger basidiome, and echinulated spores with conic spines without coalescence; *T. cycophorum*, that presents scutelated mouth, truly membranous exoperidium, smaller spores (3.5–4.5 μm diam) which has anastomosed verrucae, not spines; and *T. exasperatum* Mont., that has lignicolous habit, conspicuous verrucose exoperidium and truly reticulated spores. This species was cited for Mexico by Calonge, Guzmán, Ramírez-Guillén, & Gándara (2007), and it is a new record from Sonora where was found in oak forest and tropical deciduous forest.

Tulostoma macrocephalum *Long, Mycologia 36(4): 337 (1944)* Figures *7–9*

Spore sac large, globose to globose-depressed, up to 22 mm diam, easily separable from stem. Exoperidium hyphal, forming an agglutinated layer of sand and hyphae that wears off. Endoperidium almost white (2A2), smooth, pale yellowish with weathering (4A4). Mouth circular, up to 3.8 mm diam, not projecting or slightly so <1 mm. Socket conspicuous, up to 10 mm diam, separated from the stem, with an entire membrane irregularly denticulate. Gleba ferruginous to brown (7E5–7F8). Stem up to 40 mm long and 7 mm wide, squamous or striated, deep yellow to oxid yellow (4A8–5C7), tapering towards the base, where exhibits a large volvoid structure. Spores globose to elliptic, wall thickness 0.61 ± 0.06 μm, verrucose under LM, coloured, 4.3–5.6(6) μm diam [$x = 4.9 \pm 0.4 \times 4.8 \pm 0.4$ μm, $Q_m = 0.97$, ($n = 100$)]. Under SEM, the ornamentation appears formed by uneven, appressed tubercles or verrucae varying in size, some anastomosed. Capillitium hyaline to slightly coloured, 3–5 μm diam [$x = 4.1 \pm 0.3$], thick-walled 1.03 ± 0.17 μm, lumen visible in some, but solid in most, disarticulated, scarcely swollen, hyaline to slightly coloured septa 3.3–8.7 μm diam [$x = 5.3 \pm 1.1$].

Taxonomic summary

The Sonoran material consisted of 2 spore sacs with fragmented stipes. Mexico, Sonora, Municipality of Hermosillo, El Crucero, August-3-1994, *leg.* G. Yañez & J. Jiménez (UES 1612b).

Distribution. United States, Argentina, Spain, Mexico.

Remarks

This is a distinct species due to larger basidiome, circular stoma, hyphal exoperidium and verrucose spores. This species was mixed with *T. obesum*, from which differs by its membranous exoperidium and smooth spores. It could also be confused with *T. australianum*, but the latter has undefined to fibrillose stoma, and verrucose spores, which are very different under SEM. Also, spore ornamentation showed high variability under SEM, fine-meshed, verrucose, tuberculate-nodulose, perhaps due to maturity, weathering or environmental stress. Moreno, Altés, Ochoa, and Wright (1995) cited this species from Baja California, Mexico. This is a new record for Sonoran mycobiota observed in mezquital vegetation.

Tulostoma wrightii *Berk., Grevillea 19(92): 95 (1891)* Figures *10–12*

Spore sac globose-depressed, up to 10 mm diam, exoperidium thinly membranous to submembranous. Endoperidium almost white to cream colour (1B1–2A2). Mouth fibrillose-dentate to undefined. Socket conspicuous up to 3.8 mm diam, slightly appressed to the stem. Gleba ferruginous to light brown (7E5–7E8). Stem up to 34 mm long and 3.8 mm thick, pale yellow to wood colour (4A2-5A3), rugose to striated, ending in a small volvoid structure strongly mixed with debris. Spores globose to subglobose, wall thickness 0.51 ± 0.03 μm, verrucose under LM, 3.5–5 μm diam [$x = 4.1 \pm 0.3 \times 4.1 \pm 0.3$, $Q_m = 1$, $n = 100$]. Under SEM, the ornamentation appears formed by low, uneven verrucae, smaller ones can be seen between the larger ones, sometimes partly anastomosed. Capillitium hyaline, 2–5(8) μm diam [$x = 3.4 \pm 0.8$] some appear ribbon-like, scantily septate and branched, thick-walled 1.14 ± 0.20 μm, solid lumen, scarce septa, slightly swollen and yellowish [$x = 5.5 \pm 1.2$ μm ($n = 50$)].

Taxonomic summary

The Sonoran material consisted of 2 complete basidiomes and 2 spore-sacs. Mexico, Sonora, Municipality of Cumpas, El Mezquital, May-25-2005, A. Sánchez, M. Rivera, & S. Gómez (UES 5608).

Distribution. United States, Mexico.

Remarks

This species is recognized by the fibrillose mouth, submembranous exoperidium and irregularly verrucose spores. It is a poorly known species, which needs more revision. We decided to keep this identification because of its clear differences with others Sonoran taxa. According to Wright (1987), this species is similar to *T. meridionale* J. E. Wright, but differs by presenting larger spores (6.5–8 μm diam) and a circular mouth. This species was cited from Chihuahua, Mexico by Pérez-Silva and Aguirre-Acosta (1986), but description, studied material and photographs were not included.

Discussion

We had previously cited 26 species and a variety of *Tulostoma* for Sonora, Mexico (Esqueda et al., 2010). Later, we cited *T. gracilipes*, *T. longii*, *T. membranaceum*, and *T. subsquamosum* Long & Ahmad (Hernández-Navarro et al., 2015; Piña-Páez et al., 2010; Piña-Páez, Esqueda, Gutiérrez, & González-Ríos,

2013). After our review of the existing collections, we discarded 4 species: *T. exitum* Long & Ahmad, *T. operculatum* Long & Ahmad, and *T. punticulosum* Long & Ahmad, which were synonymized with *T. submembranaceum* (Moreno et al., 1995) and *T. leiosporum* R. E. Fr. (Moreno, Altés, Ochoa, & Wright, 1997). We also discarded *T. subsquamosum*, because it did not match the original description (Altés, Moreno, & Wright, 1996; Calonge, Llimona, & Martín, 2011), remained thus undetermined. With the description of 4 new records herein, the number of *Tulostoma* species known from Sonora reaches 30. Index Fungorum includes 155 species; thus, in Sonora inhabits about 20% of the known species worldwide.

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