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Notes of 15 unrecorded macrofungi in Korea

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Macrofungi are essential decomposers in the forest environment. Although more than 70% of the land is mountainous, there has been a lack of research on mushroom diversity in Korea compared to the global species estimation. For this reason, the need for further research became apparent. The surveys were conducted from 2014 to 2022 nationwide. As a result, 15 unrecorded macrofungal species were discovered: *Agaricus thiersii*, *Baorangia alexandri*, *Boletellus putuoensis*, *Entoloma bulakhae*, *Entoloma pygmaeopapillatum*, *Entoloma subtenuicystidiatum*, *Gerronema kuruvense*, *Hyphoderma nudicephalum*, *Hyphoderma tenue*, *Macrolepiota subcitrophylla*, *Mycena jingyinga*, *Mycena yuezhuoi*, *Ophiocordyceps vespulae*, *Scytinostroma acystidiatum*, and *Steccherinum straminellum*. These species are identified based on morphological, molecular, and phylogenetic analyses using the internal transcribed spacer (ITS) region and the nuclear large subunit rRNA (LSU) region. Here, we provided macro- and micro-morphological figures with phylogenetic trees to support 15 species as unrecorded to Korea.

Keywords: ITS, LSU, macrofungi, phylogeny, taxonomy

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Introduction

Macrofungi play an important role in forest ecosystems as ectomycorrhizal, parasitic, saprobic, and wood-decaying corticioid or polyporoid forms. They decompose leaf litter and dead wood, which contributes to nutrient cycles such as carbon or nitrogen cycles (Van Geffen *et al*., 2010; Bani *et al*., 2018). In addition, they form symbiotic relationships with plant species, which promote plant growth by providing nutrients and water (Smith and Read, 2010; Policelli *et al*., 2020). In Korea, about 70% (70,200 km^2) of the land is mountainous (NGII, 2016), which provides suitable habitats for macrofungi.

The recent estimation of the number of fungal species on Earth is 11.7−13.2 million species (Wu *et al*., 2019). This result is due to the advancement of sequencing techniques such as high throughput sequencing and resources like environmental DNA (Wu *et al*., 2019). Among these fungi, macrofungi on Earth is estimated to account for 220,000−380,000 species (Sridhar and Deshmukh, 2019), but this result is based on the estimation of 2.2−3.8 million fungal species in 2017 (Hawksworth and Lücking, 2017). However, by following the calculation of Hawksworth (2001), about 10% of fungal species are estimated to be macrofungal species, so current estimation of macrofungal species might be up to 1.2−1.3 million species. In Korea, 4,927 fungal species have been recorded up to 2022, and among them, 2,086 species are macrofungi (NIBR, 2022). The number of recorded macrofungal species in Korea falls far short of the number of estimated macrofungal species on Earth. This suggests that there are many species yet to be discovered in Korea. Therefore, continuous efforts are required to discover new and unrecorded indigenous macrofungal species and to acquire biological resources.

In this study, we surveyed various mountainous areas

in Korea from 2014 to 2022 to discover the diversity of macrofungi in Korea. The sampling was conducted in national parks, mountains, islands, and urban forested areas. As a result, 15 species are identified as new to Korea: *Agaricus thiersii*, *Baorangia alexandri*, *Boletellus putuoensis*, *Entoloma bulakhae*, *Entoloma pygmaeopapillatum*, *Entoloma subtenuicystidiatum*, *Gerronema kuruvense*, *Hyphoderma nudicephalum*, *Hyphoderma tenue*, *Macrolepiota subcitrophylla*, *Mycena jingyinga*, *Mycena yuezhuoi*, *Ophiocordyceps vespulae*, *Scytinostroma acystidiatum*, and *Steccherinum straminellum*. We provide detailed macro- and micro-morphological figures and phylogenetic trees to support the 15 species as unrecorded species in Korea.

Materials and Methods

Sampling

The sampling was conducted from 2014 to 2022 in forested areas across the country. Sampling sites were widely distributed, including three national parks (Juwangsan, Seoraksan, and Taebaeksan), three mountains (Mt. Gaewoon, Gwangdeok, and Seonwoon), three urban green areas (Korea Research Institute of Bioscience and Biotechnology, Korea University Campus, and Seoul National University Campus), two islands (Byeongpung and Ulleung), and one arboretum (Seoul National University Arboretum). Every specimen was dried at 60°C for 24 h and stored with silica gel. The specimens were deposited in the Korea University Collection (KUC) and National Institute of Biological Resources (NIBR).

Morphological identification

Macroscopic features of specimens were taken using a Sony α 6500 camera (Sony, Tokyo, Japan). Microscopic characteristics were observed and measured using an Olympus BX51 light microscope (Olympus, Tokyo, Japan) and DP20 microscope camera (Olympus). Microscopic structures were observed from the slide mounted by 5% KOH. The following abbreviations are used: L = mean spore length; W = mean spore width; Q = L/W ratio.

Molecular analysis

DNA extraction was performed using an AccuPrep® Genomic DNA Extraction Kit (Bioneer, Daejeon, Korea) from the dried specimens. The internal transcribed spacer (ITS) region was amplified using the primer sets ITS1F/ITS4, ITS5/ITS4, and ITS5/LR3 (White *et al*., 1990; Gardes and Bruns, 1993), and nuclear large subunit rRNA (LSU) region was amplified using the primer set LR0R/LR5 (Vilgalys and Hester, 1990; Hopple Jr and Vilgalys, 1994). The purification of PCR products was performed using an AccuPrep® PCR Purification Kit (Bioneer) following the manufacturer's instructions. Sanger sequencing was conducted at Bioneer (Daejeon, Korea), Cosmogenetech (Seoul, Korea), and Macrogen Inc. (Seoul, Korea). Editing of each sequencing result was conducted using the SeqMan Lasergene package version 7.0.0 (DNAStar Inc., Madison, WI). The sequences of closely related species were obtained from the NCBI GenBank database (www.ncbi.nlm.nih.gov/genbank/). Reference sequences were searched through BLASTn v. 2.13.0 (Altschul *et al*., 1990). Multiple sequence alignment was performed with MAFFT v. 7.453 (Katoh and Standley, 2013). The alignment trimming was conducted using trimAI v. 1.4 with algorithm gt (Capella-Gutiérrez *et al*., 2009). Modeltest was performed through IQ-TREE. The phylogenetic tree was constructed by maximum likelihood (ML) method. ML tree analysis was performed with RAxML v. 8.2.12 using BIC criterion with 1,000 bootstrap replicates (Stamatakis, 2014). All steps written above including sequence identification, alignment, trimming, and tree construction were conducted using FunID v. 0.3.17 (https://github.com/Changwanseo/FunID).

Results

After the survey of 12 different areas including national parks, mountains, and islands, 15 unrecorded species including 21 specimens were discovered from 2014 to 2022. Each species was identified using ITS or LSU sequence datasets, and phylogenetically analyzed by ML tree. The 15 species are *Agaricus thiersii*, *Baorangia alexandri*, *Boletellus putuoensis*, *Entoloma bulakhae*, *Entoloma pygmaeopapillatum*, *Entoloma subtenuicystidiatum*, *Gerronema kuruvense*, *Hyphoderma nudicephalum*, *Hyphoderma tenue*, *Macrolepiota subcitrophylla*, *Mycena jingyinga*, *Mycena yuezhuoi*, *Ophiocordyceps vespulae*, *Scytinostroma acystidiatum*, and *Steccherinum straminellum* (Table 1). The unrecorded species show various ecological traits; saprobic (9 species), wood-decaying corticoid (4 species), ectomycorrhizal (2 species), and parasitic (1 species). According to the phylogenetic analysis, *A. thiersii*, *Ba. alexandri*, *Bo. putuoensis*, *E. bulakhae*, *E. subtenuicystidiatum*, *My. yuezhuoi*, *Sc. acystidiatum*, and *St. straminellum* formed a clear monophyletic clade, and their sister groups were *A. parasubrutilescens*, *Ba. pseudocalopus*, *Bo. chrysenteroides*, *E. pleurotoides*, *E. stylophorum*, *My. pearsoniana*, *Sc. renisporum*, and *St. ciliolatum*, respectively (Figs. 3–6, 10, 12, 13). *E. pygmaeopapillatum*, *G. kuruvense*, *H. nudicephalum*, *H. tenue*, *Ma. subcitrophylla*, *My. jingyinga*, *O. vespulae* were distinctly separated from other group and formed a monophyletic clade with high bootstrap value (99–100) (Figs. 6–11).

Table 1. Molecular identification and collection information of fifteen unrecorded species in Korea.

Identity	Specimen ID	Collection date	Locality	Habitat	GenBank accession number		Reference
					ITS	LSU	
Agaricus thiersii	KUC20180907-19	07 Sep 2018	Mt. Gwangdeok	Mixed hardwood forest	OR600245	–	This study
Baorangia alexandri	KUC20190731-65	31 Jul 2019	Juwangsan National Park	Mixed hardwood forest	OR600246	–	This study
Boletellus putuoensis	KUC20190731-68	31 Jul 2019	Juwangsan National Park	Mixed hardwood forest	OR600247	–	This study
Entoloma bulakhae	SFC20150903-26	03 Sep 2015	Ulleung Island	Hardwood forest	OR600248	–	This study
	SFC20150903-31	03 Sep 2015	Ulleung Island	Hardwood forest	OR600249	–	This study
Entoloma pygmaeopapillatum	SFC20190822-20	22 Aug 2019	Taebaeksan National Park	Mixed hardwood forest	OR600250	–	This study
Entoloma subtenuicystidiatum	SFC20140624-04	24 Jun 2014	Korea Research Institute of Bioscience and Biotechnology	Lawn	OR600251	–	This study
Gerronema kuruvense	KUC20220701-03	01 Jul 2022	Korea University Campus	Hardwood forest	OR600252	–	This study
Hyphoderma nudicephalum	SFC20150108-26	08 Jan 2015	Seoul National University Campus	Mixed hardwood forest	OR600253	–	This study
	SFC20150113-05	13 Jan 2015	Seoul National University Arboretum	Mixed hardwood forest	OR600254	–	This study
	SFC20180704-83	04 Jul 2018	Byeongpung Island	Hardwood forest	OR600255	–	This study
Hyphoderma tenue	KUC20180919-27	19 Sep 2018	Seoraksan National Park	Mixed hardwood forest	–	OR593346	This study
Macrolepiota subcitrophylla	KUC20220825-04	25 Aug 2022	Seonwoonsa Temple	Mixed hardwood forest	OR600256	–	This study
Mycena jingyinga	KUC20220626-09	26 Jun 2022	Mt. Gaewoon	Mixed hardwood forest	OR600257	–	This study
	KUC20220626-13	26 Jun 2022	Mt. Gaewoon	Mixed hardwood forest	OR600258	–	This study
	KUC20220626-14	26 Jun 2022	Mt. Gaewoon	Mixed hardwood forest	OR600259	–	This study
Mycena yuezhuoi	KUC20190731-37	31 Jul 2019	Juwangsan National Park	Coniferous forest	OR600260	–	This study
	KUC20191011-27A	11 Oct 2019	Juwangsan National Park	Hardwood forest	OR600261	–	This study
Ophiocordyceps vespulae	KUC20220825-06	25 Aug 2022	Seonwoonsa Temple	Mixed hardwood forest	OR600262	–	This study
Scytinostroma acystidiatum	KUC20190620-28	20 Jun 2019	Juwangsan National Park	Mixed hardwood forest	OR600263	–	This study
	KUC20121019-32	19 Oct 2012	Odaesan National Park	Mixed hardwood forest	KJ668461	KJ668313	Jang *et al.*, 2016b
Steccherinum straminellum	KUC20181101-53	01 Nov 2018	Juwangsan National Park	Mixed hardwood forest	OR600264	OR593347	This study



Fig. 1. Macro-morphological characteristics of fifteen unrecorded macrofungi in Korea. A. *Agaricus thiersii*; B. *Baorangia alexandri*; C. *Boletellus putuoensis*; D. *Entoloma bulakhae*; E. *Entoloma pygmaeopapillatum*; F. *Entoloma subtenuicystidiatum*; G. *Gerronema kuruvense*; H. *Hyphoderma nudicephalum*; I. *Hyphoderma tenue*; J. *Macrolepiota subcitrophylla*; K. *Mycena jingyinga*; L. *Mycena yuezhuoi*; M. *Ophiocordyceps vespulae*; N. *Scytinostroma acystidiatum*; O. *Steccherinum straminellum* (scale bar = 10 mm for A–D, G–J, M–O; 5 mm for E, F, L; and 2.5 mm for K).

Taxonomy

***Agaricus thiersii* Kerrigan & Vellinga,**
Memoirs of the New York Botanical Garden 114: 340 (2016) [MB#802557] (Figs. 1A and 2A)
Korean name: 솔방울주름버섯

Pileus convex, margin slightly incurved, 34 mm in diam. **Pileus surface** dark vinaceous to reddish brown, formed of radially oriented hyphae, forming large blunt appressed concentric zones distal to the disc, background whitish. **Lamellae** free, close. **Veils** are not observed in young state. **Stipe** equal, 35 × 6 mm, surface glabrous, white. **Hyphal system** monomitic, generative hyphae simple septate, rarely branched, without clamp connections, thin-

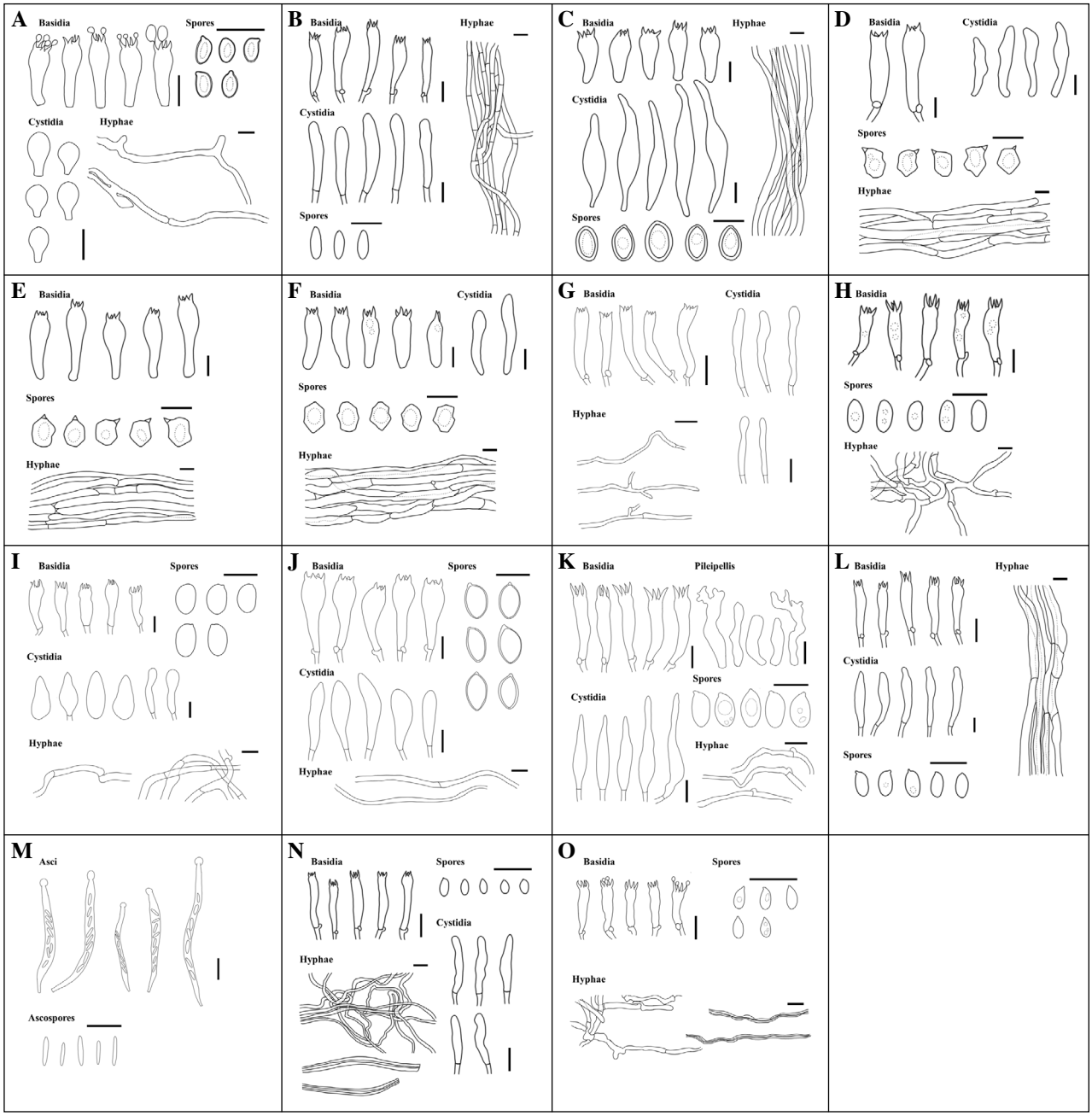


Fig. 2. Micro-morphological characteristics of fifteen unrecorded macrofungi in Korea. A. *Agaricus thiersii*; B. *Baorangia alexandri*; C. *Boletellus putuoensis*; D. *Entoloma bulakhae*; E. *Entoloma pygmaeopapillatum*; F. *Entoloma subtenuicystidiatum*; G. *Gerronema kuruvense*; H. *Hyphoderma nudicephalum*; I. *Hyphoderma tenue*; J. *Macrolepiota subcitrophylla*; K. *Mycena jingyinga*; L. *Mycena yuezhuoi*; M. *Ophiocordyceps vespulae*; N. *Scytinostroma acystidiatum*; O. *Steccherinum straminellum* (scale bars = 10 μm).

walled, hyaline, 2.7−4.9 μm. **Basidia** clavate, 4-spored, smooth, thin-walled, hyaline, without a clamp connection, 17.1−26.7 × 4.5−7.9 μm. **Cheilocystidia** obovoid to pyriform, smooth, thin-walled, hyaline, 9.6−12.7 × 6.1−7.6 μm. **Basidiospores** cylindrical, smooth, thick-walled, yellowish to pale brown, 4.9−6.2 × 2.9−3.5 μm [Q = 1.69−1.78].

Specimen examined. Korea, Gangwon-do, Hwacheon-gun, Mt. Gwangdeok, 38°06′59.68″N, 127°25′58.83″E, 1,023 m, mixed hardwood forest, occurring solitary on the ground covered with litters and substrates, 07 Sep 2018, S. Jang and S. L. Kwon, KUC20180907-19 (**NIBRFG 0000514540**).

Notes − *Agaricus* L. is a genus that includes more than

500 species worldwide (Zhao *et al*., 2011; Kerrigan, 2016; Chen *et al*., 2017), and it is classified into six subgenera and 26 sections (Zhao *et al*., 2016; Chen *et al*., 2017; Callac and Chen, 2018; He *et al*., 2018; Parra *et al*., 2018; Bashir *et al*., 2021; Ortiz-Santana *et al*., 2021). Currently, 12 species are accepted as *Agaricus* subgenus *Spissicaules* sect. *Subrutilescentes* (Edwards *et al*., 2004; Kerrigan *et al*., 2005; Zhao *et al*., 2011; Lebel and Syme, 2012; Dai *et al*., 2016; Kerrigan, 2016; Zhao *et al*., 2016; Ortiz-Santana *et al*., 2021), and only one species (*A. subrutilescens*) is reported in Korea. *Agaricus thiersii* is characterized by dark vinaceous to reddish brown pileus with large blunt-appressed concentric zones, obovoid to pyriform cystidia, and yellowish to pale brown basidiospores (Kerrigan, 2016). KUC20180907-19 has similar morphological characteristics to the original description, but our specimen has a smaller pileus compared to the original description (55–300 mm) and veils are not observed (Kerrigan, 2016). This might be due to the young stage of our specimen. Phylogenetically, *A. thiersii* is classified as *Agaricus* subgenus *Spissicaules* sect. *Subrutilescentes* (Kerrigan, 2016). *Agaricus parasubrutilescens* is the sister species (Fig. 3), but it differs from *A. thiersii* by a brown-colored pileus and larger cystidia (15–28 × 10–19 μm) (Zhao *et al*., 2016). *Agaricus thiersii* was previously reported in Canada and USA (Kerrigan, 2016), so this is the first report of *A. thiersii* in Asia.

***Baorangia alexandri* Svetash., Simonini & Vizzini,** Persoonia 40: 265 (2018) [MB#825173]
(Figs. 1B and 2B)
Korean name: 황갈색그물버섯아재비

Pileus convex, margin straight, even, 30–60 mm in diam. **Pileus surface** smooth, dark pink to pale red. **Pore** surface pale yellow, round to angular pores, 4–6 per mm. **Stipe** central, equal, slightly clavate at the bottom, 30–50 × 5–15 mm, surface smooth, concolorous with pileus, pruinose and light yellow at bottom. **Hyphal system** monomitic, generative hyphae simple septate, branched, interwoven, without clamp connections, thin-walled, hyaline, 2.6–4.7 μm. **Basidia** subclavate to cylindrical, 4-spored, smooth, thin-walled, lightly pale brown, with a clamp connection, 22.5–41.4 × 5.1–8.2 μm. **Cystidia** cylindrical, smooth, thin-walled, hyaline, without a clamp connection, 36.9–55.4 × 5.0–7.4 μm. **Basidiospores** rare, narrowly cylindrical, thin-walled, yellowish brown, 9.6–11.2 × 3.9–4.4 μm [Q = 2.46–2.55].

Specimen examined. Korea, Gyeongsangbuk-do, Cheongsong-gun, Juwangsan National Park, 36°23′43.9″N, 129°09′15.0″E, 348 m, mixed hardwood forest, occurring solitary on the ground near Yongchu Falls, 31 Jul 2019, S. Jang and S. L. Kwon, KUC20190731-65 (**NIBRFG0000506143**).

Notes – *Baorangia* G. Wu & Zhu L. Yang is a recently separated novel genus, which was considered as the *Boletus bicolor* clade (Wu *et al*., 2014; 2016). Seven species are accepted as *Baorangia* (Wu *et al*., 2016; Crous *et al*., 2018; Phookamsak *et al*., 2019; Zhang *et al*., 2021), and among them, two species are reported in Korea as *Boletus* (*Bo. bicolor* and *Bo. pseudocalopus*). In the original description, the type specimen has wider stipe (30–70 × 10–25 mm) and basidia, (25.5–30.5 × 8.0–9.5 μm) and fusiform cystidia were observed (Crous *et al*., 2018). Additional observations for cystidia and basidiospores are required for accurate identification. In the phylogenetic tree, *Ba. pseudocalopus* is the sister species of *Ba. alexandri* (Fig. 4). However, *Ba. pseudocalopus* has a grayish or brownish pileus, and slightly bigger basidiospores (9.0–12.5 × 4.0–5.0 μm) (Wu *et al*., 2016). *Baorangia alexandri* is a rare species globally, only reported from a single area (Primorsky Krai, Far East Russia) (Crous *et al*., 2018). Therefore, this study is significant for the discovery of a globally rare species and the first report of *Ba. alexandri* in the temperate region.

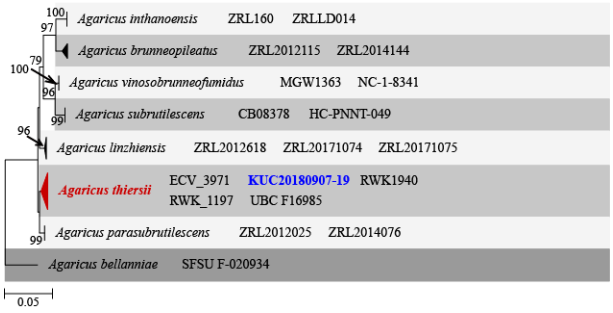


Fig. 3. The phylogenetic tree of *Agaricus thiersii* (KUC20180907-19). The tree was constructed based on ITS gene datasets of the genus *Agaricus* subgenus *Spissicaules*. *Agaricus bellanniae* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

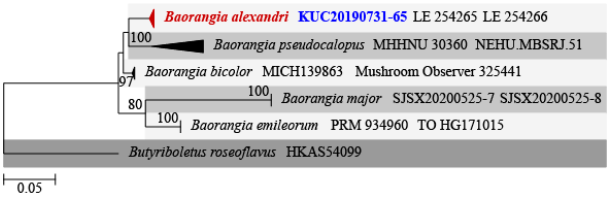


Fig. 4. The phylogenetic tree of *Baorangia alexandri* (KUC20190731-65). The tree was constructed based on ITS gene datasets of the genus *Baorangia*. *Butyriboletus roseoflavus* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

***Boletellus putuoensis* N.K. Zeng, Yi Li, Chang Xu, Xu Zhang & J.R. Wang,** Phytotaxa 554(2): 156 (2022) [MB#571000] (Figs. 1C and 2C)
Korean name: 매끈밤그물버섯

Pileus convex, margin straight, even, 40−50 mm in diam. **Pileus surface** smooth, partially cracked, brown, margin dusky red. Pore surface yellowish brown when young, becoming dark brown when old, round to angular pores, 1−2 per mm. **Stipe** central, equal, 65 × 5 mm, surface smooth, concolorous with pileus. **Hyphal system** monomitic, generative hyphae simple septate, rarely branched, without clamp connections, thin-walled, hyaline, 3.3−8.4 µm. **Basidia** obovoid to pyriform, 4-spored, smooth, thin-walled, hyaline, without a clamp connection, 21.9−30.0 × 10.5−14.2 µm. **Cystidia** fusiform to lageniform, smooth, thin-walled, hyaline, without a clamp connection, 48.8−75.7 × 10.3−13.3 µm. **Basidiospores** ellipsoid to cylindrical, striate, with 5−8 ridges, thick-walled, yellowish brown to reddish brown, bearing a guttule, 10.9−14.0 × 6.3−9.6 µm [Q = 1.45−1.73].

Specimen examined. Korea, Gyeongsangbuk-do, Cheongsong-gun, Juwangsan National Park, 36°23′43.9″N, 129° 09′15.0″E, 348 m, mixed hardwood forest, occurring solitary on the ground near Yongchu Falls, 31 Jul 2019, S. Jang and S. L. Kwon, KUC20190731-68 (**NIBRFG0000 506145**).
Notes − *Boletellus* Murrill includes about 64 species worldwide from tropical to temperate regions (Murrill, 1909; Singer, 1970; Snell and Dick, 1970; Corner, 1972; Watling and Li, 1999; Bessette *et al*., 2000; Watling, 2001; Halling and Mueller, 2005; Horak, 2011; Zeng and Yang, 2011; Sato *et al*., 2012; Bessette *et al*., 2017; Tibpromma *et al*., 2017; Parihar *et al*., 2018). Among them, nine species are recorded in Korea (Cho and Park, 1988; An, 1998). *Boletellus putuoensis* is characterized by small-sized brownish pileus, fusiform and lageniform cystidia, and thick-walled striate basidiospores (Xu *et al*., 2022). Additional observation using SEM is required to observe the surface of basidiospores clearly. The original description differs from KUC20190731-68 by a smaller pileus (17−48 mm) and observance of fusiform cystidia only (Xu *et al*., 2022). According to the phylogenetic analysis, *Bo. chrysenteroides* is the most closely related to *Bo. putuoensis* (Fig. 5). However, *Bo. chrysenteroides* has narrower basidiospores (12−16 × 4.6−7.5 µm) (Smith, 1971). *Boletellus putuoensis* was previously reported from Southeastern China, Guangdong, Hainan, and Zhejiang, which have subtropical to tropical climate (Xu *et al*., 2022; Xue *et al*., 2023). This study is the first report of *Bo. putuoensis* in the temperate region, over 30 degrees north latitude.

***Entoloma bulakhae* O.V. Morozova & Noordel.,** Mycological Progress 17(3): 391 (2017) [MB#822533] (Figs. 1D and 2D)
Korean name: 울릉외대버섯

Pileus convex to depressed, margin straight, even, 20−25 mm in diam. **Pileus surface** smooth, light gray, dark violaceus gray in the center. **Lamellae** sinuate, close,

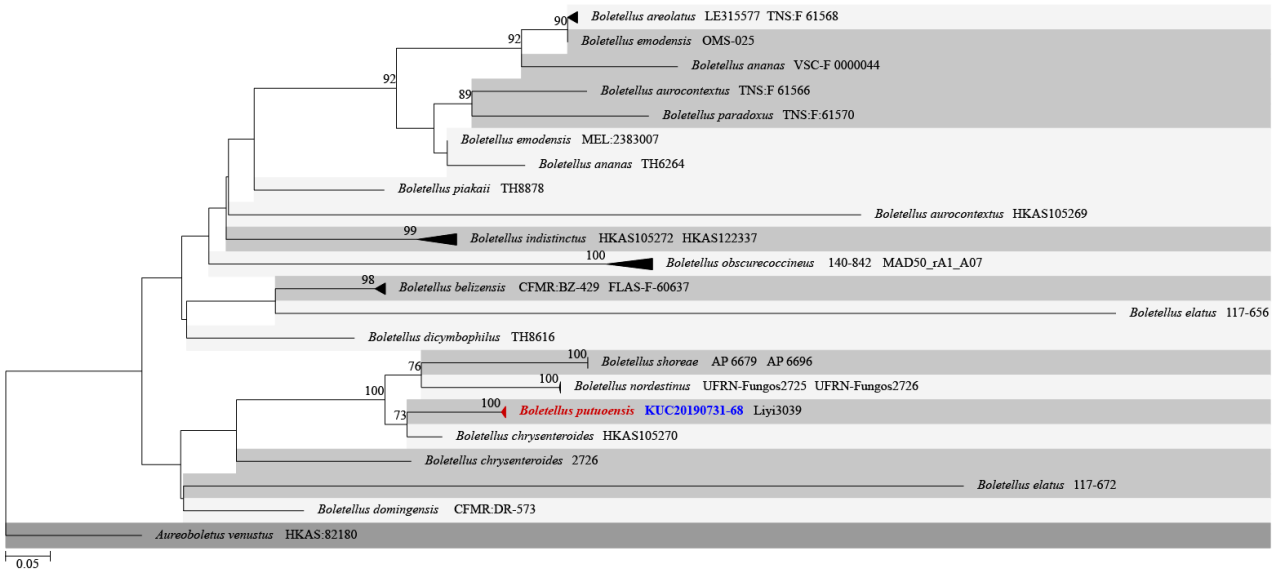


Fig. 5. The phylogenetic tree of *Boletellus putuoensis* (KUC20180907-19). The tree was constructed based on ITS gene datasets of the genus *Boletellus*. *Aureoboletus venustus* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

even. **Stipe** central, few eccentric, equal, 40−55 × 2−3 mm, surface smooth, light gray to dark gray. **Hyphal system** monomitic, generative hyphae simple septate, rarely branched, few clamp connections, thin-walled, hyaline, 3.3−7.8 μm. **Basidia** cylindrical to subclavate, 4-spored, smooth, thin-walled, hyaline, with a clamp connection, 27.7−39.1 × 9.7−13.2 μm. **Cheilocystidia** cylindrical or lageniform, some prolonged in the apex, smooth, thin-walled, some with a clamp connection, 31.5−64.5 × 5.2−8.7 μm. **Basidiospores** pentagonal, hexagonal, or heptagonal with an acute tip, smooth, thin-walled, pale brown, bearing a guttule, 9.1−11.3 × 6.5−8.1 μm [Q = 1.39−1.40].

Specimen examined. Korea, Gyeongsangbuk-do, Ulleung-gun, Ulleung Island, Nari basin, 37°31′13.9″N, 130°52′01.7″E, 364 m, hardwood forest, occurring solitary on the ground, 03 Sep 2015, Y. W. Lim, SFC20150903-26 (**NIBRFG0000500686**), SFC20150903-31 (**NIBRFG0000500691**).

Notes − *Entoloma* (Fr.) P. Kumm. is a highly diverse genus, and more than 1,500 species are reported worldwide (He *et al*., 2012; He *et al*., 2019b). Due to its high diversity, *Entoloma* is separated into several subgenera and sections (Largent, 1994; Noordeloos, 2004; Co-David *et al*., 2009; Noordeloos *et al*., 2012). Currently, more than 100 species are reported in Korea (Lee and Lee, 1957; Cho, 1993; Han *et al*., 2010; 2011; Lee, 2013; Kim *et al*., 2015a; Cho *et al*., 2019b). *Entoloma bulakhae* was previously identified as *E. violaceoserrulatum* because clamp connections were not observed (Noordeloos and Morozova, 2010). However, additional research found that it has clamp connections, which matches with our specimens, so the new species *E. bulakhae* was introduced (Morozova *et al*., 2018). *Emtoloma bulakhae* is a member of the subgenus *Violaceozonata*, and its sister species is *E. bidupense* (Morozova *et al*., 2018) (Fig. 6). *Entoloma bidupense* differs from *E. bulakhae* by pileus with less depressed center and more cylindrical and longer basidia (37.5−45.3 × 8.1−10.9 μm) (Morozova *et al*., 2018). Also, *E. bulakhae* specimens were collected in Far East Russia (Noordeloos and Morozova, 2010; Morozova *et al*., 2018), but *E. bidupense* specimens were collected in the highlands (1,600 m) of Vietnam (Morozova *et al*., 2012). Our specimens are morphologically similar to the original description (Morozova *et al*., 2018), but type specimens have umbilicate to infundibuliform pileus and decurrent lamellae (Morozova *et al*., 2018). These differences might be due to the immature state of our specimens.

***Entoloma pygmaeopapillatum* Arnolds & Winterh.,**
Zeitschrift für Mykologie 52(2): 255 (1986)
[MB#129501] (Figs. 1E and 2E)
Korean name: 난쟁이외대버섯

Pileus convex to plane, center depressed when mature margin straight, even, 5−15 mm in diam. **Pileus surface** smooth, virgate, striate, brown in the center, becoming light brown to the margin. **Lamellae** adnate, subdistant. **Stipe** central, equal, slightly fibrillose when old, brown, 40−60 × 0.7−1 mm. **Hyphal system** monomitic, generative hyphae simple septate, rarely branched, without clamp connections, thin-walled, hyaline, 4.9−7.3 μm. **Basidia** clavate to subclavate, 4-spored, smooth, thin-walled, hyaline, without a clamp connection, 34.1−42.7 × 9.7−13.3 μm. **Cystidia** absent. **Basidiospores** pentagonal or hexagonal with an acute tip, smooth, thin-walled, pale yellow, bearing guttules, 9.2−11.0 × 6.9−8.9 μm [Q = 1.23−1.33].

Specimen examined. Korea, Gangwon-do, Taebaek-si, Taebaeksan National Park, 37°06′48.9″N, 128°56′51.0″E, 915 m, mixed hardwood forest, scattered on the ground covered with fallen leaves near Danggol, 22 Aug 2019, Jae Young Park, SFC20190822-20 (**NIBRFG0000505796**).

Notes − *Entoloma pygmaeopapillatum* is characterized by a brown striate pileus, 5−6 angled basidiospores with an acute tip (Arnolds and Winterhoff, 1986). *Entoloma pygmaeopapillatum* is classified as *Entoloma* sect. *Nolanea*, subsect. *Minuta* (Reschke *et al*., 2022). Many species in subsect. *Minuta* have a basidiome with depressed center and fibrillose stipe (Reschke *et al*., 2022), which accord with *E. pygmaeopapillatum*. According to the phylogenetic analysis, *E. pygmaeopapillatum* formed a monophyletic clade with high bootstrap value (Fig. 6). Interestingly, the closely related species (*E. incanosquamulosum*, *E. minutum*, *E. ortonii*, *E. vindovonense*) were all collected in Europe (Reschke *et al*., 2022). Also, reported specimens of *E. pygmaeopapillatum* were collected in France, Germany, Slovakia (Reschke *et al*., 2022), so this study is the first report of *E. pygmaeopapillatum* in Asia.

***Entoloma subtenuicystidiatum* Xiao Lan He & T.H. Li,**
Mycological Progress 11: 921 (2012) [MB#563509]
(Figs. 1F and 2F)
Korean name: 잔디외대버섯아재비

Pileus convex to plane, center depressed when mature, margin straight, even, 8−12 mm in diam. **Pileus surface** smooth, lightly virgate, yellowish brown, reddish brown in the center. **Lamellae** adnate, subdistant. **Stipe** central, equal, light brown, 20−25 × 0.7−1.2 mm. **Hyphal system** monomitic, simple septate, unbranched, with few clamp connections, thin-walled, hyaline, 3.9−7.4 μm. **Basidia** subclavate to cylindrical, 4-spored, rarely 2-spored, smooth, thin-walled, hyaline, without a clamp connection, some bearing guttules, 24.3−31.3 × 7.9−11.0 μm. **Cheilocystidia** cylindrical, smooth, thin-walled, without a clamp

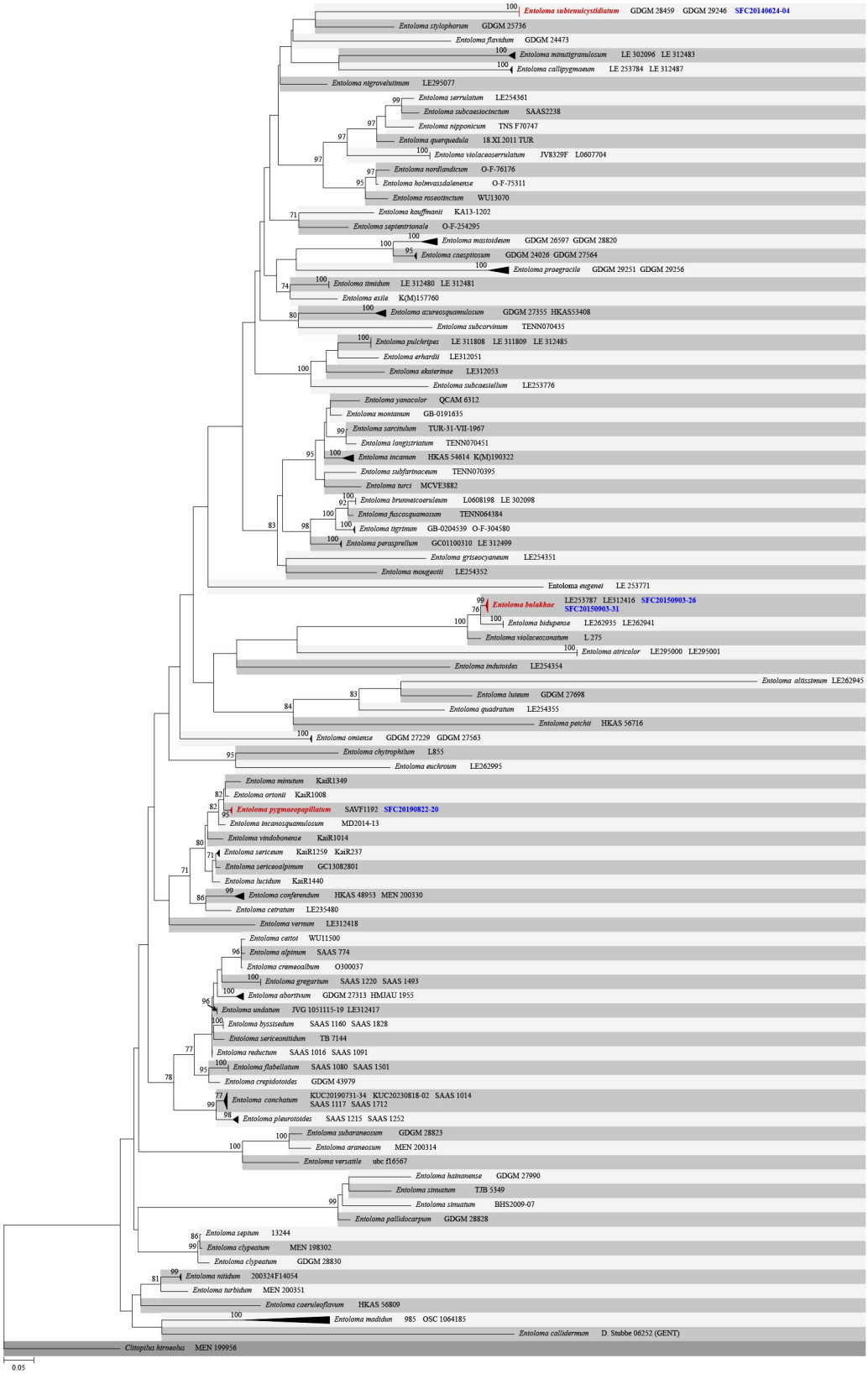


Fig. 6. The phylogenetic tree of *Entoloma bulakhae* (SFC20150903-26 and SFC20150903-31), *E. pygmaeopapillatum* (SFC20190822-20), and *E. subtenuicystidiatum* (SFC20140624-04). The tree was constructed based on ITS gene datasets of the genus *Entolma*. *Clitopilus hirneolus* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

connection, 25.6−33.3 × 7.2−8.2 μm. **Pleurocystidia** absent. **Basidiospores** hexagonal or heptagona, smooth, thick-walled, pale yellow, bearing a guttule, 9.1−10.9 × 6.3−8.2 μm [Q = 1.33−1.44].

Specimen examined. Korea, Daejeon, Yuseong-gu, Korea Research Institute of Bioscience and Biotechnology (KRIBB), 36°22′36.0″N, 127°21′30.9″E, 53 m, occurring scattered on a lawn, 24 Jun 2014, Y. W. Lim, SFC2014 0624-04 (**NIBRFG0000136737**).

Notes − SFC20140624-04 is morphologically similar to the original description (He *et al*., 2012), but the original description has longer cheilocystidia (40−70 × 7−10 μm) and bigger basidiospores (9.5−13 × 7.5−9 μm) than our specimen (He *et al*., 2012). *Entoloma subtenuicystidiatum* resembles *E. tenuicystidiatum* morphologically, but *E. tenuicystidiatum* has pale brown to brown pileus and larger basidiospores (10−15 × 8−10 μm) (Noordeloos and Gates, 2009). *Entoloma subtenuicystidiatum* occurred on a lawn, which accords with the original description (He *et al*., 2012). However, these specimens were reported in Southern China, Jiangxi, and Fuzhou (He *et al*., 2012), so this study is the first report of *E. subtenuicystidiatum* in the region above 30 degrees north latitude.

***Gerronema kuruvense* K.P.D. Latha & Manim.,**
Phytotaxa 364(1): 84 (2018) [MB#824927]
(Figs. 1G and 2G)
Korean name: 변색오목패랭이버섯

Pileus convex when very young, becoming convex to planate, 15 mm in diam. **Pileus surface** yellowish when young, becoming grayish brown when mature. **Lamellae** subdecurrent, distant, little waxy, pale grayish yellow. **Stipe** slightly eccentric, slightly clavate, striate, grayish yellow at the top, becoming pale yellow at the bottom, 20−25 × 2−4 mm. **Hyphal system** monomitic, generative hyphae septate with clamp connections, thin-walled, hyaline, 2.5−3.4 μm. **Basidia** clavate to broadly clavate, 2-spored, thin-walled, smooth, hyaline, 22.1−34.0 × 4.1−7.1 μm. **Caulocystidia** broadly cylindrical to cylindrical, thin-walled, smooth, hyaline, 23.2−37.1 × 3.1−7.7 μm. Cheilocystidia and pleurocystidia absent. **Basidiospores** not observed.

Specimen examined. Korea, Seoul, Seongbuk-gu, Korea University Campus, 37°35′08.6″N, 127°01′32.6″E, 34 m, hardwood forest, occurring solitary on the ground covered with leaf litters, 01 Jul 2022, M. Cho, KUC20220701-03 (**NIBRFG0000514541**).

Notes − *Gerronema* Singer is a small genus which is mainly distributed in subtropical to tropical regions. Currently, about 60 species have been described worldwide (Singer, 1951; 1959; Liu, 1995; Takahashi, 2000; Desjardin *et al*., 2005; Banares *et al*., 2006; Degreef and Ndong, 2007; Cooper, 2014; Latha *et al*., 2018; Liu *et al*., 2019; Na *et al*., 2022). In Korea, only one species, *G. nemorale*, is reported (Antonín *et al*., 2008). The morphological characteristics of KUC20220701-03 are generally in accordance with the original description (Latha *et al*., 2018). However, the pileus color was observed to be more brownish in a mature state in our specimen. Also, basidia were smaller in our specimen compared to the original description, 30−47 × 6−9 μm (Latha *et al*., 2018). Basidiospores were not observed in our specimen, so additional observations are needed for accurate identification. *Gerronema kuruvense* formed a monophyletic clade with high bootstrap value according to the phylogenetic analysis (Fig. 7). *Gerronema kuruvense* was previously reported

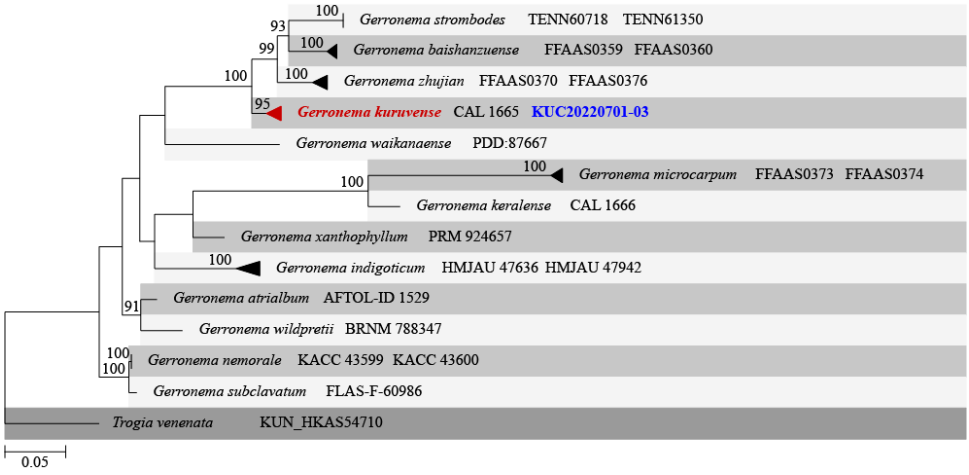


Fig. 7. The phylogenetic tree of *Gerronema kuruvense* (KUC20220701-03). The tree was constructed based on ITS gene datasets of the genus *Gerronema*. *Trogia venenata* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

in South Asia, India, Thailand and Guizhou, China according to the GenBank database and paper (Latha *et al*., 2018). This is the first report of *G. kuruvense* in Northeast Asia, above 30 degrees north latitude.

***Hyphoderma nudicephalum* Gilb. & M. Blackw.,**
Mycotaxon 33: 378 (1988) [MB#134906]
(Figs. 1H and 2H)
Korean name: 매끈목재고약버섯

Basidiome resupinate, widely effused, thin. **Hymenial surface** crustaceous, smooth, partially poroid, few with cracks when dried, cream white, few light brown, margin concolorous with basidiome. **Hyphal system** monomitic, generative hyphae abundant, simple septate, frequently branched, with clamp connections, thin-walled, hyaline, 2.6−9.0 µm. **Basidia** cylindrical to subclavate, 4-spored, smooth, thin-walled, hyaline, with a clamp connection, 19.1−26.0 × 5.2−6.7 µm. **Basidiospores** cylindrical to narrowly cylindrical, smooth, thin-walled, bearing guttules, 8.4−9.9 × 3.9−5.1 µm [Q = 1.94−2.15]. **Cystidia** absent.

Specimen examined. Korea, Seoul, Gwanak-gu, Seoul National University Campus, 37°27′32.6″N, 126°56′49.8″E, 76 m, mixed hardwood forest, occurring on hardwood branch, 08 Jan 2015, Y. W. Lim, SFC20150108-26 (**NIBRFG0000139942**); Korea, Gyeonggi-do, Anyang-si, Seoul National University Arboretum, 37°25′11.2″N, 126°56′08.0″E, 97 m, mixed hardwood forest, occurring on hardwood branch, 13 Jan 2015, Y. W. Lim, SFC20150113-05 (**NIBRFG0000139943**); Korea, Jeollanam-do, Jindo-gun, Byeongpung Island, 34°58′06.3″N, 126°12′24.1″E, 41 m, hardwood forest, occurring on the hardwood branch, 04 Jul 2018, J. Y. Park, SFC20180704-83 (**NIBRFG0000514542**).

Notes − *Hyphoderma* Wallr. is a white-rot fungus, and about 110 species have been described worldwide from tropical to temperate regions (Wu, 1997; Nakasone, 2008; Baltazar *et al*., 2016; Martín *et al*., 2018; Guan and Zhao, 2021; Ma *et al*., 2021; Qian-Xin and Chang-Lin, 2021; Duan *et al*., 2023). In Korea, eight species are listed as *Hyphoderma* (Cho and Oh, 1996; Kim *et al*., 2009; Jang *et al*., 2016a; Jang *et al*., 2016b). According to the phylogenetic analysis, *H. nudicephalum* formed a monophyletic

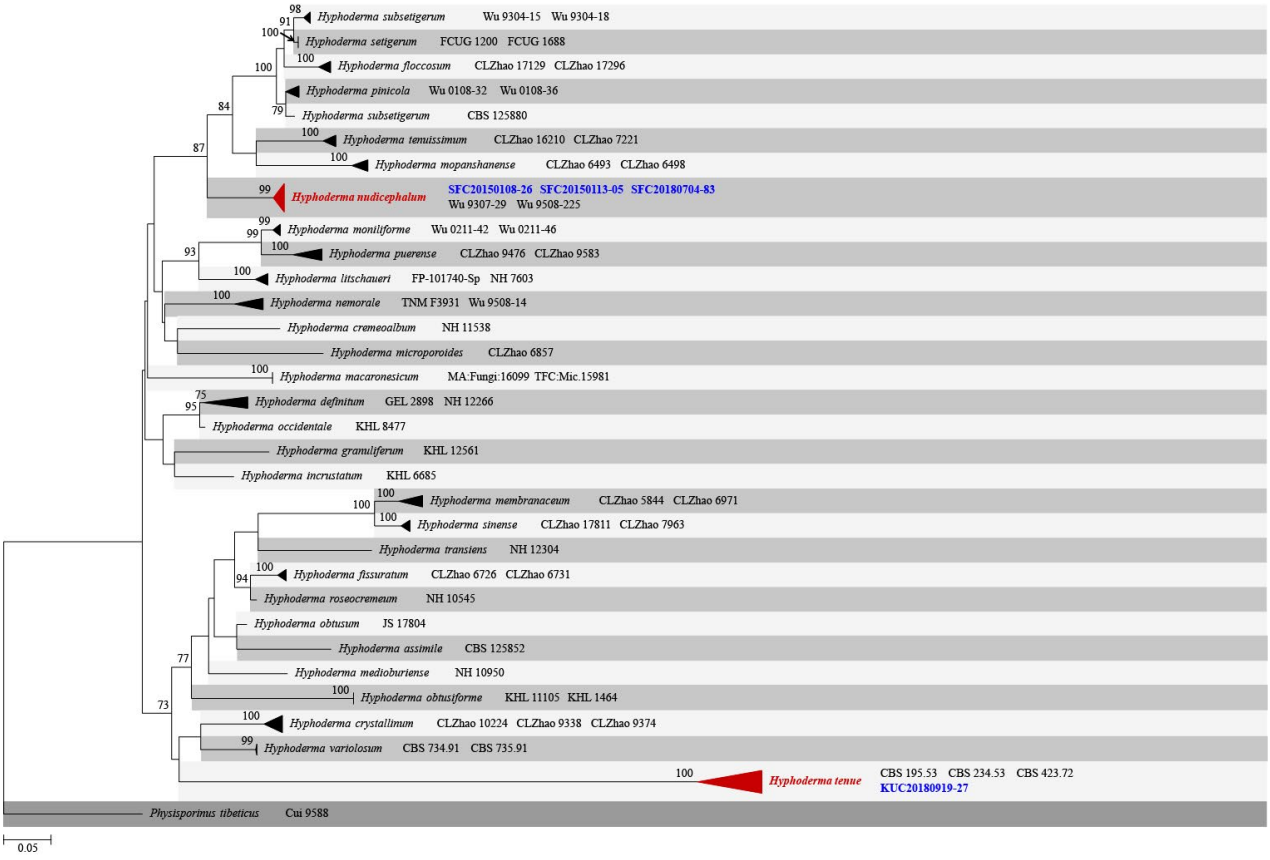


Fig. 8. The phylogenetic tree of *Hyphoderma nudicephalum* (SFC20150108-26, SFC20150113-05, and SFC20180704-83) and *H. tenue* (KUC20180919-27). The tree was constructed based on ITS and LSU gene datasets of the genus *Hyphoderma*. *Physisporinus tibeticus* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

clade with high bootstrap value (Fig. 8). *Hyphoderma nudicephalum* is a member of *H. setigerum* complex (Wu, 1997). *Hyphoderma nudicephalum* shows distinguishable morphological characteristics compared to *H. setigerum* and *H. subsetigerum*, representative species in *H. setigerum* complex (Wu, 1997). The basidiospore size of *H. setigerum* (7.5−12.5 × 3.5−5 μm) and *H. subsetigerum* (6−8 × 2.8−3.2 μm) are smaller than *H. nudicephalum* (Wu, 1997). In the original description, capitate and encrusted cystidia were described (Gilbertson and Blackwell, 1988), but cystidia were not observed in our specimens. The host trees of our specimens were all angiosperm trees, which accords with the original description (Gilbertson and Blackwell, 1988).

***Hyphoderma tenue* (Pat.) Donk,**
Fungus 27: 15 (1957) [MB#298781] (Figs. 1I and 2I)
Korean name: 작은돌기목재고약버섯

Basidiome resupinate, widely effused, thin. **Hymenial surface** crustaceous, odontoid, cracked when old, yellowish white to cream-colored, margin white to yellowish white. **Hyphal system** monomitic, generative hyphae simple septate, sometimes branched, without clamp connections, thin-walled, hyaline, 3.0−5.0 μm. **Basidia** clavate to subclavate, 4-spored, smooth, thin-walled, hyaline, 15.5−32.0 × 5.2−9.1 μm. **Cystidia** obovoid, smooth, thin-walled, hyaline, 15.8−41.1 × 4.1−12.4 μm. **Basidiospores** ellipsoid, smooth, thin-walled, hyaline, 6.5−9.4 × 4.3−5.9 μm [Q = 1.51−1.59].

Specimen examined. Korea, Gangwon-do, Sokcho-si, Seoraksan National Park, 38°10′18.5″N, 128°29′32.1″E, 198 m, mixed hardwood forest, occurring on the conifer branch, 19 Sep 2018, S. Jang and S. L. Kwon, KUC2018 0919-27 (**NIBRFG0000514543**).
Notes − *Hyphoderma tenue* is characterized by crustaceous and odontoid hymenial surface, and obovoid cystidia. According to the phylogenetic analysis, *H. tenue* formed a monophyletic clade with high bootstrap value, and closely related with *H. crystallinum* and *H. variolosum* (Fig. 8). *Hyphoderma variolosum* differs from *H. tenue* by narrower and cylindrical cystidia (40−50 × 4−6 μm) (Boidin and Gilles, 1991). In addition, *H. crystallinum* has two forms of cystidia; tubular and encrusted, and longer basidiospores (10.5−)11−14.5(−15) × 4−5.5(−6) μm (Guan and Zhao, 2021), which differs from *H. tenue*. The molecular work in this study was conducted using LSU region, so additional analysis using the ITS region is required for more accurate identification.

***Macrolepiota subcitrophylla* Z.W. Ge,**
Mycologia 53: 286 (2011) [MB#561826] (Figs. 1J and 2J)
Korean name: 노란주름큰갓버섯

Pileus ovoid to hemispherical when young, becoming convex to planate when mature, 12 cm in diam. **Pileus surface** white, covered with brownish yellow to light brown colored scales, scattered. **Lamellae** free, crowded, yellow, up to 1 cm. **Stipe** white, 14.0 × 1.5 cm, with white annulus. **Hyphal system** monomitic, generative hyphae septate with clamp connections, moderately branched, 2.1−5.5 μm in diam. **Basidia** clavate, 4-spored, smooth, hyaline, thin-walled, with a basal clamp connection, 25.3−35.2 × 9.3−11.4 μm. **Cheilocystidia** narrowly clavate, fusiform, smooth, thin-walled, hyaline, 24.0−50.2 × 5.8−9.5 μm. **Pleurocystidia** absent. **Basidiospores** ellipsoid, thick-walled, smooth, hyaline, 8.5−13.0 × 5.9−8.4 μm [Q = 1.44−1.55].

Specimen examined. Korea, Jeollabuk-do, Gochang-gun, Mt. Seonwoon, Seonwoonsa Temple, 35°29′51.4″N, 126°34′51.1″E, 33 m, mixed hardwood forest, occurring solitary on the ground covered with leaf litters, 25 Aug 2022, M. Cho, KUC20220825-04 (**NIBRFG0000514544**).
Notes − *Macrolepiota* Singer has a big pileus with scales on surface, and 40 species have been reported worldwide (Ge *et al*., 2010; Ge *et al*., 2012; Lebel and Syme, 2012; Otieno, 2018; Perez *et al*., 2018; Cho *et al*., 2019a). In Korea, four species were described previously (Cho *et al*., 2019a). *Macrolepiota subcitrophylla* is characterized by yellowish lamellae, narrowly clavate cheilocystidia, and ellipsoid basidiospores. *Macrolepiota subcitrophylla* has relatively small-sized basidiospores compared to other *Macrolepiota* species (Ge *et al*., 2012). The morphological characteristics of KUC20220825-04 are similar to the original description, but our specimen has longer cheilocystidia than the original description, 18−38 × 7−15 μm (Ge *et al*., 2012). *Macrolepiota subcitrophylla* is similar to *Ma. dolichaula* by having white pileus with brownish

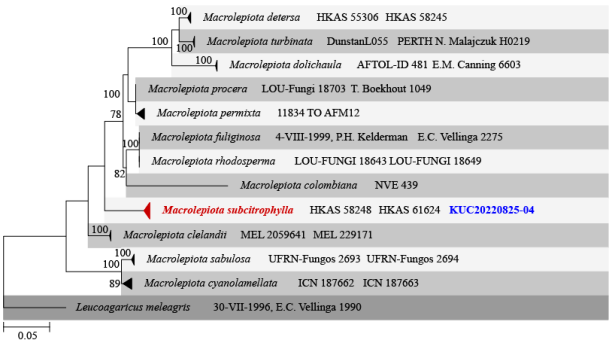


Fig. 9. The phylogenetic tree of *Macrolepiota subcitrophylla* KUC 20220825-04. The tree was constructed based on ITS gene datasets of the genus *Macrolepiota*. *Leucoagaricus meleagris* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

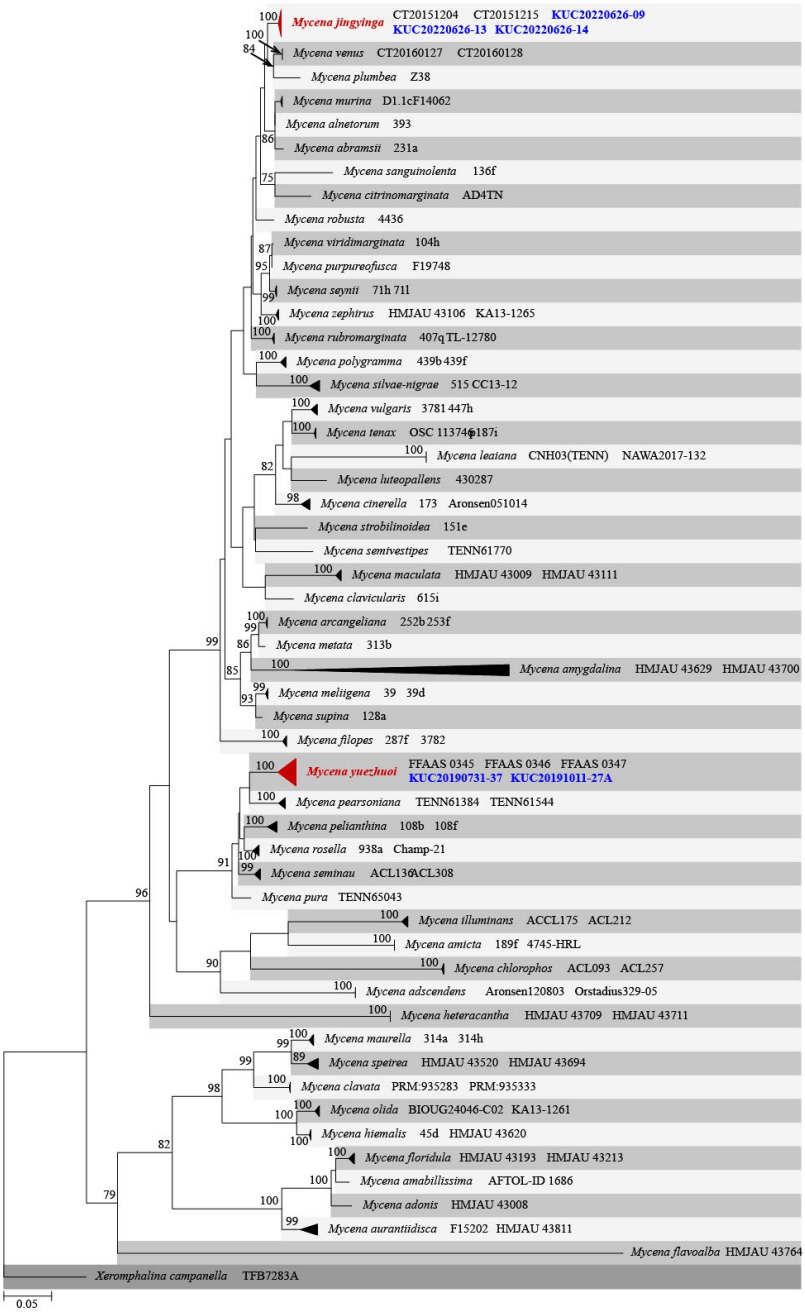


Fig. 10. The phylogenetic tree of *Mycena jingyinga* (KUC20220626-09, KUC20220626-13, and KUC20220626-14) and *My. yuezhuoi* (KUC20190731-37 and KUC20191011-27A). The tree was constructed based on ITS gene datasets of the genus *Mycena*. *Xeromphalina campanella* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

scales. However, *Ma. dolichaula* was only discovered in Southern regions such as Sri Lanka and Southern China, and it has larger basidiospores, 12.5−16.0 × 8.0−10.5 µm (Ge *et al*., 2010).

***Mycena jingyinga* C.C. Chang, C.Y. Chen, W.W. Lin & H.W. Kao,** Taiwania 65(3): 399 (2020) [MB#824043] (Figs. 1K and 2K)

Korean name: 반짝애주름버섯

Pileus convex to bell-shaped, 2−5 mm in diam. **Pileus surface** virgate, polished, white, grayish brown in the center. **Lamellae** adnate to subdecurrent, distant, entire, white, 10−13 mm. **Stipe** central, equal, covered with white pubescence becoming denser in the basal part, grayish white, 8−15 × 0.2−0.3 mm. **Hyphal system** monomitic, generative hyphae septate without clamp connections,

covered with short and simple projections, 2.7−4.0 μm in diam. **Pileipellis cells** are located in terminal of pileipellis, cylindrical, diverculate, have various forms, 23.3−37.0 × 4.8−6.8 μm. **Basidia** cylindrical, 4-spored, smooth, hyaline, thin-walled, 28.7−36.9 × 5.9−8.9 μm. **Cheilocystidia** lageniform to fusoid, smooth, hyaline, thin-walled, rarely diverculate in the apex, 35.6−68.8 × 6.0−10.7 μm. **Pleurocystidia** absent. **Basidiospores** cylindrical to ellipsoid, smooth, hyaline, thin-walled, sometimes containing guttules, 8.5−12.6 × 4.9−7.2 μm [Q = 1.73−1.75].

Specimen examined. Korea, Seoul, Seongbuk-gu, Mt. Gaewoon, 37°35′45.7″N, 127°01′42.2″E, 100 m, mixed hardwood forest, occurring gregarious on decayed wood, 26 Jun 2022, M. Cho, KUC20220626-09 (**NIBRFG0000514545**), KUC20220626-13 (**NIBRFG0000514546**), KUC20220626-14 (**NIBRFG0000514547**).

Notes − *Mycena* (Pers.) Roussel is large genus which has several bioluminescent species, and approximately 600 species are distributed worldwide (Desjardin *et al*., 2010; Harder *et al*., 2010; 2013; Robich, 2016; He *et al*., 2019a). In Korea, 41 *Mycena* species are reported (Cho, 2001; 2002; 2003; Han *et al*., 2010; 2011; Seok *et al*., 2015; Park *et al*., 2017; Kwon *et al*., 2020). *Mycena jingyinga* is characterized by white, convex to bell-shaped pileus with polished surface, lageniform cheilocystidia, and bioluminescent hyphae in the dark (Chang *et al*., 2020). *Mycena abramsii* was the most closely related species with *My. jingyinga* in the phylogenetic analysis (Fig. 10). They both have similar morphological characteristics. However, *My. abramsii* has larger pileus (10−40 mm) with grayish brown to dark brown surface, and pleurocystidia present (Maas Geesteranus, 1988; Aronsen and Læssøe, 2016). Also, bioluminescence of *My. abramsii* was not reported although *My. jingyinga* has bioluminescent characteristics (Chang *et al*., 2020). *Mycena jingyinga* specimens in the original description were all distributed in Taiwan, but due to the high elevation (above 1,000 m) and collection month (Dec to May) (Chang *et al*., 2020), the climatic conditions might be similar to our site.

***Mycena yuezhuoi* Z.W. Liu, Y.P. Ge & Q. Na,**
Phytotaxa 511(2): 153 (2021) [MB#838747]
(Figs. 1L and 2L)
Korean name: 보라애주름버섯

Pileus bell-shaped, decurved, 8−12 mm in diam. **Pileus surface** smooth, striate in the margin, light reddish brown in the center, becoming purple to the margin. **Lamellae** adnate, subdistant. **Stipe** central, equal, smooth, pale brown, 25−35 × 1−2 mm. **Hyphal system** monomitic, generative hyphae simple septate, rarely branched, without clamp connections, thin-walled, hyaline, 3.2−7.8 μm. **Basidia** cylindrical to subclavate, 4-spored, smooth, thin-walled, hyaline, with a clamp connection, 15.9−24.8 × 3.7−6.1 μm. **Cheilocystidia** rare, cylindrical to subclavate, 24.9−39.7 × 6.4−8.5 μm. **Pleurocystidia** absent. **Basidiospores** cylindrical, smooth, thin-walled, hyaline, sometimes bearing a guttule, 5.6−8.3 × 3.1−4.2 μm [Q = 1.81−1.98].

Specimen examined. Korea, Gyeongsangbuk-do, Cheongsong-gun, Juwangsan National Park, 36°24′02.4″N, 127°25′58.8″E, 346 m, coniferous forest, occurring gregarious on ground covered with leaf litter near Yongchu Falls, 31 Jul 2019, S. Jang and S. L. Kwon, KUC20190731-37 (**NIBRFG0000506126**); 36°23′56.6″N, 129°11′41.5″E, 828 m, hardwood forest, occurring on decayed Oriental oak (*Quercus variabilis*) trunk near Gamebong, 11 Oct 2019, S. Jang and S. L. Kwon, KUC20191011-27A (**NIBRFG0000506192**).

Notes − *Mycena yuezhuoi* is classified as *My. pura* complex in *Mycena* sect. *Calodontes* and is characterized by lilac to purple and bell-shaped pileus less than 35 mm in diam (Liu *et al*., 2021; 2022). *Mycena pearsoniana* is grouped with *My. yuezhuoi* in the phylogenetic analysis (Fig. 10). *Mycena pearsoniana* was previously reported in Juwangsan National Park (Kwon *et al*., 2020), which shows same habitat with KUC20190731-37 and KUC20191011-27A. *Mycena pearsoniana* differs from *My. yuezhuoi* by having a white to light brown pileus, clavate basidia, and wider basidiospores 5.5−9.1 × 3.5−4.8 μm (Singer, 1958; Maas Geesteranus, 1992; Kwon *et al*., 2020).

***Ophiocordyceps vespulae* F.Y. Long, Y.P. Xiao & T.C. Wen,** Phytotaxa 478(1): 35 (2021) [MB#556626]
(Figs. 1M and 2M)
Korean name: 땅벌포식동충하초

Stroma 4 cm long, 0.1 mm in diam, branched, stipitate, yellow to pale orange, arising from thorax of the host. **Fertile head** is not observed. ***Sexual morph*: Asci** narrowly cylindrical, thin-walled, hyaline, apex with apical cap, 40.3−73.2 × 3.4−6.9 μm. **Ascospores** narrowly cylindrical, filiform, smooth, thin-walled, hyaline, 5.1−9.1 × 0.7−1.3 μm. ***Asexual morph*** is not determined.

Specimen examined. Korea, Jeollabuk-do, Gochang-gun, Mt. Seonwoon, Seonwoonsa Temple, 35°29′51.4″N, 126°34′51.1″E, 33 m, mixed hardwood forest, occurring on Coleoptera species, 25 Aug 2022, M. Cho, KUC20220825-06 (NIBRFG0000514548).

Notes − *Ophiocordyceps* Petch is a parasitic genus on insects, and about 200 species are accepted worldwide, mostly in tropical forests (Ban *et al*., 2015; Sanjuan *et al*., 2015; Yang *et al*., 2015; Araújo *et al*., 2018; Khonsanit *et al*., 2019; Xiao *et al*., 2019; Long *et al*., 2021).

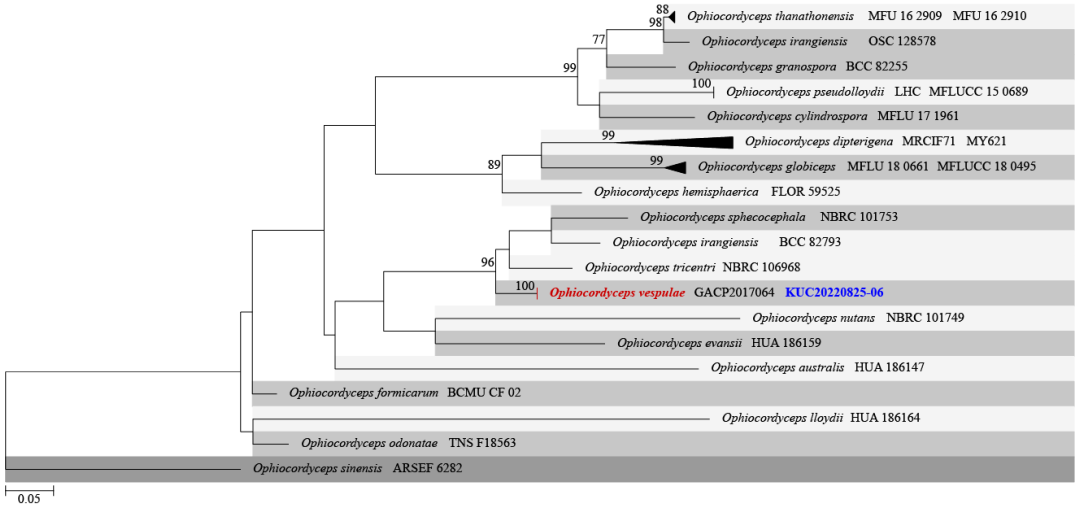


Fig. 11. The phylogenetic tree of *Ophiocordyceps vespulae* (KUC20220825-06). The tree was constructed based on ITS gene datasets of the genus *Ophiocordyceps*. *Ophiocordyceps sinensis* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

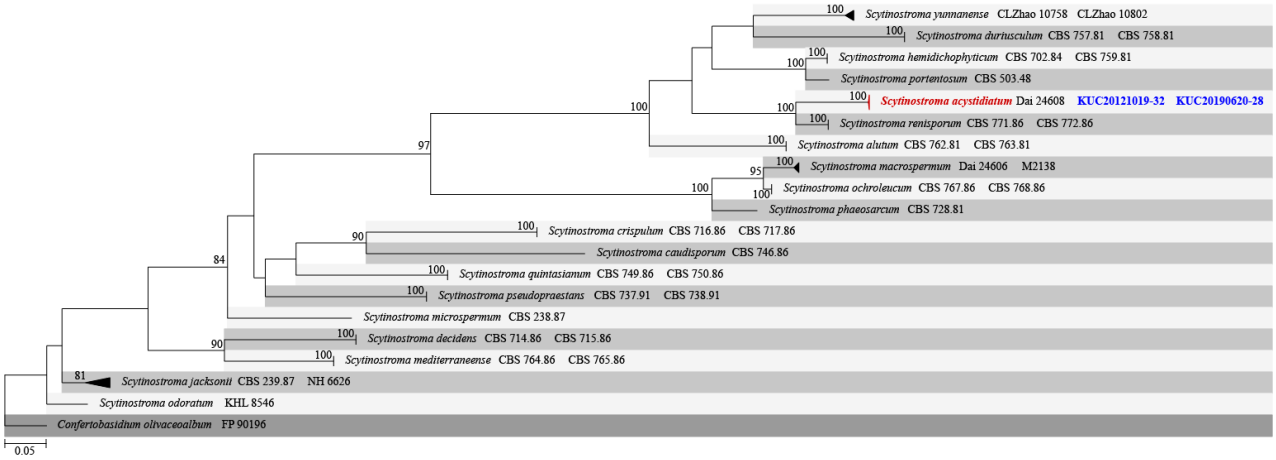


Fig. 12. The phylogenetic tree of *Scytinostroma acystidiatum* (KUC20121019-32 and KUC20190620-28). The tree was constructed based on ITS gene datasets of the genus *Scytinostroma*. *Confertobasidium olivaceoalbum* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

In Korea, 24 species are listed as *Ophiocordyceps* (Sung *et al*., 2011a; 2011b). This species is characterized by branched, yellow to pale orange stroma, and asci with apical cap (Long *et al*., 2021). KUC20220825-06 has similar morphological characteristics to the original description (Long *et al*., 2021), but fertile heads are not observed in our specimen. Also, the host is recorded as Coleoptera species in our specimen, but the host is identified as *Vespula* (Hymenoptera) in the original description (Long *et al*., 2021). According to the phylogenetic analysis, *O. tricentri* is identified as the most closely related species (Fig. 11). However, *O. tricentri* differs from *O. vespulae* by having wider asci, 5.3−7.5 µm in width (Long *et al*., 2021).

***Scytinostroma acystidiatum* Q.Y. Zhang, L.S. Bian & Q. Chen,** Frontiers in Cellular and Infection Microbiology 564(1): 13 (2023) [MB#848524] (Figs. 1N and 2N)
Korean name: 연노랑기질고약버섯

Basidiome annual, resupinate, effused, thin. **Hymenial surface** coriaceous, smooth, slightly cracked, pale yellow, margin white. **Hyphal system** dimitic, generative hyphae simple septate, rarely branched, without clamp connections, thin-walled, hyaline, 1.4−2.1 µm. Skeletal hyphae aseptate, frequently branched, interwoven, without clamp connections, thick-walled, hyaline, 1.9−2.8 µm. **Basidia**

subclavate to cylindrical, 4-spored, smooth, thin-walled, hyaline, with a basal clamp connection, 10.5−19.0 × 2.6−4.5 µm. **Cystidia** rare, cylindrical, slightly bent, 20.9−26.3 × 4.3−5.1 µm. **Basidiospores** narrowly ellipsoid to cylindrical, smooth, thin-walled, hyaline, 3.5−5.1 × 2.0−2.8 µm [Q = 1.75−1.82].

Specimen examined. Korea, Gyeongsangbuk-do, Cheongsong-gun, Juwangsan National Park, 36°26′26.0″N, 129°08′17.6″E, 346 m, mixed hardwood forest, occurring on hardwood branch near Dalgi Falls, 20 Jun 2019, S. Jang and S. L. Kwon, KUC20190620-28 (**NIBRFG0000506080**).

Notes − *Scytinostroma* Donk is a white-rot corticioid fungus, and 36 species have been reported worldwide (Donk, 1956; Nakasone, 2008; Wang *et al*., 2020; Zhang *et al*., 2023). Two species have been reported in Korea (Lee *et al*., 2004; Park *et al*., 2017). *Scytinostroma acystidiatum* is characterized by resupinate and coriaceous pale yellow basidiome, and dimitic hyphal system (Zhang *et al*., 2023). Morphologically, KUC20190620-28 has smaller basidiospores compared to original description, (4.5−)4.7−7 × (3−)3.5−4.7(−5) µm (Zhang *et al*., 2023). Also, cystidia were not described in the original description (Zhang *et al*., 2023), but few cystidia was observed in our specimen. In the phylogenetic analysis, *Sc. renisporum* is grouped with *Sc. acystidiatum* with high bootstrap value (Fig. 12). However, *Sc. renisporum* has membranaceous basidiome and larger cystidia, 20−35 × 6−10 µm (Boidin and Lanquetin, 1987). Furthermore, KUC20121019-32 was previously reported as Lachnocladiaceae sp. 1 in Jang *et al*. (2016b), and it was figured out as *Sc. acystidiatum* in this study.

***Steccherinum straminellum* (Bres.) Melo,**
Mycotaxon 54: 126 (1995) [MB#414192]
(Figs. 1O and 2O)
Korean name: 돌기바늘버섯

Basidiome annual, resupinate, effused, thin. **Hymenial surface** corky, tuberculate, aculei up to 0.4 mm, fibrillose at the margin, very pale yellow, margin white. **Hyphal system** dimitic, generative hyphae simple septate, branched, with clamp connections, thin-walled, hyaline, 2.1−3.4 µm. Skeletal hyphae aseptate, unbranched, without clamp connections, thick-walled, hyaline, 2.7−4.5 µm. **Basidia** subclavate to cylindrical, 4-spored, smooth, thin-walled, hyaline, with a basal clamp connection, 14.8−22.2 × 3.7−5.5 µm. **Basidiospores** narrowly ellipsoid to cylindrical, smooth, thin-walled, hyaline, bearing few guttules, 3.1−4.8 × 1.9−2.5 µm [Q = 1.63−1.92]. **Cystidia** rare.

Specimen examined. Korea, Gyeongsangbuk-do, Cheongsong-gun, Juwangsan National Park, 36°22′19.0″N, 129°11′06.2″E, 388 m, mixed hardwood forest, occurring on rotten *Pinus* branches near Jeolgol, 01 Nov 2018, S. Jang and S. L. Kwon, KUC20181101-53 (**NIBRFG0000514361**).

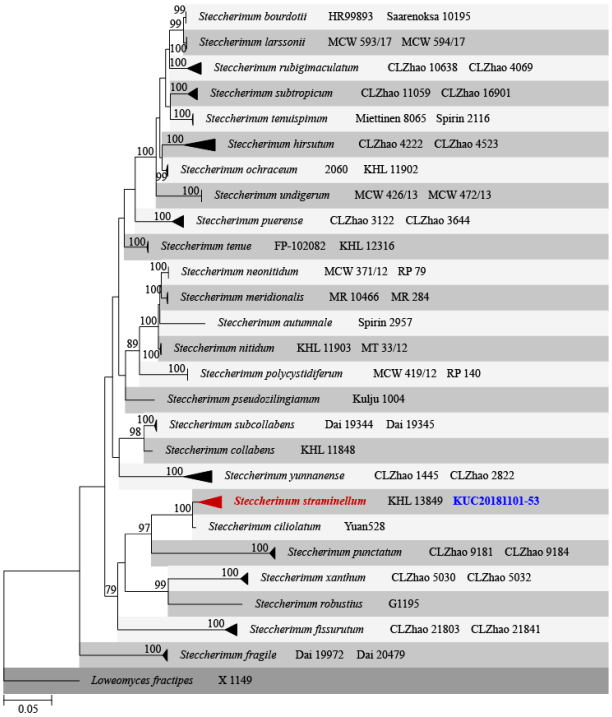


Fig. 13. The phylogenetic tree of *Steccherinum straminellum* (KUC201811101-53). The tree was constructed based on ITS and LSU gene datasets of the genus *Steccherinum*. *Loweomyces fractipes* was used as an outgroup. The newly generated sequence is shown in blue and bold. Bootstrap support values more than 70 are shown.

Notes − *Steccherinum* Gray is a wood-inhabiting genus, and approximately 80 species are accepted worldwide (Fries, 1821; Banker, 1912; Cunningham, 1958; Lindsey and Gilbertson, 1979; Melo, 1995; Spirin *et al*., 2007; Hjortstam and Ryvarden, 2008; Bernicchia and Gorjón, 2010; Westphalen *et al*., 2021; Dong *et al*., 2023). In Korea, seven species have been reported (Jung, 1996; Kim *et al*., 2009; Kim *et al*., 2015b; Jang *et al*., 2016b; Park *et al*., 2018). *Steccherinum straminellum* is characterized by corky and tuberculate hymenial surface with aculei, and narrowly ellipsoid to cylindrical basidiospores (Melo, 1995). KUC20181101-53 is well matched with the original description (Melo, 1995). According to the phylogenetic analysis, *St. straminellum* is grouped with *St. ciliolatum* and *St. punctatum* (Fig. 13). *St. ciliolatum* has dimitic hyphal system, and cylindrical basidiospores [Q = 1.81−2.04] (Maas Geesteranus, 1974), similar with *St. straminellum*. However, *St. punctatum* has monomitic hyphal system, and wider basidiospores, 3.6−4.5 × 2.6−3.4 µm (Melo, 1995).

Discussion

In this study, we discovered 15 unrecorded macrofungal species in various forested areas in Korea. These species were supported as unrecorded by morphological, molecular, and phylogenetic analyses. Among them, eight species are saprobic (*A. thiersii*, *E. bulakhae*, *E. pygmaeopapillatum*, *E. subtenuicystidiatum*, *G. kuruvense*, *Ma. subcitrophylla*, *My. jingyinga*, and *My. yuezhuoi*), four are wood-decaying corticioid (*H. nudicephalum*, *H. tenue*, *Sc. acystidiatum*, and *St. straminellum*), two are ectomycorrhizal (*Ba. alexandri* and *Bo. putuoensis*), and one parasitic (*O. vespulae*).

Interestingly, *A. thiersii*, *Bo. putuoensis*, *E. pygmaeopapillatum*, *E. subtenuicystidiatum*, *G. kuruvense*, and *My. jingyinga* are new to the temperate region of Northeast Asia. In addition, *Ba. alexandri* is a rare species globally, which was only reported from a single station in Far East Russia (Crous *et al*., 2018), and Southeast Korea in this study. This supports that *Ba. alexandri* prefers subarctic to temperate climate, which might be more severely affected by shifts in the distribution of host trees due to climate change. In this study, we identified seven species which are rare or newly discovered in temperate habitat of East Asia. This indicates that there are still many cryptic species in Korea, so continuous research is needed to discover new and rare macrofungal species.

Conflicts of Interest

The author of this paper has no affiliation with any interests and is solely responsible for the paper.

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