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Seventeen Unrecorded Species from Gayasan National Park in Korea

Hyun Lee^a, Myung Soo Park^a, Ji-Hyun Park^a, Hae Jin Cho^b , Ki Hyeong Park^a, Shinnam Yoo^a, Jun Won Lee^a, Nam Kyu Kim^c, Jin Sung Lee^c, Jae Young Park^d, Changmu Kim^e, Jae-Jin Kim^f and Young Woon Lim^a

^aSchool of Biological Sciences and Institute of Microbiology, Seoul National University, Seoul, Republic of Korea; ^bForest Plant Industry Department, Baekdudaegan National Arboretum, Bonghwa, Korea; ^cYurim Mushroom, Asan, Republic of Korea; ^dQ-myc Co, Seoul, Republic of Korea; ^eMicroorganism Resources Division, National Institute of Biological Resources, Incheon, Republic of Korea; ^fDivision of Environmental Science and Ecological Engineering, College of Life Science & Biotechnology, Korea University, Seoul, Republic of Korea

ABSTRACT

Macrofungi play important roles in forest ecology as wood decayers, symbionts, and pathogens of living trees. For the effective forest management, it is imperative to have a comprehensive overview of macrofungi diversity in specific areas. As a part of the National Institute of Biological Resources projects for discovering indigenous fungi in Korea, we collected macrofungi in Gayasan National Park from 2017 to 2018. These specimens were identified based on morphological characteristics and sequence analysis of internal transcribed spacer (ITS) or the nuclear large subunit rRNA (LSU) region. We discovered 17 macrofungi new to Korea: *Butyrea japonica*, *Ceriporia nanlingensis*, *Coltricia weii*, *Coltriciella subglobosa*, *Crepidotus crocophyllus*, *Cylindrobasidium laeve*, *Fulvoderma scaurum*, *Laetiporus cremeiporus*, *Lentinellus castoreus*, *Leucogyrophana mollusca*, *Marasmius insolitus*, *Nidularia deformis*, *Phaeophlebiopsis peniophoroides*, *Phanerochaete angustocystidiata*, *Phlebiopsis pilatii*, *Postia coeruleivirens*, and *Tengioboletus fujianensis*. We described their detailed morphological characteristics.

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1. Introduction

Macrofungi are fungal species that form large fruiting bodies visible by the naked eye [1]. They commonly include Basidiomycota and Ascomycota with large spore bearing structures, but also a few Zygomycota. Macrofungal species have crucial roles in ecosystems for nutrient cycles and wood decomposition. Depending on the nutritional modes, they can be classified into three groups: saprotrophs, symbiotrophs, and pathotrophs [2]. Saprotrophs decompose organic matters and contribute to cycling of various elements, such as carbon, nitrogen, and oxygen [3]. Symbiotrophs mobilize nutrients from soil to plants with mycorrhiza, helping the survival of plants [4]. Pathotrophs cause disease in living plants, leading to economic loss, but at the same time, play an essential role of maintaining the ecological balance in forest [5]. Some wild macrofungi are useful to human and animal for their nutritional and medicinal properties [6].

Due to their significant ecological and economic importance, it is necessary to understand macrofungal diversity based on trustworthy and

comprehensive information for their practical conservation [7,8]. Macrofungi have strong correlation with plant species diversity, and thus act as important indicators of forest community dynamics [9]. In addition, fungal community studies often reveal crucial information, including of rare and edible fungi [10]. An exhaustive fungal survey of an interested area, often achieved by repeated visits, can be useful for discovering new or unrecorded species.

Gayasan is located in Gyeongsangnam-do and Gyeongsangbuk-do at the eastern part of South Korea. For the preservation of the ecosystem and protection of biodiversity, Gayasan was designated as the National Park of Korea in 1972. Gayasan National Park has a well-preserved natural ecosystem which has been often surveyed for its composition and diversity of flora, fauna, and macrofungi [11–13]. Two previous fungal investigations of this region in 2007 and 2016 [14] confirmed that Gayasan has high levels of macrofungal diversity. As a part of the projects by the National Institute of Biological Resources, we surveyed the macrofungi in Gayasan National Park from 2017 to 2018, under the objective of better understanding fungal diversity

CONTACT Young Woon Lim ywlim@snu.ac.kr

Supplemental data for this article can be accessed [here](#).

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of the area and finding new or unrecorded fungal species.

For the identification of fungal species, we employed both morphological observation and molecular analysis. Many macrofungi cannot be identified at the species level using only morphological characters due to their morphological similarities. Sequence-based identification of fungi is now commonly used to overcome the limitation of morphology-based identification [15,16]. The collected samples were initially identified by the analysis of the ribosomal RNA sequence, then re-confirmed and described morphologically by microscopic observation. In this study, we identified 17 macrofungal species new to Korea based on morphological and molecular analyses and provided the detailed morphological descriptions.

2. Materials and methods

2.1. Sampling

Gayasan National Park (35°45'00"~35°49'30"N, 128°02'30"~128°09'30"E) is located across Hapcheon-gun and Geochang-gun of Gyeongsangnam-do and Goryeong-gun, Sungju-gun, and Gimcheon-si of Gyeongsangbuk-do, South Korea. Specimens were collected from 2017 to 2018 in Gayasan National Park. Dried specimens were deposited in the Seoul National University Fungus Collection (SFC).

2.2. DNA sequence-based identification

Genomic DNA was extracted using a modified CTAB extraction protocol [17]. The internal transcribed spacer (ITS) region, a fungal barcode sequence [18], was amplified in a C1000 thermal cycler (Bio-Rad, Richmond, CA) with primer sets of ITS1F/ITS4 [19] or ITS1F/ITS4B [20], as described in previous studies [21]. For *Tengioboletus fujianensis*, we used primer sets of LR0R/LR5 to amplify the nuclear large subunit rRNA (LSU) region [22,23]. The PCR products were purified with ExpinTM PCR Purification Kit (GeneAll Biotechnology, Seoul, Korea) according to the manufacturer's instructions. DNA sequencing was performed with corresponding PCR primer sets at Macrogen (Seoul, Korea) using ABI Prism 3700 Genetic Analyzer (Life Technologies, Gaithersburg, MD). Prior to the molecular identification, each sequence was compared with reference sequences in GenBank database using BLAST. Sequences were edited and aligned using MAFFT v7 [24]. Neighbor-joining phylogenetic analyses were performed in MEGA6 using the Kimura 2-parameter model and 1000 bootstrap replicates for tree inference. All the sequences of 17 species have been deposited in GenBank (Table 1).

2.3. Morphological observation

Identifications of the specimens were confirmed by their macro- and microscopic features, following the published descriptions. Microscopic observation was performed with 5% (w/v) KOH, 1% (w/v) phloxine, Congo red, and Melzer's reagent (IKI), using a Nikon SMZ1500 dissecting microscope and a Nikon Eclipse 80i optical microscope (Nikon, Tokyo, Japan). We measured basidia ($n=20$ /specimen), cystidia ($n=20$ /specimen), and basidiospores ($n=20$ /specimen).

3. Results and discussion

A total of 17 species were identified as unrecorded species in Korea using phylogenetic analyses of ITS or LSU sequences (Supporting Information Figure 1~6). Most species were identified by ITS phylogenetic trees, but *T. fujianensis* was identified based on LSU phylogenetic analysis [25]. All species showed 98.8%–100% sequence similarity with previously reported species and formed distinct clades (92–100 in Neighbor-joining bootstrap values). Subsequently, we observed morphology of each specimen and confirmed the identification by phylogenetic analyses. Among 17 unrecorded species, seven species were included in order Polyporales and four in order Agaricales. Other species belonged to order Hymenochaetales (3 species), Boletales (2 spp.), and Russulales (1 sp.). Eight unrecorded species had resupinate basidiocarps. The reverse taxonomy approach was appropriate for these species due to their subtle macro-morphological differences [26].

Five genera were new to Korea: *Butyrea* Miettinen, *Fulvoderma* L.W. Zhou & Y.C. Dai, *Nidularia* Fr. & Nordholm, *Phaeophlebiopsis* Floudas & Hibbett, and *Tengioboletus* G. Wu & Zhu L. Yang. *Butyrea* was segregated from *Junghuhnia* [27], *Fulvoderma* from *Pyrrhoderma* [28], and *Phaeophlebiopsis* from *Phlebiopsis* [29]. Morphologically, *Butyrea* has a straw colored basidiocarp and cylindrical basidiospores, whereas *Junghuhnia* bears a whitish basidiocarp and ellipsoid basidiospores [27]. The basidiocarp of *Fulvoderma* is yellowish brown, in contrast to that of *Pyrrhoderma* which is reddish brown to almost black [28]. In the case of *Phaeophlebiopsis* and *Phlebiopsis* which form distinct clades in the molecular phylogenetic analysis, there is no apparent character to distinguish two genera [29]. Therefore, phylogenetic analyses were vital to correctly identify species belonging to these genera.

Some species have long been misidentified as other species or genus because of the similarities in morphological features. These species are difficult to identify correctly without molecular phylogenetic analyses. To date, *Cylindrobasidium laeve* has been misidentified as *C. evolvens* [30–33] because of the shared



Figure 1. Fruiting bodies of the 17 unrecorded species in Korea. (A) *Crepidotus crocophyllus*; (B and C) *Cylindrobasidium laeve*; (D) *Marasmius insolitus*; (E) *Nidularia deformis*; (F) *Leucogyrophana mollusca*; (G) *Tengioboletus reticulatus*; (H) *Coltricia weii*; (I) *Coltriciella subglobosa*; (J) *Fulvoderma scaurum*; (K) *Butyrea japonica*; (L) *Ceriporia nanlingensis*; (M) *Laetiporus cremeiporus*; (N) *Phaeophlebiopsis peniophoroides*; (O) *Phanerochaete angustocystidiata*; (P) *Phlebiopsis pilatii*; (Q) *Postia coeruleivirens*; (R) *Lentinellus castoreus*.

morphological characters, such as almost resupinate and grayish basidiocarp. In the case of *Laetiporus cremeiporus*, the accurate identification was difficult due to overlapping micro- and macro-morphological characteristics with *L. surphureus*, of which are orange pileus and cream to white pores [30,31,34,35]. *Postia coeruleivirens* also has been incorrectly identified as

P. caesia [30,34–36] because of the shared characters between two species: conchate and whitish basidiocarp sometimes with bluish flecks. *Nidularia deformis* and *T. fujianensis* have long been identified as members of *Cyathus* and *Xerocomus*, respectively, based on morphological observations [33,37]. Overlooking the presence of funicular cords under peridioles caused

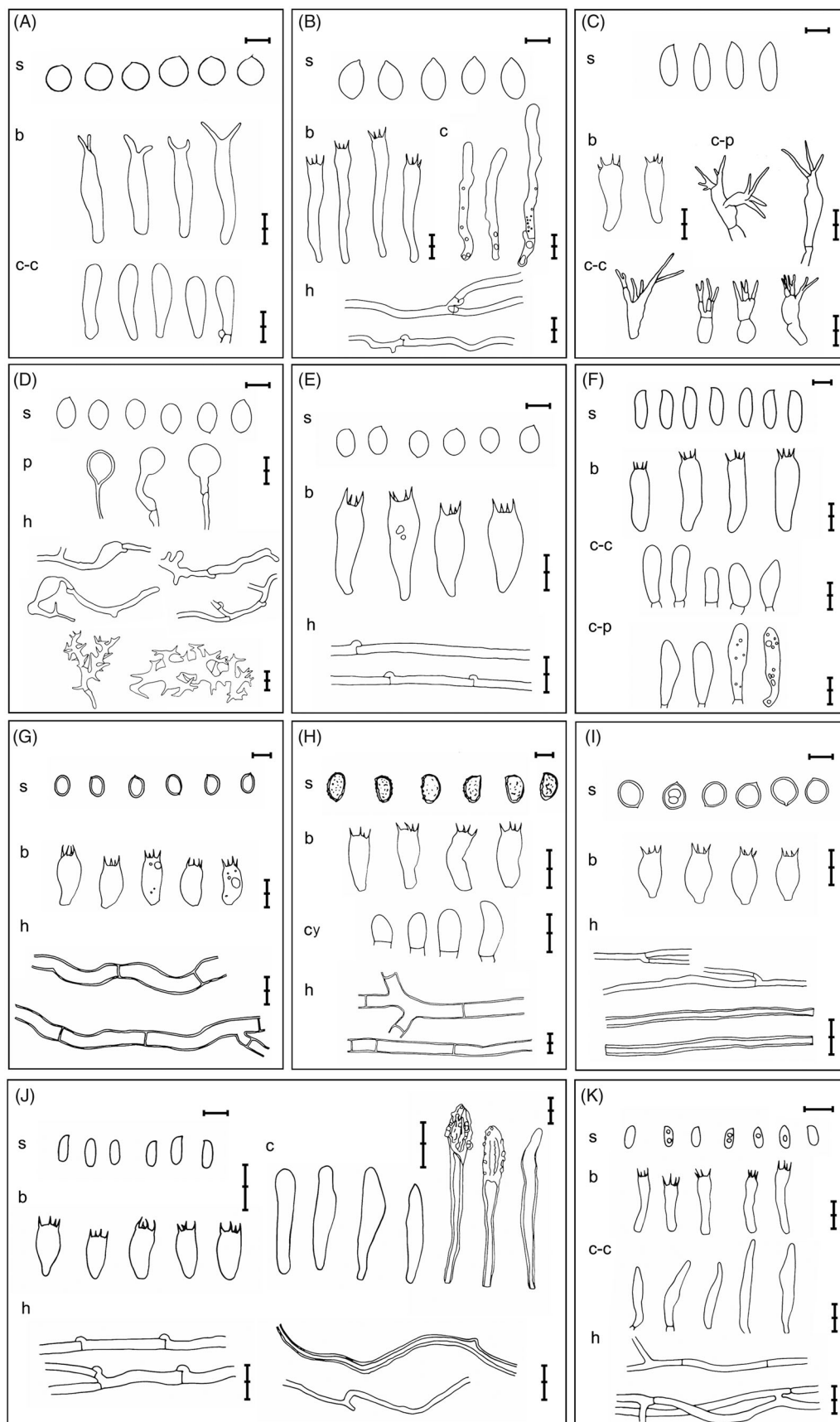


Figure 2. Microscopic feature of the 17 unrecorded species in Korea. (A) *Crepidotus crocophyllus*; (B) *Cylindrobasidium laeve*; (C) *Marasmius insolitus*; (D) *Nidularia deformis*; (E) *Leucogyrophana mollusca*; (F) *Tengioboletus reticulatus*; (G) *Coltricia weii*; (H) *Coltriciella subglobosa*; (I) *Fulvoderma scaurum*; (J) *Butyrea japonica*; (K) *Ceriporia nanlingensis*; (L) *Laetiporus cremeiporus*; (M) *Phaeophlebiopsis peniophoroides*; (N) *Phanerochaete angustocystidiata*; (O) *Phlebiopsis pilatii*; (P) *Postia coeruleivirens*; (Q) *Lentinellus castoreus*. (s: basidiospores, b: basidia, c: cystidia, c-c: cheilocystidia, c-p: pleurocystidia, cy: cystidioles, dh: dendrohyphidia h: hyphae, p: peridioles; a scale bar = 5 μm).

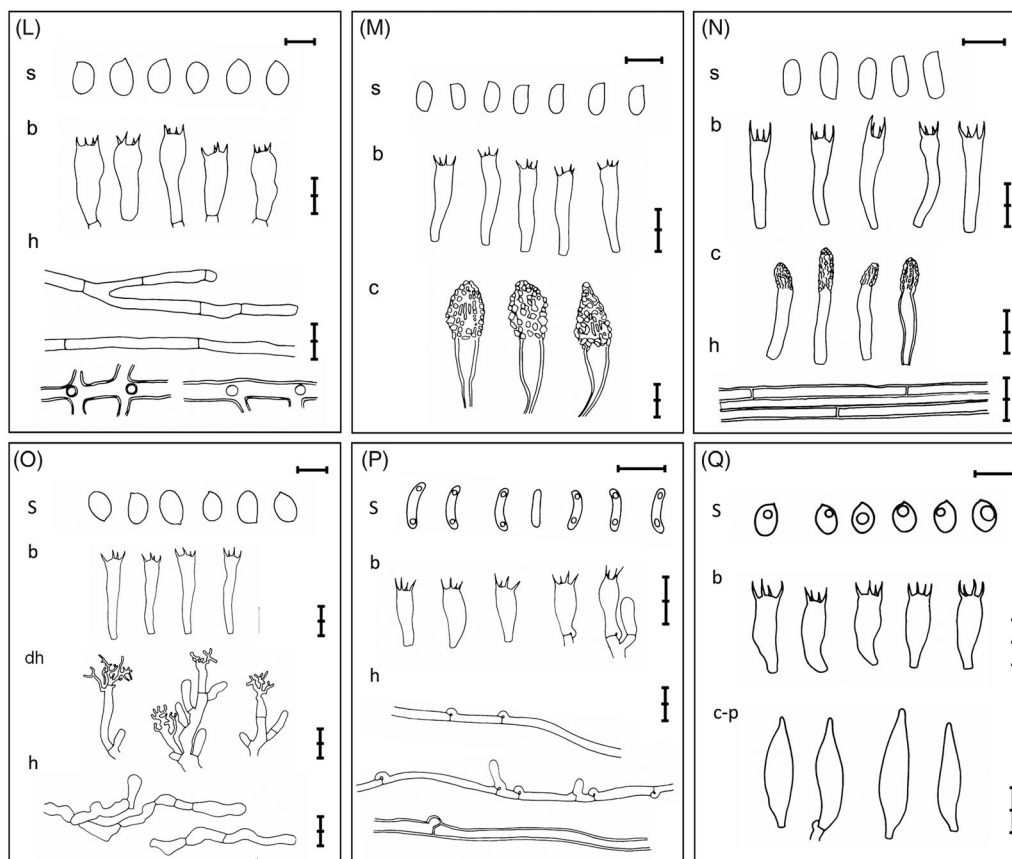


Figure 2. Continued.

misidentification of *Nidularia* as *Cyathus* [38]. In the past, boletes with tomentose, dry, and brownish pileus were treated as *Xerocomus* in Korea [30,31,34,35,39]. However, some distinctive characters of *Tengioboletus*, such as white to yellow hymenophore and context without color change when broken, make it possible to distinguish *Tengioboletus* from *Xerocomus* [25].

Numerous misidentifications found in the past reports suggest that much fungal diversity of Korea is yet to be discovered. In order to identify macrofungi precisely, molecular analysis must be performed with a well-curated macrofungal sequence database and coupled with morphological observation [16]. Backed by exhaustive and continuous fungal surveys, the combined approach will increase the possibility of discovering more unrecorded or novel macrofungi in Korea.

4. Taxonomy

4.1. Order Agaricales

4.1.1. *Crepidotus crocophyllus* (Berk.) Sacc., *Syll. fung. (Abellini)* 5: 886 (1887)

Pileus 10–65 mm in diam., semicircular to fan-shaped, broadly convex, sometimes applanate, whitish to ocherous brown or pale orange brown, with reddish brown fibrils or small scales, sometimes with whitish to pale orange fuzz around the attachment part to the substrate. **Lamellae** crowded,

whitish when young, becoming brown when mature. **Cheilocystidia** subcylindrical to clavate, sometimes subutriform, $20\text{--}35 \times 5\text{--}10\ \mu\text{m}$. **Basidia** clavate to narrowly clavate, $25\text{--}47 \times 6\text{--}9\ \mu\text{m}$, with a basal clamp and mainly 2-spored, often 4-spored, rarely 1-spored. **Basidiospores** globose, occasionally subglobose, $5.1\text{--}7.2 \times 4.9\text{--}7.0\ \mu\text{m}$, finely punctate (Figures 1A and 2A).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, $35^{\circ}47'41''\text{N}$ $128^{\circ}05'02''\text{E}$, 618 m, 7 Sep 2018, H. Lee, N. H. Kim & A. Lupala, SFC20180907-112.

Remarks: This species is characterized by having an orange brown pileus with fibrils or small scales. Unlike the previous description of *C. crocophyllus* given by Bandala et al. [40], 2-spored basidia were frequently observed in the specimen observed.

4.1.2. *Cylindrobasidium laeve* (Pers.) Chamuris, *Mycotaxon* 20(2): 587 (1984)

Basidiocarps resupinate, sometimes semipileate, easily detached from the substrate, whitish spots when young which expand to radial lines and then form cracks, on vertical substrates with pileus-like edges or pileoli; upper surface of exposed edge tomentose, often zonate. **Hymenophore** uneven to tuberculate, cream to reddish ocher when young, grayish when old, margin white and finely redented when young. **Hyphal system** monomitic, hyphae thin- to thick-

Table 1. Molecular and morphological identification of unrecorded species obtained from Gayasan National Park.

Species	Order	Specimen ID	Gen. Acc. Nos.	
			ITS	LSU
<i>Nidularia deformis</i>	Aga.	SFC20170908-34	MN973804	
<i>Crepidotus crocophyllus</i>	Aga.	SFC20180907-112	MN973792	
<i>Marasmius insolitus</i>	Aga.	SFC20180907-121	MN973791	
<i>Cylindrobasidium laeve</i>	Aga.	SFC20170208-07	MN973793	
<i>Lentinellus castoreus</i>	Rus.	SFC20170726-44	MN973790	
<i>Tengioboletus fujianensis</i>	Bol.	SFC20180725-31		MN960592
<i>Leucogyrophana mollusca</i>	Bol.	SFC20170822-61	MN973805	
<i>Coltricia weii</i>	Hym.	SFC20170725-23	MN973796	
<i>Coltriciella subglobosa</i>	Hym.	SFC20170316-01	MN973795	
<i>Fulvoderma scaurum</i>	Hym.	SFC20170908-69	MN973803	
<i>Phaeophlebiopsis peniophoroides</i>	Pol.	SFC20170908-86	MN973794	
<i>Laetiporus cremeiporus</i>	Pol.	SFC20170908-42	MN973806	
		SFC20180830-40	MN973807	
<i>Postia coeruleivirens</i>	Pol.	SFC20180725-73	MN973798	
<i>Ceriporia nanlingensis</i>	Pol.	SFC20180626-06	MN973802	
<i>Phanerochaete angustocystidiata</i>	Pol.	SFC20170316-16	MN973801	
<i>Phlebiopsis pilatii</i>	Pol.	SFC20170208-01	MN973800	
		SFC20170208-05	MN973799	
<i>Butyrea japonica</i>	Pol.	SFC20170823-29	MN973797	

Order: Aga: Agaricales; Bol: Boletales; Hym: Hymenochaetales; Pol: Polyporales; Rus: Russulales.

walled, 3–5 µm in diam., septa with clamp connections. **Leptocystidia** cylindrical to slenderly subclavate, sometimes tortuous, 40–75 × 3–6 µm. **Basidia** cylindrical to slenderly subclavate, 45–60 × 5–8 µm, 4-spored, with a basal clamp. **Basidiospores** oval, smooth, hyaline, 7.5–10.3 × 5.2–6.1 µm (Figures 1B, 1C, and 2B).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'50"N 128°05'44"E, 585 m, 8 Feb 2017, Y. W. Lim, N. K. Kim & H. J. Cho, SFC20170208-07.

Remarks: This species has been misidentified as *Cylindrobasidium evolvens* in Korea. *C. laeve* differs from *C. evolvens* by the shape and dimension of leptocystidia. While the leptocystidia of *C. laeve* is cylindrical to slenderly subclavate, that of *C. evolvens* is fusiform and wider (45–70 × 5–7 µm) [41].

4.1.3. *Marasmius insolitus* Kiyashko & E.F. Malysheva, *Phytotaxa* 186(1): 14 (2014)

Pileus 8–20 mm in diam., hemispherical to convex, sometimes indistinctly umbonate, slightly pruinose when young, pale yellow with slightly darker center; margin slightly inflexed. **Lamellae** adnate, crowded, with 2–3 series of lamellulae, whitish to pale cream; lamellar edge serrulate. **Stipe** 30–60 × 2–3 mm, cylindrical, hollow, pruinose, pale cream in upper part, grayish brown at base, with whitish basal tomentum. **Cheilocystidia** numerous, thick-walled, broom-shaped, main body subcylindrical to subclavate, sometimes irregular in outline, 12.3–28.8 × 3.8–7.1 µm, thick-walled apical projections up to 15 µm long. **Pleurocystidia** numerous, similar to cheilocystidia in shape and size. **Basidia** clavate, 22.7–29.4 × 5.5–7.2 µm, 4-spored. **Basidiospores**

ellipsoid, 9.4–12.5 × 3.7–4.4 µm, smooth, thin-walled, hyaline (Figures 1D and 2C).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'11"N 128°05'09"E, 653 m, 7 Sep 2018, H. Lee, N. H. Kim & A. Lupala, SFC20180907-112.

Remarks: *M. insolitus* is characterized by having a pale yellowish pileus, a pruinose stipe, and broom-like cystidia. The original description of this species [42] states that the pileus and the stipe are similar in color. In this specimen, however, the color of the stipe is darker than the pileus.

4.1.4. *Nidularia deformis* (Willd.) Fr., in Fries & Nordholm, *Symb. gasteromyc. (Lund)* 1: 3 (1817)

Basidiocarp small, 3–10 mm in diam., globose to subglobose, often pea-shaped, tuberculate; sessile and broadly attached at the base. **Peridium** creamy white to grayish cinnamon, floccose, inner side smooth, completely enclosing when young, cover falling away when mature. **Peridioles** 1–1.8 mm in diam., lenticular, brown to coffee brown, smooth and glossy, immersed in mucus. **Peridial hyphae** 2–7 µm in diam., with many spinose branches, pale brown, with slightly thickened wall. **Basidia** not observed. **Basidiospores** 6.4–8.1 × 3.8–4.6 µm, broadly ellipsoid to ovoid, hyaline, with slightly thickened wall (Figures 1E and 2D).

Specimen examined: Korea. Gyeongsangbuk-do Seongju-gun, Gayasan National Park, 35°48'25"N 128°08'24"E, 622 m, 8 Sep 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170908-34.

Remarks: The genus *Nidularia* is first to be reported in Korea. In the past, a species having peridioles with funicular cords was identified as *Cyathus*, but the specimen in this study has spiny hyphae and peridioles without funicular cords,

which are typical characteristics of the genus *Nidularia* [38].

4.2. Order Boletales

4.2.1. *Leucogyrophana mollusca* (Fr.) Pouzar, *Česká Mykol.* 12(1): 33 (1958)

Basidiocarps annual, resupinate, effused, thin and delicate. **Hymenophore** meruloid to smooth, bright orange when fresh, buff to pale yellow when dry; margin whitish and floccose to fimbriate when fresh. **Subiculum** monomitic, subicular hyphae with clamp connections, thin walled, 2–4.5 µm in diam., occasionally branching. **Basidia** clavate to subclavate, 8–10 × 23–35 µm, 4-spored, with a basal clamp. **Basidiospores** broadly ellipsoid to ellipsoid, 5.2–6.3 × 4–5.5 µm, smooth, dextrinoid (Figures 1F and 2E).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'53"N 128°05'55"E, 640 m, 22 Aug 2017, H. J. Cho & K. H. Park, SFC20170822-61.

Remarks: *L. mollusca* is morphologically similar to *L. pseudomollusca*, a species previously reported in Korea. *L. mollusca* is distinguished by the basidiospore size which is smaller than that of *L. pseudomollusca* (6–7.5 (–9) × 4–5 µm) [41].

4.2.2. *Tengioboletus reticulatus* G. Wu & Zhu L. Yang, in Wu, Li, Zhu, Zhao, Han, Cui, Li, Xu & Yang, *Fungal Diversity* 81: 146 (2016)

Pileus 50–120 mm in diam., convex when young, applanate when mature, olive brown to dark brown, smooth, dry. **Context** pale yellow, non-discoloration when cut. **Hymenophore** adnate to slightly sinuate, yellow, up to 10 mm thick; pores ca. 1/mm; tubes up to 10 mm long, yellow. **Stipe** 70–140 × 10–20 mm, subcylindrical to subclavate, light yellow to yellowish brown, with distinct olive brown reticulations, non-discoloration when cut; basal mycelium cream colored. **Cheilocystidia** scattered, 15–32 × 6–9 µm, cylindrical to subclavate, thin-walled. **Pleurocystidia** scattered, 30–55 × 8–10 µm, fusiform, thin-walled. **Basidia** subclavate to clavate, 31–38 × 8–13 µm, 4-spored. **Basidiospores** subfusiform, 11–14 × 3.5–5.7 µm, yellowish brown, smooth (Figures 1G and 2F).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'43"N 128°08'24"E, 622 m, 25 Jul 2018, H. Lee, H. J. Cho & N. H. Kim, SFC20180725-31.

Remarks: *Tengioboletus* is the genus introduced to Korea by this study. The specimen collected in Korea is generally consistent with the original

description of *T. reticulatus* [25], but the reticulation of stipe is rather dark.

4.3. Order Hymenochaetales

4.3.1. *Coltricia weii* Y.C. Dai, in Dai, Yuan & Cui, *Sydowia* 62(1): 16 (2010)

Basidiocarps annual, stipitate, leathery, corky. **Pilei** circular, applanate to slightly infundibuliform, 25–40 mm in diam. **Upper surface** orange brown to dark reddish brown, distinctly zonate, velutinous; margin entire, sometimes crenate, often wavy. **Pore surface** cream to pale buff when young, becoming grayish brown; pores round to angular, 2–4/mm; dissepiments entire, often slightly lacerate. **Stipe** dark brown, corky, velutinous, 10–17 × 2–3 mm. **Hyphal system** monomitic, generative hyphae simple septate, yellowish brown, slightly thick-walled, occasionally branched, 5–8 µm in diam. **Basidia** clavate to subclavate, 15–22 × 7–9.5 µm, 4-spored. **Basidiospores** mostly broadly ellipsoid, 5.5–6.3 × 4.5–5.2 µm, thick-walled, smooth (Figures 1H and 2G).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'41"N 128°05'02"E, 604 m, 25 Jul 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170725-23.

Remarks: *C. weii* is morphologically similar to *C. cinnamomea*, but the size of basidiospore is smaller than that of *C. cinnamomea* (5.6–6.8 × 4.3–5.0 µm vs 6.9–8.1 × 5.5–6.4 µm) [43].

4.3.2. *Coltriciella subglobosa* Y.C. Dai, *Fungal Diversity* 45: 160 (2010)

Basidiocarps annual, resupinate to reflexed, soft, filaceous when fresh, cottony when dry. **Pilei** often fused, sometimes imbricate. **Upper surface** velutinous, grayish brown. **Pore surface** reddish brown, margin cream to pale yellow; **pores** round, 3–4/mm; dissepiments slightly lacerate. **Hyphal system** monomitic, simple septate, yellowish brown, frequently branched, 6–9 µm in diam. **Cystidioles** present, subcylindrical to slightly ventricose, 5–22 × 6–8 µm. **Basidia** clavate to subclavate, 19–24 × 8–11 µm, thin-walled, 4-spored. **Basidiospores** subglobose to broadly ellipsoid, 6.4–8.1 × 5.0–6.2 µm, yellowish brown, verrucose (Figures 1I and 2H).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°48'20"N 128°06'05"E, 692 m, 16 Mar 2017, Y. W. Lim, SFC20170316-01.

Remarks: The specimen in this study morphologically fits the original description of *C. subglobosa* [44]. *C. subglobosa* is easily distinguished from other species by effused-reflexed basidiocarp and subglobose basidiospore.

4.3.3. *Fulvoderma scaurum* (Lloyd) L.W. Zhou & Y.C. Dai, in Zhou, Ji, Vlasák & Dai, *Mycologia* 110(5): 879 (2018)

Basidiocarps semi-stipitate to stipitate, on dead woods. **Pilei** applanate, sometimes convex, depressed at the center, up to 75 mm in diam., margin entire. **Upper surface** with a yellow to brown, becoming blackish brown, glabrous, zonate, rugose, and sulcate, margin white when young; if present, stipe lateral, 60 × 10 mm, glabrous, same or darker color with pilei. **Pore surface** yellowish brown to brown; pores round, 6–8/mm. **Hyphal system** monomitic, generative hyphae up to 5 µm in diam., parallel. **Basidia** clavate, 11–16 × 6–10 µm, 4-spored. **Basidiospores** globose to subglobose, 5–6.5 × 5–6 µm, smooth, hyaline, sometimes guttulate (Figures 1J and 2I).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'51"N 128°05'43"E, 584 m, 8 Sep 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170908-69.

Remarks: *Fulvoderma* is first to be reported in Korea. *F. scaurum* was used to be identified as *Pyrrhoderma scaurum*, but Zhou et al. [28] recently introduced a new genus *Fulvoderma*. *P. scaurum* was subsequently transferred to the genus *Fulvoderma*. While the genus *Pyrrhoderma* has resupinate basidiocarp, the genus *Fulvoderma* has sessile or stipitate basidiocarp.

4.4. Order Polyporales

4.4.1. *Butyrea japonica* (Núñez & Ryvarden) Miettinen & Ryvarden, *Ann. bot. fenn.* 53(3–4): 161 (2016)

Basidiocarps annual, resupinate, up to 80 mm in diam. **Pore surface** cream to pale yellow; pores circular to angular, 5–7/mm. **Hyphal system** dimitic, generative hyphae thin-walled, with clamp connections, 2–3 µm in diam., skeletal hyphae thick-walled, 2–4 µm in diam. **Cystidia** cylindrical to subclavate, 25–38 × 4–7 µm. **Basidia** clavate, 12–19 × 3.5–5 µm, 4-spored, with a basal clamp. **Basidiospores** cylindrical, straight to suballantoid, 4–5 × 2–2.4 µm, smooth, inamyloid (Figures 1K and 2J).

Specimen examined: Korea. Gyeongsangbuk-do Seongju-gun, Gayasan National Park, 35°48'28"N 128°08'21"E, 654 m, 23 Aug 2017, H. J. Cho & K. H. Park, SFC20170823-29.

Remarks: *Butyrea* is the genus first reported in Korea from this study. Miettinen & Ryvarden [27] established a new genus *Butyrea*, which included only two species, *B. japonica* and *B. luteoalba*. *B. japonica* is distinguished from *B. luteoalba* by the presence of gloeocystidia. In addition, *B. japonica* is

distributed in Asia, while *B. luteoalba* is distributed in North Europe.

4.4.2. *Ceriporia nanlingensis* B.K. Cui & B.S. Jia, in Jia & Cui, *Mycotaxon* 116: 458 (2011)

Basidiocarps annual, resupinate, corky, fragile when dry, up to 0.6 mm thick. **Pore surface** white to pale pink when fresh, brownish when dry; pores irregular, 3–6/mm; dissepiments mostly thin, entire. **Hyphal system** monomitic, generative hyphae thin-walled, sometimes thick-walled, often branched, 3–7 µm in diam. **Basidia** clavate, 18–28 × 3.5–5 µm, 4-spored. **Basidiospores** ellipsoid to oblong, 3.5–5 × 1.5–2 µm, mostly with guttules (Figures 1L and 2K).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'07"N 128°04'59"E, 721 m, 26 Jun 2018, H. Lee, H. J. Cho & N. H. Kim, SFC20180626-06.

Remarks: *C. nanlingensis* is characterized by having cystidia and a lavender colored pore surface. *C. viridans* is morphologically similar to *C. nanlingensis*, but the former does not have cystidia [45].

4.4.3. *Laetiporus cremeiporus* Y. Ota & T. Hatt., *Mycol. Res.* 113(11): 1289 (2009)

Basidiocarps annual, imbricate, imbricate clusters up to 400 mm long. **Pileus** flabelliform, up to 300 mm wide. **Upper surface** bright orange to reddish, often zonate, radially rugose. **Pore surface** white to pale cream; pores nearly circular to angular, 2–3/mm, with thin dissepiments. **Hyphal system** dimitic, generative hyphae thin-walled, rarely branched, 4–11 µm in diam., binding hyphae thick-walled, non-septate, up to 20 µm in diam. **Basidia** clavate, 16–28 × 5–8 µm, 2- or 4-spored. **Basidiospores** ellipsoid to oblong, 5–7.5 × 3.5–5 µm (Figures 1M and 2L).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'29"N 128°06'01"E, 515 m, 30 Aug 2018, H. Lee, N. H. Kim & A. Lupala, SFC20180830-40; *ibid*, 35°47'32"N 128°05'52"E, 535 m, 8 Sep 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170908-42.

Remarks: Due to the light orange to reddish orange pileus surface and yellowish white to cream pore surface, *L. cremeiporus* has often been misidentified as *L. sulphureus*. However, Ota et al. [46] confirmed that *L. sulphureus* s. lat. was geographically divided into three phylogenetic species (East Asia, Europe, and North America) based on ITS sequences. Although it is difficult to distinguish three species based on morphological characteristics, *L. sulphureus* in East Asia is identified as *L. cremeiporus*, in accordance with the phylogenetic analyses and geographical distribution [46].

4.4.4. *Phaeophlebiopsis peniophoroides* (Gilb. & Adask.) Floudas & Hibbett, *Fungal Biology* 119(7): 710 (2015)

Basidiocarps annual, entirely resupinate, with cracks. **Hymenophore** pale gray to yellowish gray, smooth, margin whitish. **Hyphal system** monomitic, hyphae with frequent branching, 2–6 µm in diam. **Cystidia** conical, incrustated with crystals, 10–25 × 7–15 µm. **Basidia** subcylindrical to subclavate, 17–28 × 3–5.5 µm, 4-spored. **Basidiospores** ellipsoid to oblong, 3.5–5 × 2–2.5 µm, smooth, thin-walled, inamyloid (Figures 1N and 2M).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°48'25"N 128°06'18"E, 743 m, 8 Sep 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170908-86.

Remarks: *Phaeophlebiopsis* is first reported in Korea. Floudas and Hibbett [29] introduced the new genus *Phaeophlebiopsis* to accommodate several *Phlebiopsis*-like species. The specimen collected in Korea morphologically corresponds to the original description [47] and is distinguished from other *Phlebiopsis* species recorded in Korea by having a grayish hymenophore.

4.4.5. *Phanerochaete angustocystidiata* Sheng H. Wu, *Bot. Bull. Acad. Sin., Taipei* 41(2): 166 (2000)

Basidiocarps annual, entirely resupinate, membranaceous. **Hymenophore** whitish gray to light cream, cracked; margin white. **Hyphal system** monomitic, generative hyphae 2–6 µm in diam., thin-walled to thick-walled. **Lamprocystidia** cylindrical, subulate, incrustated with crystals at upper part, 25–50 × 4–8 µm. **Basidia** clavate to subclavate, 17–33 × 3.5–5 µm, 2- or 4-spored. **Basidiospores** cylindrical, 5.5–7.5 × 2–3 µm, inamyloid (Figures 1O and 2N).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°48'23"N 128°05'41"E, 684 m, 16 Mar 2017, Y. W. Lim, SFC20170316-16.

Remarks: This species is characterized by having narrow cystidia, basidiospore, and lamprocystidia with encrustation. Morphological characteristics of this specimen generally correspond to the original description given by Wu [48], but the color of the hymenophore is more whitish.

4.4.6. *Phlebiopsis pilatii* (Parmasto) Spirin & Miettinen, in Miettinen, Spirin, Vlasák, Rivoire, Stenroos & Hibbett, *MycKeys* 17: 25 (2016)

Basidiocarps annual, phleboid, fragile, cracked. **Hymenophore** light brown to yellowish brown, smooth to meruloid. **Hyphal system** monomitic, generative hyphae 2–4 µm in diam., thick-walled, clamp connections lacking. **Dendrohyphidia**

multiple branched, up to 40 µm long. **Basidia** subcylindrical to subclavate, 22–35 × 5.5–7 µm, 4-spored. **Basidiospores** ellipsoid to oblong, 5–8 × 4–5 µm, inamyloid (Figures 1P and 2O).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'23"N 128°06'05"E, 497 m, 8 Feb 2017, Y. W. Lim, N. K. Kim & H. J. Cho, SFC20170208-01; *ibid*, 35°47'33"N 128°05'54"E, 538 m, 8 Feb 2017, Y. W. Lim, N. K. Kim & H. J. Cho, SFC20170208-05.

Remarks: *P. pilatii* has a phleboid basidiocarp and simple-septate hyphae with thick-walled [49]. In addition, this species is easily distinguished from other species by having a yellowish brown hymenophore and multiple branched dendrohyphidia.

4.4.7. *Postia coeruleivirens* (Corner) V. Papp, *Mycotaxon* 129(2): 411 (2015)

Basidiocarps conchate to flabellate, fragile. **Upper surface** white to cream, often with bluish flecks, pubescent. **Pore surface** white to pale cream, sometimes with grayish tint; pores 6–8/mm. **Hyphal system** monomitic, thin-walled to slightly thick-walled, 3–6 µm in diam. **Basidia** clavate to subclavate, 8.5–15 × 3.5–5 µm, 4-spored. **Basidiospores** cylindrical, 4–6 × 1–1.5 µm (Figures 1Q and 2P).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'13"N 128°05'06"E, 659 m, 25 Jul 2018, H. Lee, H. J. Cho & N. H. Kim, SFC20180725-73.

Remarks: This species has been misidentified as *Postia caesia* in Korea. The pore size of *P. caesia* is larger (4–5/mm) than that of *P. coeruleivirens* (6–8/mm) [50]. Moreover, the basidiospore width of *P. caesia* is broader than that of *P. coeruleivirens* (1.42–1.64 vs 1–1.5 µm in width).

4.5. Order Russulales

4.5.1. *Lentinellus castoreus* (Fr.) Kühner & Maire, *Bull. Trimest. Soc. Mycol. Fr.* 50: 16 (1934)

Basidiocarps conchate to flabellate, 15–50 mm in diam., subimbricate. **Pileus** yellowish brown to reddish brown, tomentose. **Lamellae** subdistant, up to 4 mm broad, cream to pale brown, margin serrate. **Hyphal system** trimitic, generative hyphae thin-walled, 3–8 µm in diam., with clamp connections. **Pleurocystidia** fusiform, 22–30 × 4–7 µm, lanceolate, with basal clamps. **Gloeocystidia** 20–45 × 5–7 µm, subcylindrical to subclavate, sometimes slightly capitate. **Basidia** subclavate to clavate, 13–22 × 5–7 µm, 4-spored. **Basidiospores** subglobose to broadly ellipsoid, 3–4.5 × 3–4 µm, thin-walled, amyloid (Figures 1R and 2Q).

Specimen examined: Korea. Gyeongsangnam-do Hapcheon-gun, Gayasan National Park, 35°47'53"N

128°05'60"E, 652 m, 26 Jul 2017, H. J. Cho, K. H. Park & N. H. Kim, SFC20170726-44.

Remarks: Because the macromorphology of *L. castoreus* is very diverse, it is not easy to distinguish between *L. castoreus* and its closely related species, *L. ursinus*. However, the former has bigger basidiospores than those of *L. ursinus* ($3\text{--}4.6 \times 2\text{--}3.5 \mu\text{m}$) [51].

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ORCID

Hae Jin Cho  <http://orcid.org/0000-0003-3041-5824>
Young Woon Lim  <http://orcid.org/0000-0003-2864-3449>

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