# Morphological and molecular identification of three new species of Tomentella from Finland

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Short title: New *Tomentella* from Finland

# Morphological and molecular identification of three new species of *Tomentella* from Finland

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**ABSTRACT**

Three new species of *Tomentella* (Thelephorales) from Finland, *T. globosa*, *T. lammiensis* and *T. longisterigmata*, are described and illustrated with morphological characteristics and nuc rDNA ITS1-5.8S-ITS2 sequences (ITS). *T. globosa* is characterized by mucedinoid, pale to dark brown basidiocarps adherent to the substrate, generative hyphae with clamps and rarely with simple septa and echinulate globose basidiospores (echinuli up to 1.5 μm long). *T. lammiensis* is characterized by mucedinoid, oxide yellow to golden brown basidiocarps separable from the substrate, generative hyphae with clamps and echinulate ellipsoid, triangular or lobbed basidiospores (echinuli up to 2 μm long). *T. longisterigmata* is characterized by mucedinoid, dark brown to chestnut basidiocarps separable from the substrate, generative hyphae clamped and rarely with simple septa, the long basidial sterigmata (7–11 µm long) and echinulate globose basidiospores (echinuli up to 2 µm long). An absence of rhizomorphs and cystidia is their common morphological feature. Molecular analyses by maximum likelihood, maximum parsimony and Bayesian analysis confirm the phylogenetic position of these three new species. The discriminating characters of these new species and their closely related species are discussed in this study. A key to the species from Finland is provided in order to facilitate future studies of the genus.

**KEY WORDS:** ITS, phylogeny, taxonomy, Tomentelloid fungi

## INTRODUCTION

The genus *Tomentella* Pers. ex Pat. belongs to Thelephoraceae, Thelephorales, Basidiomycota. Species of this genus usually grow on fallen wood, leaf litter, soil and other substrates and form a cottony or spider web-like reproductive structure on them (Larsen 1974; Kõljalg 1996; Erland and Taylor 1999; Tedersoo et al. 2003). Current evidence suggests that the genus *Tomentella* is composed by exclusively mycorrhizal species (Erland and Taylor 1999; Jakucs et al. 2005; Kõljalg et al. 2000; Geml et al. 2012). Species of *Tomentella* can form ectomycorrhiza with different plant hosts and receive energy from their host plants and transport nutrients to their hosts (Danielson et al. 1984; Erland and Taylor 1999; Tedersoo et al. 2003; Jakucs and Erős-Honti 2008) and they are of great ecological importance as ectomycorrhiza formers in temperate and tropical forests (Gardes and Bruns 1996; Erland and Taylor 1999; Haug et al. 2005; Jakucs et al. 2015; Kuhar et al. 2016).

The genus *Tomentella* is characterized by an annual habitat, resupinate and arachnoid, mucedinoid, crutose or pelliculose basidiocarps, which are separable from or adherent to the substrate; white, reddish brown, yellow or green hymenophore; smooth, granulose, colliculose or hydnoid hymenophoral surface; the monomitic or dimitic hyphal system with clamped or simple septate generative hyphae; the monomitic or dimitic hyphal cords present in subiculum and margins or absent; cystidia absent or arising from subhymenial hyphae or subicular hyphae; thick- or thin-walled, triangular, lobed, ellipsoid, subglobose to globose basidiospores with echinulate or bifurcate ornamentation (Larsen 1966; 1968; 1974; Kõljalg 1996).

*Tomentella* was reported to be widely distributed in the world in places such as Eurasia (Larsen 1998), North America (Alvarez-Manjarrez et al. 2015), South America (Haug et al. 2005; Kuhar et al. 2016), India (Thind and Rattan 1971), Korea (Jung 1994), West Africa (Yorou and Agerer 2008; Yorou et al. 2012), Australia (Agerer et al. 2001) and so on. The descriptions of the genus were based mainly on morphological characteristics before 2000, and mycologists may not distinguish closely related species that have limited characteristic differences. In the recent decades most species of the genus were described on the basis of rDNA sequence analyses combining with morphological characteristics descriptions. Morphological and phylogenetic analyses have provided more accurate identification for distinguishing the closely related species.

There are many studies on species diversity and taxonomy of *Tomentella* reported in Europe, while systematic collection, genetic diversity researches and classification of this species is still scarce in Finland at present, and approximately 23 species were recorded (Kotiranta et al. 2009; Kunttu et al. 2012; Kunttu et al. 2015; Kuhar et al. 2016). However, three species, *T. crinalis* (Fr.) M.J. Larsen, *T. ferruginea* (Pers.) Pat. and *T. fibrosa* (Berk. & M.A. Curtis) Kõljalg, were translocated to *Odontia* Pers. according to the recent phylogenetic and the stable isotopes study (Tedersoo et al. 2014). Thus, 20 species of *Tomentella* were recorded. In 2016, several investigations of wood-inhabiting fungi in Finland were carried out, and dozens of *Tomentella* specimens were collected from the forests surrounding Lammi Biological Station of Helsinki University. The forests are mainly dominated by coniferous trees such as *Larix* spp., *Picea* spp., *Pinus* spp., and a small number of broad-leaved trees are scattered in the forests. During the study of these specimens, three undescribed species were found using morphological characters and phylogenetic analyses of internal transcribed spacer (ITS) sequences. Here we described them as new species.

## MATERIALS AND METHODS

*Morphological studies*.—The studied specimens were deposited at the herbarium of Institute of Applied Ecology, Chinese Academy of Sciences (IFP). The microscopic procedures followed He and Dai (2012). Microscopic drawings were made with the aid of a drawing tube. Microscopic measurements were made from slide preparations stained with cotton blue and Melzer’s reagent. Cotton blue: 0.1 mg aniline blue dissolved in 60 g pure lactic acid; Melzer’s reagent: 1.5 g KI (potassium iodide), 0.5 g I (crystalline iodine), 22 g chloral hydrate, distilled water 20 mL. The following abbreviations were used in the text: KOH = 5% potassium hydroxide, IKI = Melzer’s reagent, IKI– = neither amyloid nor dextrinoid, CB = cotton blue, CB+ = cyanophilous, CB– = acyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the ratios of L/W between specimens studied, n = number of spores measured from a given number of specimens. Special color terms follow Kornerup (Kornerup and Wanscher 1981). Sections were studied at magnifications up to ×1000 using a Nikon Eclipse E600 microscope with phase contrast illumination, and dimensions were estimated subjectively with an accuracy of 0.1 μm. Special color terms are cited from Rayner (1970).

*Molecular procedures and phylogenetic analyses.*—DNA was extracted from dried herbarium specimens with a Thermo Scientific Phire Plant Direct PCR Kit (for USA Thermo Fisher Scientific) according to the manufacturer’s instructions. PCR reactions were performed in 30 μL reaction mixtures containing 15 μL of 2×Phire® Plant PCR buffer, 0.6 μL Phire® Hot Start II DNA Polymerase, 1.5 μL of each PCR primer (10 μM), 10.5 μL doubly deionized

$H_2O$, and 0.9 µL template DNA. The nuc rDNA ITS1-5.8S-ITS2 regions (ITS) was amplified with the primers ITS5 (5′ GGAAGTAAAAGTCGTAACAAGG 3′) and ITS4 (5′ TCCTCCGCTTATTGATATGC 3′) (Lang et al. 2011; Tedersoo et al. 2014), SSU1318-Tom (5′ CGATAACGAACGAGACCTTAT 3′) and LSU-Tom4 (5′ GCCCTGTTCCAAGAGACTTA 3′) (Taylor and McCormick 2008). The partial 28S regions was amplified with the primers LROR (5′ ACCCGCTGAACTTAAGC 3′) and LR3 (5′ CCGTGTTTCAAGACGGG 3′) (Jumpponen et al. 2015).

The PCR thermal cycling program condition was set as follows: initial denaturation at 98 C for 5 min, followed by 39 cycles at 98 C for 30 s, × C for 30 s, 72 C for 30 s, and a final extension at 72 C for 1 min. The PCR products were sequenced at Beijing Genomics Institute (BGI), with primer ITS5 and ITS4, SSU1318-Tom and LSU-Tom4. Six ITS rDNA sequences of these three new species were deposited in GenBank NCBI. Additional ITS rDNA sequences in the dataset used to establish phylogenetic relationships were downloaded from GenBank (http://www.ncbi.nlm.nih.gov/genbank) and UNITE (https://unite.ut.ee/index.php) (TABLE 1).

The ITS sequences were used to determine the phylogenetic position of the new species. DNA sequences were aligned with MUSCLE in MEGA 7 (Kumar et al. 2016). Alignments were manually adjusted to allow maximum alignment and minimize gaps, and deposited in TreeBASE (study no. 21889). Maximum parsimony (MP), maximum likelihood (ML) and Bayesian analysis were applied to the ITS dataset. All characters were weighted, and gaps were treated as missing data. MP analyses were conducted with PAUP* version 4.0b10 (Swofford 2002). Trees were inferred by the heuristic search option with TBR branch swapping and 1,000 random sequence additions. Max-trees were set to 5000 and no-increase, branches of zero length were collapsed and all parsimonious trees were saved. Clade stability was assessed with bootstrap (BT) analyses with 1,000 replicates (Gaget et al. 2017).

Descriptive tree statistics tree length (TL), consistency index (CI), retention index (RI), rescaled consistency index (RC), and homoplasy index (HI) were calculated for all trees generated under different optimality criteria. Bayesian analysis with MrBayes 3.2.4 (Cannatella 2015) implementing the Markov chain Monte Carlo (MCMC) technique and parameters predetermined with MRMODELTEST 2.3 (Posada and Crandall 1998; Nylander 2004) were performed, and the parameters in MrBayes were set as follows: lset nst=6, rates= invgamma. Four simultaneous Markov chains were run starting from random trees, and keeping one tree every 100th generation until the average standard deviation of split frequencies was below 0.01. The value of burn-in was set to discard 25% of trees when calculating the posterior probabilities. Bayesian posterior probabilities were obtained from the 50% majority rule consensus of the trees kept. An ML tree with bootstrap support values was reconstructed with RAxML (implemented in raxmlGUI1.5b1), RAxML is currently among the fastest and most accurate programs for phylogenetic tree inference under the maximum likelihood (ML) criterion (Silvestro and Michalak 2012; Hundsdoerfer and Kitching 2017).

## RESULTS

The dataset includes six ITS sequences of the newly described species and 108 sequences of 59 other species. *Odontia fibrosa* was used as the outgroup. In the alignment of the 114 samples, the data matrix comprised 630 bp with 266 constant characters, 55 parsimony-uninformative variable characters and 309 parsimony informative positions. MP and ML analyses produced a similar topology (TL = 1842, CI = 0.318, RI = 0.697, RC = 0.221, HI = 0.682). The ML tree is shown in FIG. 1. Only bootstrap values superior to 50% are displayed on the tree figures. The same dataset and alignment was analyzed with MrBayes 3.2.4. Bayesian analysis ran 7 million generation and resulted in an average standard deviation of split frequencies = 0.007198. The Bayesian analysis yielded a topology similar to that generated by MP. In the phylogenetic tree, six sampled specimens formed three single clades with full support (100 % in ML, 100 % in MP and 1.00 BPP), and clustered in the clade that comprised most species of *Tomentella*. It confirmed the affinity of these new species in *Tomentella*. *T. globosa* and *T. longisterigmata* clustered together with strong support (100 % in ML, 98 % in MP and 1.00 BPP) and formed a clade with *T. bresadolae* with moderate support (93 % in ML, 87 % in MP and 0.99 BPP); *T. lammiensis* clustered with *T. bryophila* with strong support (86 % in ML, 94 % in MP and 0.99 BPP).

## TAXONOMY

***Tomentella globosa*** X. Lu, K. Steffen & H.S. Yuan, sp. nov. FIGS. 2–4

MycoBank MB824716

*Typification:* Finland. Lammi Biological Station, on rotten angiosperm wood debris, 14 Sep 2016, *Yuan 11603* (**holotype** IFP 19180). UNITE Accession No.

*Etymology: Globosa*: from the latin globosus, in reference to the globose basidiospores.

*Diagnosis:* Differs from *Tomentella bresadolae* in having mucedinoid basidiocarps adherent to the substrate, farinaceous sterile margin, shorter basidia and smaller basidiospores with shorter echinuli.

Basidiocarps annual, resupinate, adherent to the substrate, mucedinoid, without odor or taste when fresh, 0.5–0.8 mm thick, continuous. Hymenophoral surface granulose or smooth, pale to dark brown (6F4-6F7) and turning darker than the subiculum when dry. Sterile margin often indeterminate, farinaceous, lighter than hymenophore, pale brown.

Rhizomorphs absent.

Subicular hyphae monomitic, generative hyphae clamped and rarely with simple septa, thick-walled, 3–6 μm diam., without encrustation, pale to dark brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid. Subhymenial hyphae clamped and rarely with simple septa, thin-walled, 4–7 μm diam., without encrustation, hyphal cells short and inflated, pale or dark brown in 2.5% KOH and in distilled water, slightly cyanophilous, inamyloid.

Cystidia and cystidioles absent.

Basidia 20–55 μm long and 5–12 μm diam. at apex, 3–7 μm at base, with a clamp connection at base, utriform, not stalked, sinuous, without transverse septa, pale brown in 2.5% KOH and in distilled water, 4 sterigmata; sterigmata 4–8 μm long and 2–3 μm diam. at base.

Basidiospores slightly thick-walled, (6–)6.5–7.5(–8) × (5.5–)6–7(–7.5) μm, L = 7.05 μm, W = 6.35 μm, Q = 1.11–1.15 (n = 60/2), subglobose to globose frontal and lateral face, echinulate, yellow brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid; echinuli usually isolated, up to 1.5 μm long.

*Additional specimen examined*: Finland. Lammi Biological Station, on rotten angiosperm wood debris, 14 Sep 2016, *Yuan 11618* (**paratype** IFP 19180).

***Tomentella lammiensis*** X. Lu, K. Steffen & H.S. Yuan, sp. nov. FIGS. 5–7

MycoBank MB824717

*Typification:* Finland. Lammi Biological Station, on rotten angiosperm wood debris, 14 Sep 2016, *Yuan 11617* (**holotype** IFP 19182). UNITE Accession No.

*Etymology: Lammiensis*: in reference to the Lammi Biological Station, where the specimens were found.

*Diagnosis:* Differs from *Tomentella galzinii* in having continuous basidiocarps separable from the substrate, oxide yellow to golden brown hymenophore, thick-walled subicular hyphae and an absence of cystidia.

Basidiocarps annual, resupinate, separable from the substrate, mucedinoid, without odor or taste when fresh, 0.6–1 mm thick, continuous. Hymenophoral surface granulose or smooth, oxide yellow to golden brown (5C7-5D7) and concolorous with the subiculum when dry. Sterile margin often indeterminate, byssoid, often paler than hymenophore, pale yellowish.

Rhizomorphs absent.

Subicular hyphae monomitic, generative hyphae clamped, thick-walled, 4–7 μm diam., without encrustation, pale brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid. Subhymenial hyphae clamped, thin-walled, 5–8 μm diam., hyphal cells short and inflated, yellowish in 2.5% KOH and in distilled water, cyanophilous, inamyloid.

Cystidia and cystidioles absent.

Basidia 20–60 μm long and 5–9 μm diam. at apex, 3–6 μm at base, with a clamp connection at base, utriform, not stalked, sinuous, without transverse septa, yellowish in 3% KOH and in distilled water, 4 sterigmata; sterigmata 3–6 μm long and 2–4 μm diam. at base.

Basidiospores thick-walled, (8–)8.5–9.5(–10) × (7–)7.5–8.5(–9) μm, L = 8.12 μm, W = 7.27 μm, Q = 1.08–1.12 (n = 60/2), ellipsoid, triangular or lobed frontal and ellipsoid lateral face, echinulate, golden yellow in 2.5% KOH and in distilled water, cyanophilous, inamyloid; echinuli usually isolated, sometimes grouped in 2 or more, up to 2 μm long.

*Additional specimen examined*: Finland. Lammi Biological Station, on rotten angiosperm wood debris and broad leaf litter, 14 Sep 2016, *Yuan 11597* (**paratype** IFP 19178).

***Tomentella longisterigmata*** X. Lu, K. Steffen & H.S. Yuan, sp. nov. FIGS. 8–10

MycoBank MB824718

*Typification:* Finland. Lammi Biological Station, on rotten angiosperm wood debris, 14 Sep 2016, *Yuan 11610* (**holotype** IFP 19181). UNITE Accession No.

*Etymology: longisterigmata*: in reference to the long sterigmata of the basidia.

*Diagnosis:* Differs from *Tomentella lapida* in having basidiocarps separable from the substrate, dark brown to chestnut smooth hymenophore and an absence of Rhizomorphs.

Basidiocarps annual, resupinate, separable from the substrate, mucedinoid, without odor or taste when fresh, 0.6–1.0 mm thick, continuous. Hymenophoral surface smooth, dark brown to chestnut (6E7-6F7) and turning darker than the subiculum when dry. Sterile margin often indeterminate, byssoid, paler than hymenophore.

Rhizomorphs absent.

Subicular hyphae monomitic, generative hyphae clamped and rarely with simple septa, thick-walled, 4–7 μm diam., without encrustation, light brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid. Subhymenial hyphae clamped and rarely with simple septa, thin- to slightly thick-walled, 5–8 μm diam.; hyphal cells not short and not inflated, hyaline to light brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid.

Cystidia and cystidioles absent.

Basidia 20–55 μm long and 6–9 μm diam. at apex, 5–7 μm at base, with a clamp connection at base, utriform, not stalked, sinuous, hyaline in 2.5% KOH and in distilled water, 4 sterigmata; sterigmata 7–11 μm long and 2–3 μm diam. at base.

Basidiospores thick-walled, (7–)7.5–8.5(–9) × (6–)7–8(–8.5) μm in lateral and frontal face, L =8.03 μm, W =7.39 μm, Q = 1.05–1.09 (n = 60/2), subglobose to globose frontal and lateral face, echinulate, light brown in 2.5% KOH and in distilled water, cyanophilous, inamyloid; echinuli usually isolated, up to 2 μm long.

*Additional specimen examined*: Finland. Lammi Biological Station, on rotten angiosperm wood debris, 14 Sep 2016, *Yuan 11602* (**paratype** IFP 19179).

## DISSCUSSION

As the tree topologies of the previous studies for *Tomentella* had shown, molecular phylogenetic analyses of the ITS dataset by ML, MP and MrBayes in this study showed a low rate of support in the deeper nodes of the topology, but high support at the species level (De Smet et al. 2015; Jakucs et al. 2015; Kuhar et al. 2016). In our phylogenetic tree, *T. albomarginata* and *T. sublilacina* formed a clade with weak support. *T. albomarginata* was treated as the synonym of *T. sublilacina* in previous studies ( Kõljalg 1996; Jakucs et al. 2005), and share the similar characteristics: mucedinoid basidiocarps, smooth hymenophore and an absence of cystidia. However, *T. albomarginata* differs from *T. sublilacina* by having the dark brown to umber hymenophore and monomitic rhizomorphs (Kõljalg 1996; Larsen 1970), and we suggest that *T. albomarginata* and *T. sublilacina* should be kept as two independent species. *T. bresadolae* was reported to be a synonym of *T. stuposa* (Kõljalg 1996; Daemmrich 2006; Peintner and Dämmrich 2012), but the previous study has shown that they may represent the different species (Kuhar et al. 2016), and our molecular phylogenetic analyses showed *T. bresadolae* were distantly from *T. stuposa* again. Here we suggested to keep them as different species.

*Tomentella globosa* and *T. bresadolae* reveal a close phylogenetic relationship in the phylogenetic tree. They have globose basidiospores and some similar morphological characteristics, such as pale to dark brown, smooth hymenophore and an absence of rhizomorphs and cystidia. (Larsen 1969; Peintner and Dämmrich 2012). However, *T.*

*bresadolae* can be distinguished by having arachnoid basidiocarps separable from substrate, comparatively long-celled subicular hyphae, thin-walled subhymenial hyphae, longer basidia (55–70 µm) and thin-walled larger basidiospores (8.5–11 µm) (Larsen 1969; Daemmrich 2006; Peintner and Dämmrich 2012). Besides these, *T. globosa* also resembles *T. cinereoumbrina* and *T. fuscocinerea* mentioned in the previous paragraph from Finland, including basidiocarps adherent to the substrate, pale brown basidiospores and absence of rhizomorphs and cystidia. However, *T. cinereoumbrina* differs from *T. globosa* in having crustose basidiocarps, grey to light brown hymenophore, colorless to brown subicular hyphae, colourless to light brown subhymenial hyphae and pale brown basidiospores with triangular frontal and ellipsoid lateral face, also with short echinuli (0.4-1 µm) (Kõljalg 1996; Daemmrich 2006). The main difference between *T. fuscocinerea* and *T. globosa* is that the former has thin-walled subicular hyphae (Kõljalg 1996; Daemmrich 2006).

The main feature of *Tomentella lammi* is the oxide yellow to golden brown hymenophore that is somewhat similar to *T. galzinii* with pale brown to yellowish hymenophores. In addition, pale brown subicular hyphae and subhymenial hyphae, the absence of rhizomorphs and basidiospores with triangular or lobed frontal and ellipsoid lateral face of *T. galzinii* are quite similar to *T. lammi*, and *T. galzinii* differs from *T. lammi* by discontinuous basidiocarps, granulose or smooth hymenophore, thin-walled basidiospores and a presence of cystidia (Kõljalg 1996; Daemmrich 2006). Another special characteristic of *T.* lammi is that its echinuli of basidiospores sometimes grouped in 2 or more; this trait can also be observed in *T. radiosa* and *T. agbassaensis*, but *T. radiosa* exhibits slightly bi- or trifurcate echinuli of basidiospores with short echinuli (< 1µm) and *T. agbassaensis* presents isolated echinuli with very short echinuli (0.2–0.5 µm) (Kõljalg 1996; Yorou et al. 2012).

*Tomentella longisterigmata* presents unique characteristics: basidia with long sterigmata and subglobose to globose homogeneous dense basidiospores with long echinuli coincide with those of *T. lapida* and *T. africana* Yorou & Agerer (Melo et al. 2006; Yorou and Agerer 2008). *T. longisterigmata* and *T. lapida* also have common characteristics including mucedinoid basidiocarps, dark grayish brown smooth hymenophore, pale brown subicular hyphae, thin-walled subhymenial hyphae, the size of basidiospores and an absence of rhizomorphs and cystidia. However, *T. lapid* is differentiated from *T. longisterigmata* by having discontinuous basidiocarps adherent to the substrate, bluish green subhymenial hyphae and monomitic rhizomorphs (50-70 μm) (Melo et al. 2006). *T. longisterigmata* also closely related to *T.africana* in having dark brown to chestnut smooth hymenophore, thick-walled basidiospores and an absence of cystidia. Although they have some morphological deviations, *T. africana* differs from *T. longisterigmata* by having light yellow to yellow subicular hyphae, yellowish subhymenial hyphae, monomitic rhizomorphs, colorless to light yellow basidia and light yellow to pale brown, subglobose or triangular to lobed basidiospores with shorter echinuli (up to 1.5 μm) (Yorou and Agerer 2008).

*Tomentella longisterigmata* and *T. globosa* are closely related in the phylogenetic tree and share similar morphological and anatomical characteristics: dark brown or rust brown hymenophore, globose basidiospores with isolated echinuli and an absence of rhizomorphs and cystidia. However, *T. globosa* can be differentiated from *T. longisterigmata* by its basidiocarps adherent to the substrate, granulose or smooth hymenophore, shorter sterigmata of basidia and smaller basidiospores with shorter and sparsely distributed echinuli.

The species of *Tomentella* can form ectomycorrhizas with different host tree species of Pinaceae and Fagaceae, such as *Pinus banksiana*, *Picea glauca*, *Populus alba*, *Quercus cerris*, *Quecus robur* (Danielson et al. 1984; Danielson and Pruden 1989; Kõljalg 1996; Erland and Taylor 1999; Jakucs and Erős-Honti 2008). The specimens involved in this study were collected from the forests dominated by coniferous trees such as *Larix* spp., *Picea* spp., *Pinus* spp., and also scattered a small number of broad-leaved trees (*Alnus* spp., *Acer* spp., *Betula* spp., *Quercus* spp. and *Populus* spp.). Although the specimens were found on the substrates of rotten angiosperm wood debris, their hosts maybe the coniferous trees.

**KEY TO SPECIES OF TOMENTELLA FROM FINLAND**

1. Cystidia present ··········· 2

1. Cystidia absent ··········· 5

2. Cystidia acuminate or rarely hyphoid ··········· 3

2. Cystidia clavate or capitate ··········· 4

3. Basidiocarps mostly discontinuous; hymenophore greenish ··········· *T. galzinii*

3. Basidiocarps mostly continuous; hymenophore brownish ··········· *T. subtestacea*

4. Cystidia clavate, without encrustation ··········· *T. subclavigera*

4. Cystidia capitate, often encrusted ··········· *T. viridula*

5. Rhizomorphs present; sterile margin determinate ··········· 6

5. Rhizomorphs absent; sterile margin indeterminate ··········· 12

6. Subicular hyphae and subhymenial hyphae simple-septate ··········· *T. fuscocinerea*

6. Subicular hyphae and subhymenial hyphae clamped ··········· 7

7. Subhymenial hyphae cells often or sometimes short and inflated ··········· 8

7. Subhymenial hyphae cells more or less uniform ··········· 10

8. Subicular hyphae thin-walled and sometimes inflated ··········· *T. ellisii*

8. Subicular hyphae thin- to thick-walled or thick-walled and without inflated ··········· 9

9. Basidiocarps crustose ············ *T. radiosa*

9. Basidiocarps mucedinoid or arachnoid ············ *T. albomarginata*

10. Basidiospores with ellipsoid or subglobose frontal face ············ *T. cinerascens*

10. Basidiospores with triangular or lobed frontal face ············ 11

11. Basidiocarps adhere to the substrate; sterile margin farinaceous or rarely byssoid ············ *T. coerulea*

11. Basidiocarps separable from the substrate; sterile margin byssoid to fimbriate ············ *T. punicea*

12. Basidiocarps crustose ············ 13

12. Basidiocarps mucedinoid or arachnoid ············ 15

13. Subicular hyphae and subhymenial hyphae simple-septate; basidia simple-septate at base ············ *T. cinereoumbrina*

13. Subicular hyphae and subhymenial hyphae clamped; basidia clamped at base ············ 14

14. Subicular hyphae thin- to thick-walled; basidia often with transverse septa ············ *T. terrestris*

14. Subicular hyphae thick-walled; basidia rarely with transverse septa ·*T. atramentaria*

15. Basidiospores with triangular or lobed frontal and ellipsoid lateral face ············ 16

15. Basidiospores with subglobose to globose frontal and lateral face ············ 19

16. Subicular hyphae often inflated; subhymenial hyphae cells short and inflated ········ ··························································································*T. sublilacina*

16. Subicular hyphae without inflated; subhymenial hyphae cells more or less uniform · ·······························································································17

19. Subicular hyphae and subhymenial hyphae simple-septate; basidia simple-septate at base ·······························································································*T. badia*

19. Subicular hyphae and subhymenial hyphae clamped or rarely with simple septa; basidia clamped at base ····································································18

18. Basidiocarps adhere to the substrate; hymenophore smooth, oxide yellow to golden brown when dry ····································································*T. lammiensis*

18. Basidiocarps separable from the substrate; hymenophore granulose to colliculose, dark red, red, yellowish red, reddish brown when dry ·······························*T. lateritia*

19. Subhymenial hyphae cells short and inflated ·······································20

19. Subhymenial hyphae cells more or less uniform ···································21

20. Subicular hyphae encrusted; basidia rarely or often with transverse septa ··*T. lapida*

20. Subicular hyphae without encrustation; basidia without transverse septa ·*T. globosa*

21. Basidiocarps separable from the substrate; subhymenial hyphae thin- to slightly thick-walled ······························································*T. longisterigmata*

21. Basidiocarps adhere to the substrate; subhymenial hyphae thin-walled ············22

22. Hymenophore ferrugineous brown to orange when dry; basidia rarely with transverse septa ··························································· *T. bryophila*

22. Hymenophore pale to dark brown when dry; basidia often with transverse septa ····· ································································ *T. stuposa*

## ACKNOWLEDGMENTS

The corresponding author is particularly grateful to Lammi Biological Station (University of Helsinki, Finland) and Academy of Finland for accommodation when he stayed in Finland. This research was financed by the National Natural Science Foundation of China (Project No. 31470148), the Special Project of Science and Technology Foundation (Project No. 2014FY210400) and the Special Funds for the Young Scholars of Taxonomy of the Chinese Academy of Sciences (Project No. ZSBR-015).

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**LEGENDS**

**Figure 1.** Maximum likelihood tree illustrating the phylogeny of *Tomentella globosa*, *T. lammiensis*, *T. longisterigmata* and related taxa, based on ITS sequence dataset. Branches are labeled with maximum likelihood bootstrap higher than 50%, parsimony bootstrap proportions higher than 50% and Bayesian posterior probabilities more than 0.95.

**Figure 2.** A basidiocarp of *Tomentella globosa* (holotype *Yuan 11603*).

**Figure 3.** SEM of basidiospores of *Tomentella globosa* (holotype *Yuan 11603*).

**Figure 4.** Microscopic structures of *Tomentella globosa* (drawn from *Yuan 11603*). a: Section through a basidiocarp; b: Basidiospores in lateral face; c: Basidiospores in frontal face.

**Figure 5.** Basidiocarps of *Tomentella lammiensis* (holotype *Yuan 11617*).

**Figure 6.** SEM of basidiospores of *Tomentella lammiensis* (holotype *Yuan 11617*).

**Figure 7.** Microscopic structures of *Tomentella lammiensis* (drawn from *Yuan 11617*). a: Section through a basidiocarp; b: Basidiospores in lateral face; c: Basidiospores in frontal face.

**Figure 8.** A basidiocarp of *Tomentella longisterigmata* (holotype *Yuan 11610*).

**Figure 9.** SEM of basidiospores of *Tomentella longisterigmata* (holotype *Yuan 11610*).

**Figure 10.** Microscopic structures of *Tomentella longisterigmata* (drawn from *Yuan 11610*). a: Section through a: basidiocarp; b: Basidiospores in lateral face; c: Basidiospores in frontal face.

**FOOTNOTES**

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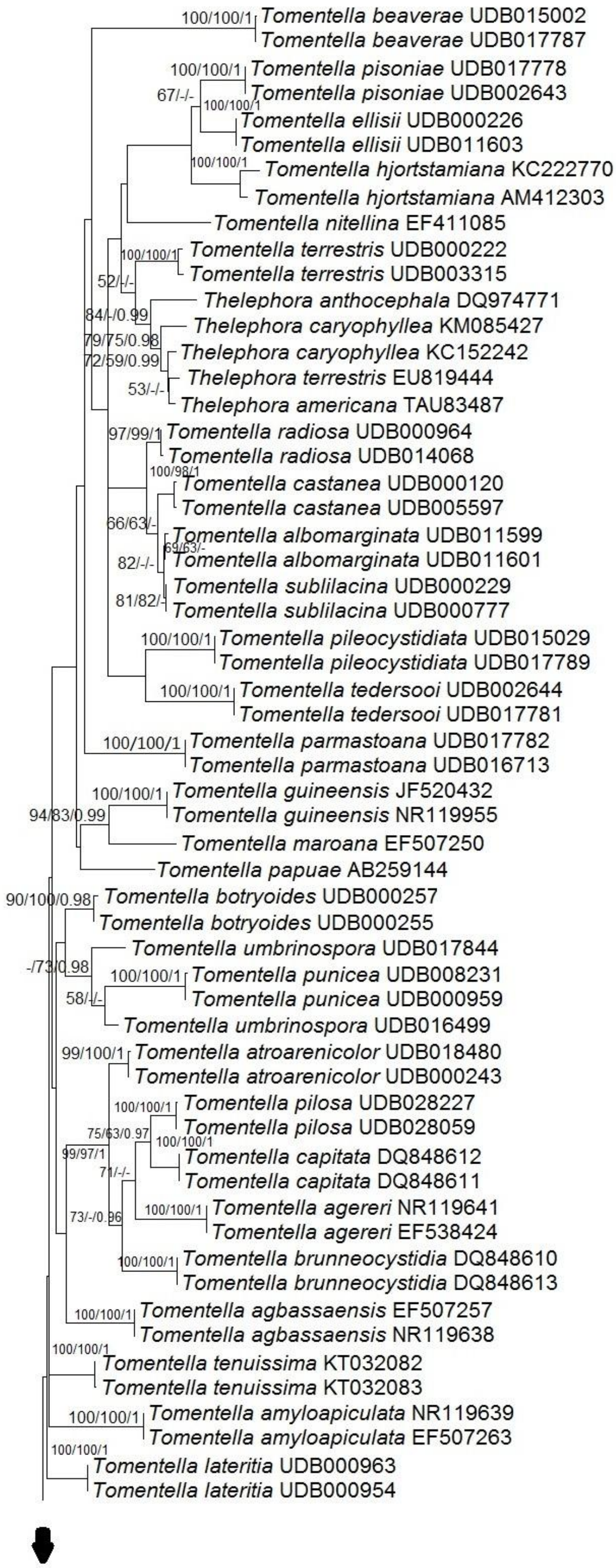

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Tomentella hjortstamiana AM412303
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Tomentella terrestris UDB003315
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Tomentella albomarginata UDB011601
Tomentella sublilacina UDB000229
Tomentella sublilacina UDB000777
Tomentella pileocystidiata UDB015029
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Tomentella guineensis JF520432
Tomentella guineensis NR119955
Tomentella maroana EF507250
Tomentella papuae AB259144
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Tomentella botryoides UDB000255
Tomentella umbrinospora UDB017844
Tomentella punicea UDB008231
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Tomentella umbrinospora UDB016499
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Tomentella pilosa UDB028227
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Tomentella capitata DQ848612
Tomentella capitata DQ848611
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Tomentella agereri EF538424
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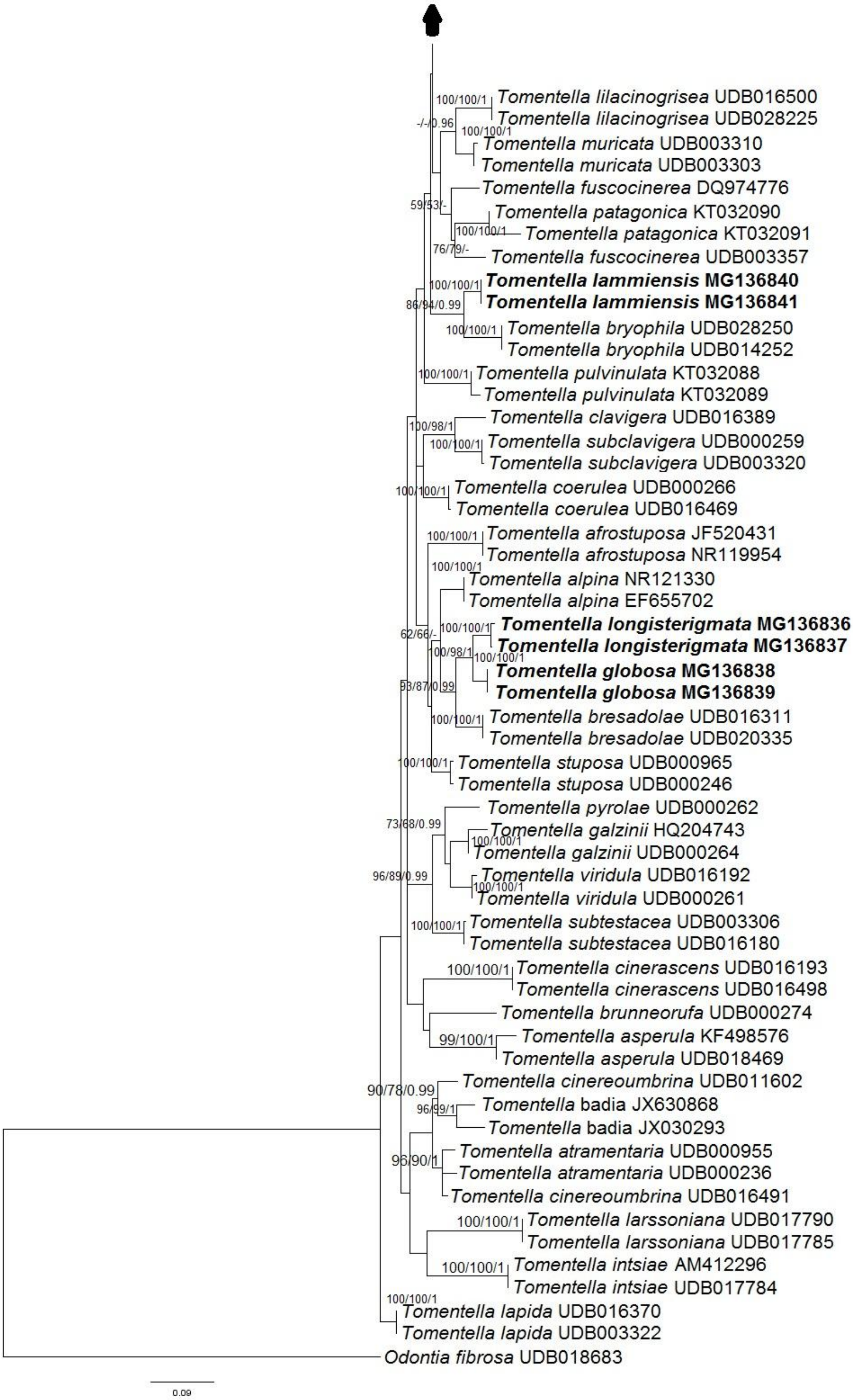
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Tomentella bryophila UDB028250
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Tomentella pulvinulata KT032088
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Tomentella clavigera UDB016389
Tomentella subclavigera UDB000259
Tomentella subclavigera UDB003320
Tomentella coerulea UDB000266
Tomentella coerulea UDB016469
Tomentella afrostuposa JF520431
Tomentella afrostuposa NR119954
Tomentella alpina NR121330
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Tomentella longisterigmata MG136837
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Tomentella globosa MG136839
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Tomentella cinerascens UDB016193
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Tomentella brunneorufa UDB000274
Tomentella asperula KF498576
Tomentella asperula UDB018469
Tomentella cinereoumbrina UDB011602
Tomentella badia JX630868
Tomentella badia JX030293
Tomentella atramentaria UDB000955
Tomentella atramentaria UDB000236
Tomentella cinereoumbrina UDB016491
Tomentella larssoniana UDB017790
Tomentella larssoniana UDB017785
Tomentella intsiae AM412296
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Tomentella lapida UDB016370
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Odontia fibrosa UDB018683
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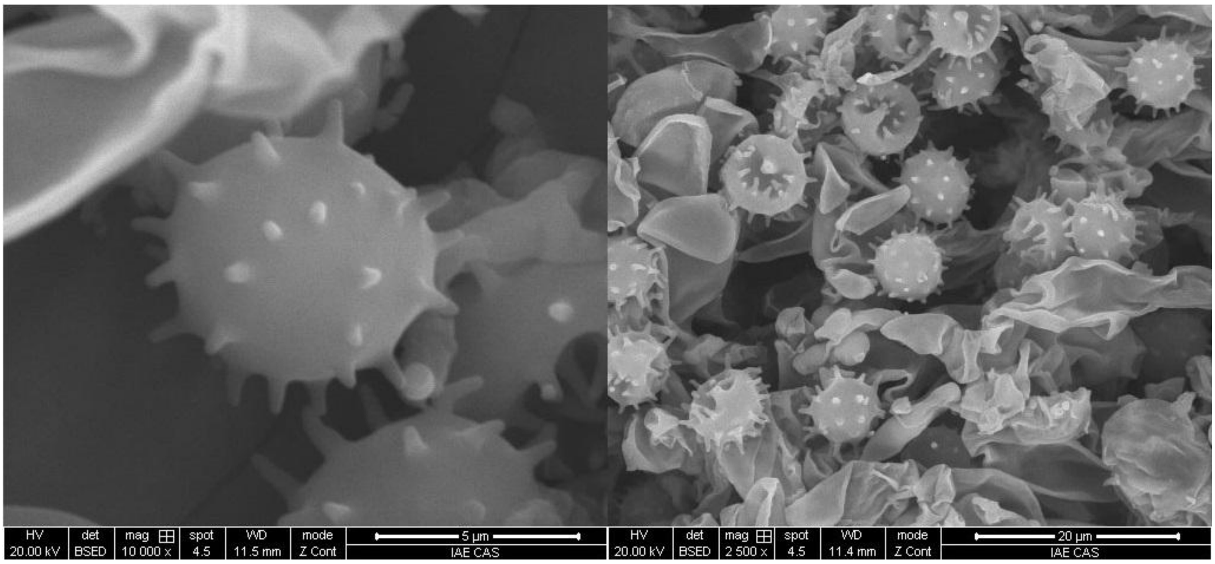
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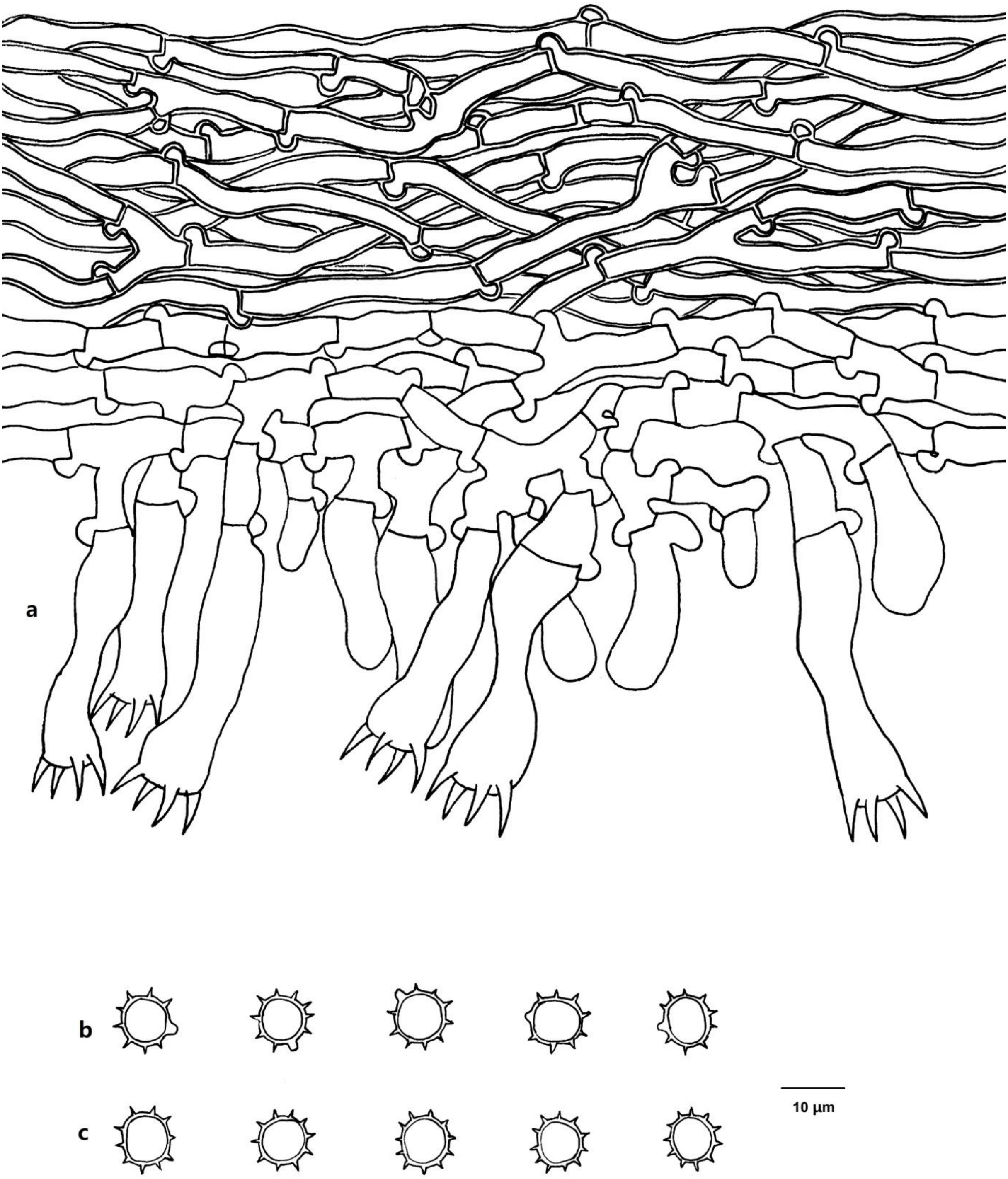


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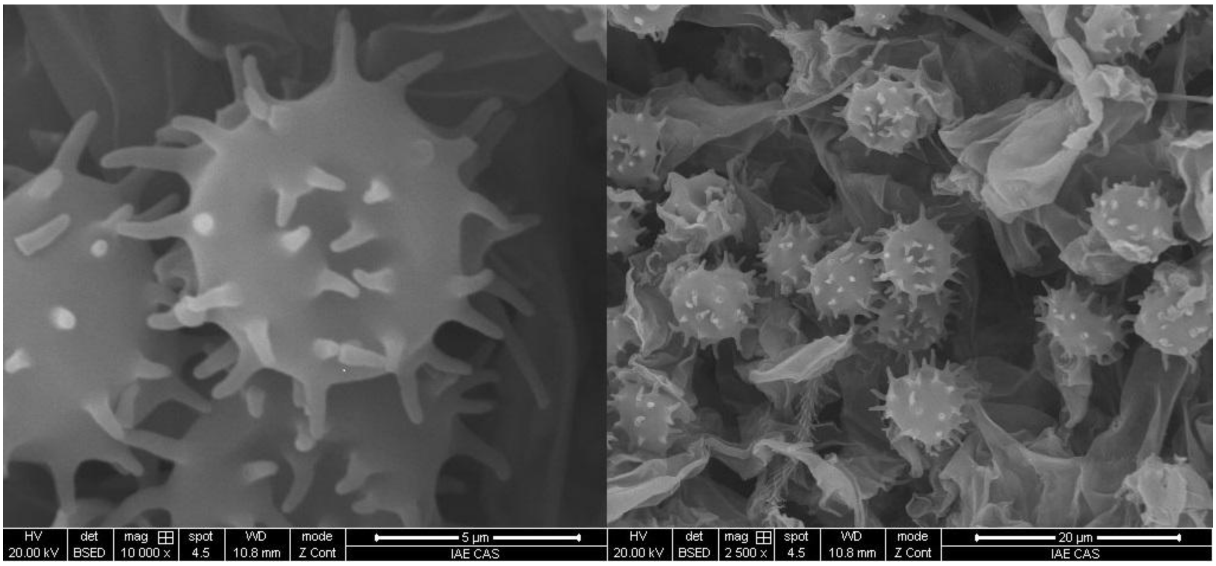
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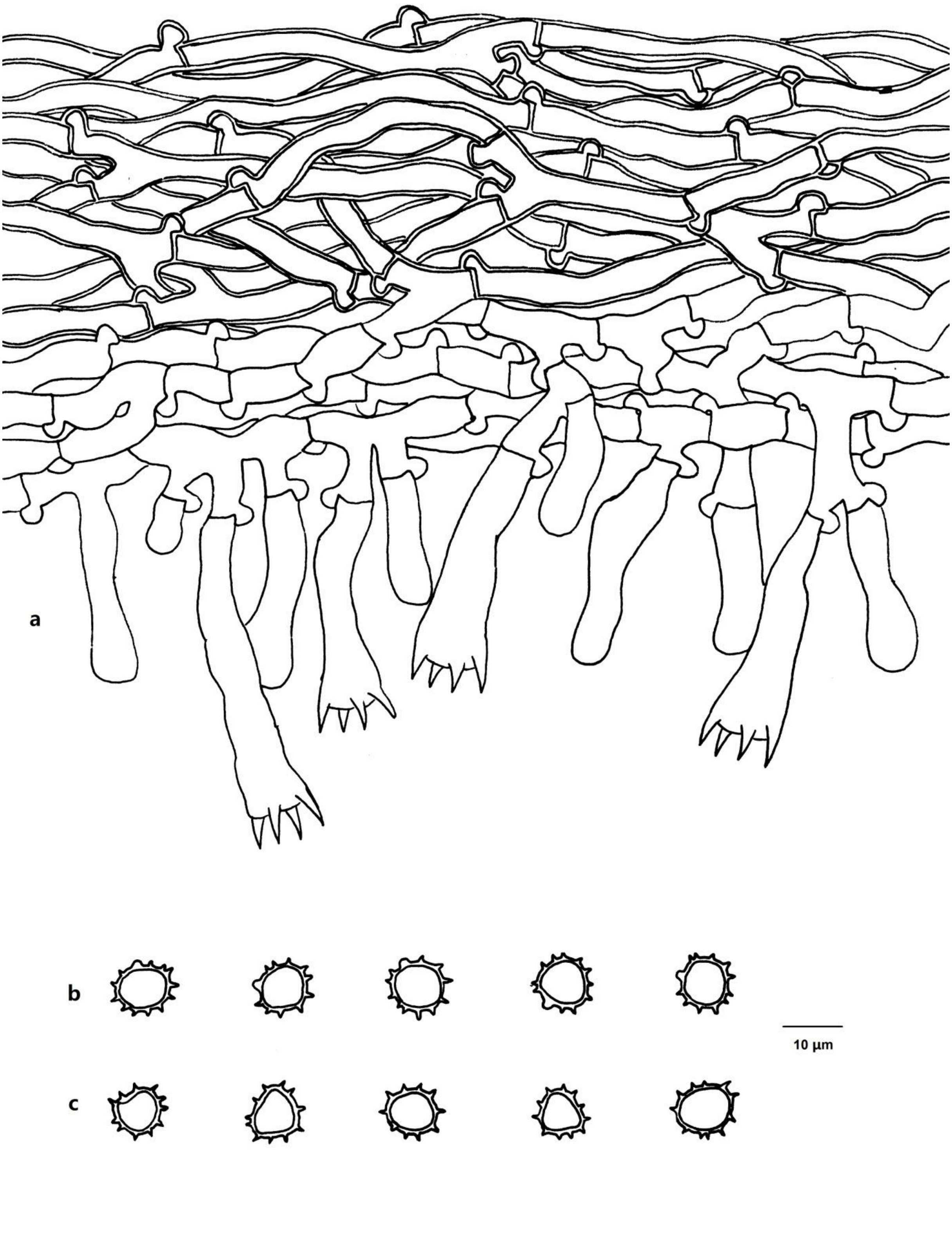
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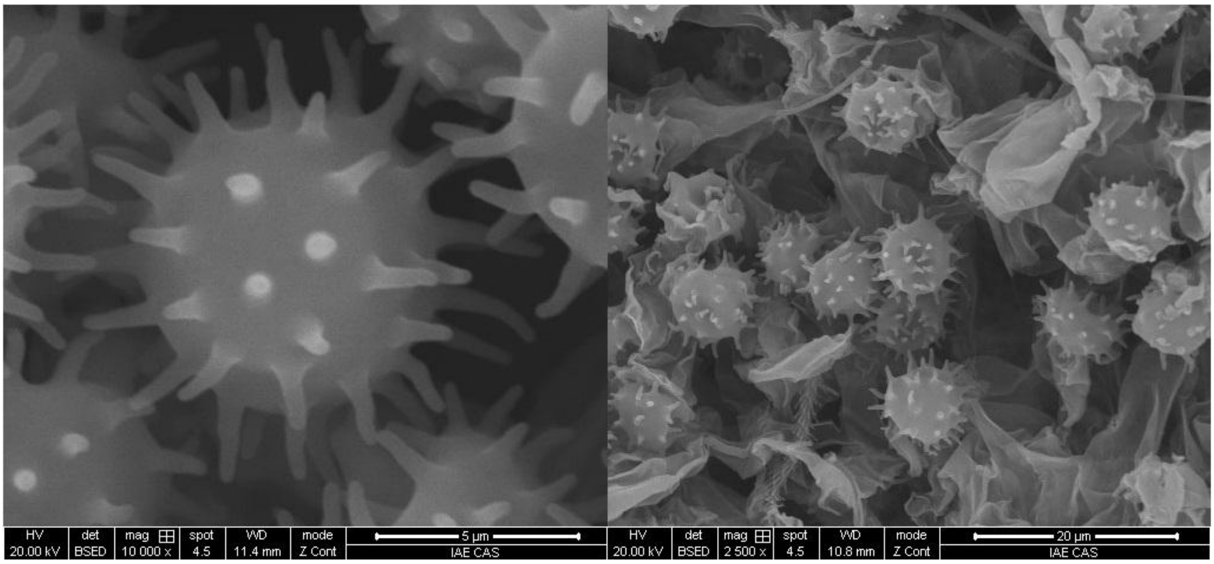
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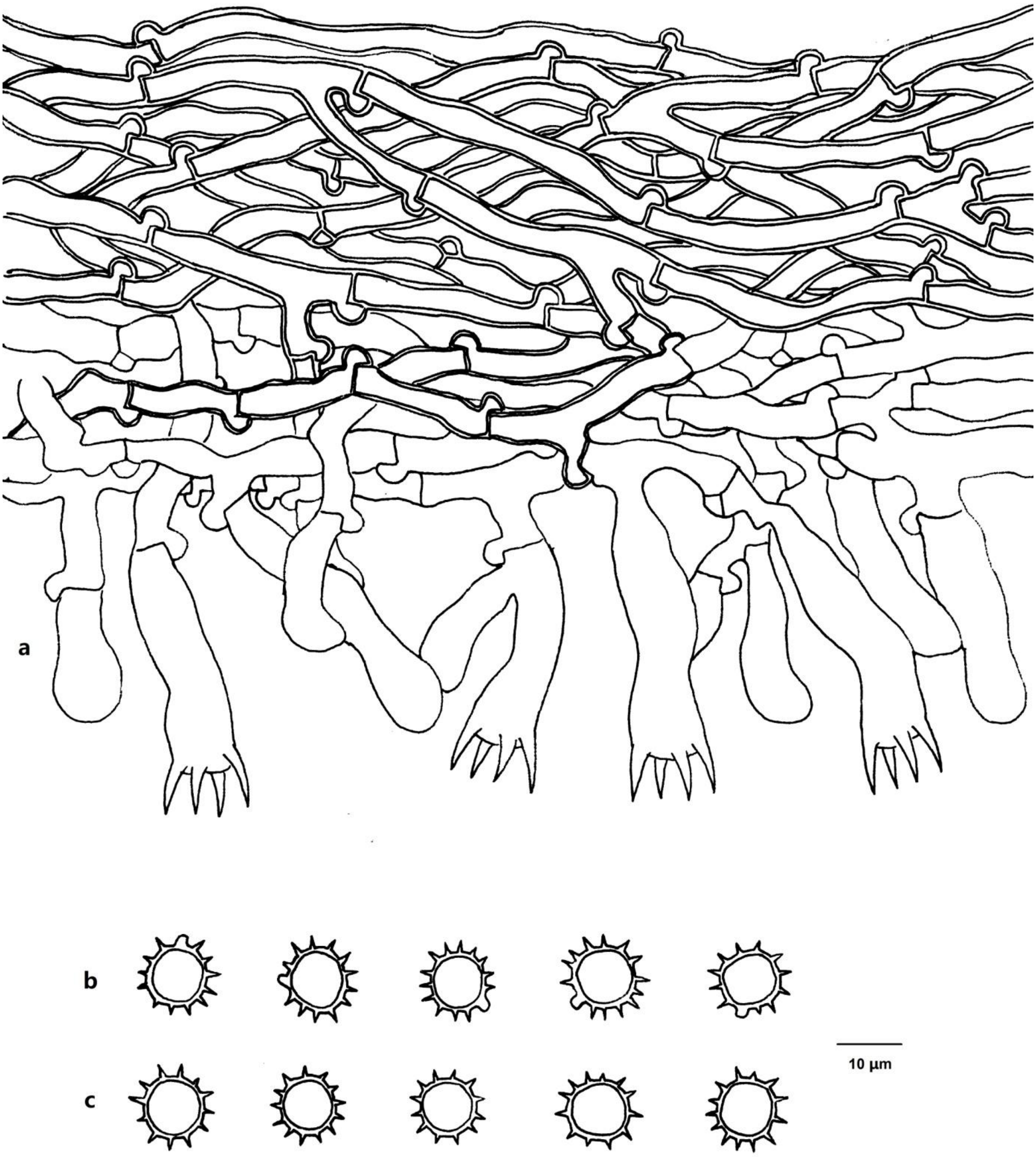
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TABLE 1. Specimens, strains, and sequences used in this study.

| Species | GenBank Accession No./UNITE Database | Specimen ID/culture voucher | Location |
|---|---|---|---|
| *Odontia fibrosa* | UDB018683 | TU115714 | India |
| *Thelephora americana* | TAU83487 | JMT17465 | USA |
| *T. anthocephala* | DQ974771 | src614 | USA |
| *T. caryophyllea* | KM085427 | ID PAN 684 | Poland |
| *T. caryophyllea* | KC152242 | GO-2010-163 | Mexico |
| *T. terrestris* | EU819444 | JMP0086 | USA |
| *Tomentella afrostuposa* | JF520431 | SYN 2292(M) | Guinea |
| *T. afrostuposa* | NR119954 | M:SYN 2292 | Guinea |
| *T. agbassaensis* | EF507257 | SYN 981 (M) | Benin |
| *T. agbassaensis* | NR119638 | M:SYN 981 | Benin |
| *T. agereri* | EF538424 | RA 13793 (M) | Benin |
| *T. agereri* | NR119641 | M:RA 13793 | Benin |
| *T. albomarginata* | UDB011601 | TU115353 | Finland |
| *T. albomarginata* | UDB011599 | TU115350 | Finland |
| *T. alpina* | EF655702 | IB20060231 | Austria |
| *T. alpina* | NR121330 | IB:20060231 | Austria |

| | | | |
|---|---|---|---|
| *T. amyloapiculata* | EF507263 | SYN 893 (M) | Benin |
| *T. amyloapiculata* | NR119639 | M:SYN 893 | Benin |
| *T. asperula* | UDB018469 | TU108147 | Estonia |
| *T. asperula* | KF498576 | — | Germany |
| *T. atramentaria* | UDB000236 | TU123491 | Germany |
| *T. atramentaria* | UDB000955 | TU108866 | Estonia |
| *T. atroarenicolor* | UDB000243 | TAAM149946 | Russia |
| *T. atroarenicolor* | UDB018480 | TU100676 | Estonia |
| *T. badia* | JX630868 | — | Canada |
| *T. badia* | Jx030293 | — | USA |
| *T. beaverae* | UDB015002 | TU105060 | Seychelles |
| *T. beaverae* | UDB017787 | TU103595 | Seychelles |
| *T. botryoides* | UDB000255 | KHL8453 | Sweden |
| *T. botryoides* | UDB000257 | TAAM149614 | Russia |
| *T. bresadolae* | UDB020335 | TU115616 | Slovenia |
| *T. bresadolae* | UDB016311 | TU115447 | Estonia |
| *T. brunneocystidia* | DQ848613 | SYN 839 (M) | Benin |
| *T. brunneocystidia* | DQ848610 | RA 13779 | Benin |
| *T. brunneorufa* | UDB000274 | TAAM159857 | Australia |

| | | | |
|---|---|---|---|
| *T. bryophila* | UDB014252 | TU116131 | Estonia |
| *T. bryophila* | UDB028250 | TU124259 | Estonia |
| *T. capitata* | DQ848611 | RA13785 | Benin |
| *T. capitata* | DQ848612 | SYN 860 (M) | Benin |
| *T. castanea* | UDB005597 | — | Iran |
| *T. castanea* | UDB000120 | TL-6886 | Denmark |
| *T. cinerascens* | UDB016193 | TU108037 | Estonia |
| *T. cinerascens* | UDB016498 | 019AS | Italy |
| *T. cinereoumbrina* | UDB011602 | — | Finland |
| *T. cinereoumbrina* | UDB016491 | 012AS | Italy |
| *T. clavigera* | UDB016389 | UDB016389 | Estonia |
| *T. coerulea* | UDB016469 | TU115602 | Estonia |
| *T. coerulea* | UDB000266 | TAAM153804 | Estonia |
| *T. ellisii* | UDB011603 | — | Finland |
| *T. ellisii* | UDB000226 | 5b-A.Heller | Germany |
| *T. fuscocinerea* | DQ974776 | src813 | USA |
| *T. fuscocinerea* | UDB003357 | LISU 178262 | Portugal |
| *T. galzinii* | UDB000264 | RS27093 | Finland |
| *T. galzinii* | HQ204743 | — | France |

| | | | |
|---|---|---|---|
| *T. globosa* | MG136838 [a] | Yuan11618 | Finland |
| *T. globosa* | MG136839 [a] | Yuan11603 | Finland |
| *T. guineensis* | JF520432 | SYN 2331(M) | Guinea |
| *T. guineensis* | NR119955 | M:SYN 2331 | Guinea |
| *T. hjortstamiana* | AM412303 | TU103641 | Seychelles |
| *T. hjortstamiana* | KC222770 | — | Australia |
| *T. intsiae* | AM412296 | — | Seychelles |
| *T. intsiae* | UDB017784 | TU105130 | Seychelles |
| *T. lammi* | MG136840 [a] | Yuan11617 | Finland |
| *T. lammi* | MG136841 [a] | Yuan11597 | Finland |
| *T. lapida* | UDB016370 | — | Estonia |
| *T. lapida* | UDB003322 | TU100884 | France |
| *T. larssoniana* | UDB017785 | TU103690 | Seychelles |
| *T. larssoniana* | UDB017790 | TU105082 | Seychelles |
| *T. lateritia* | UDB000963 | NF.S045 | Norway |
| *T. lateritia* | UDB000954 | TU108551 | Estonia |
| *T. lilacinogrisea* | UDB028225 | TU124232 | Estonia |
| *T. lilacinogrisea* | UDB016500 | 023 AS | Italy |
| *T. longisterigmata* | MG136836 [a] | Yuan11610 | Finland |

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|---|---|---|---|
| *T. longisterigmata* | MG136837 [a] | Yuan11602 | Finland |
| *T. maroana* | EF507250 | SYN 878 (M) | Benin |
| *T. muricata* | UDB003303 | — | Estonia |
| *T. muricata* | UDB003310 | TU100729 | Finland |
| *T. nitellina* | EF411085 | — | USA |
| *T. papuae* | AB259144 | — | Japan |
| *T. parmastoana* | UDB016713 | — | Seychelles |
| *T. parmastoana* | UDB017782 | TU103691 | Seychelles |
| *T. patagonica* | KT032091 | BAFC52373 | Argentina |
| *T. patagonica* | KT032090 | BAFC52372 | Argentina |
| *T. pileocystidiata* | UDB015029 | TU105068 | Seychelles |
| *T. pileocystidiata* | UDB017789 | TU105054 | Seychelles |
| *T. pilosa* | UDB028059 | TU124067 | Estonia |
| *T. pilosa* | UDB028227 | TU124234 | Estonia |
| *T. pisoniae* | UDB002643 | TU103671 | Seychelles |
| *T. pisoniae* | UDB017778 | TU103655 | Seychelles |
| *T. pulvinulata* | KT032089 | BAFC52371 | Argentina |
| *T. pulvinulata* | KT032088 | BAFC52370 | Argentina |
| *T. punicea* | UDB008231 | TU110254 | Estonia |

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|---|---|---|---|
| *T. punicea* | UDB000959 | KHL11908 | Sweden |
| *T. pyrolae* | UDB000262 | TAAM005998 | Switzerland |
| *T. radiosa* | UDB014068 | TU110022 | Ecuador |
| *T. radiosa* | UDB000964 | NF.S010 | Norway |
| *T. stuposa* | UDB000246 | TAAM159816 | Finland |
| *T. stuposa* | UDB000965 | NF.S051 | Norway |
| *T. subclavigera* | UDB000259 | TU115207 | Norway |
| *T. subclavigera* | UDB003320 | TU100877 | France |
| *T. sublilacina* | UDB000229 | TU115204 | Norway |
| *T. sublilacina* | UDB000777 | RK03-04 | Denmark |
| *T. subtestacea* | UDB016180 | TU115374 | Ukraine |
| *T. subtestacea* | UDB003306 | TU100715 | Estonia |
| *T. tedersooi* | UDB017781 | TU103673 | Seychelles |
| *T. tedersooi* | UDB002644 | TU103664 | Seychelles |
| *T. tenuissima* | KT032083 | CIEFAP FK15011 | Argentina |
| *T. tenuissima* | KT032082 | BAFC52369 | Argentina |
| *T. terrestris* | UDB000222 | EL9897 | USA |
| *T. terrestris* | UDB003315 | TU100886 | France |
| *T. umbrinospora* | UDB017844 | TU111410 | Italy |

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|---|---|---|---|
| *T. umbrinospora* | UDB016499 | TU111379 | Italy |
| *T. viridula* | UDB016192 | TU108038 | Estonia |
| *T. viridula* | UDB000261 | TU108165 | Sweden |

[a] Sequences newly generated in this study.