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Research Article

# Seven New Recorded Species in Five Genera of the Strophariaceae in Korea

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**Abstract** Most known species in the Strophariaceae are decomposers and grow on various kind of organic matter. Approximately 18 genera and 1,316 species in the Strophariaceae have been reported worldwide. Through an ongoing survey of indigenous fungi in Korea, 29 specimens belonging to the Strophariaceae were collected from 2012 to 2016. These specimens were identified based on morphological characteristics and molecular analysis of internal transcribed spacer sequences. Fifteen taxa were confirmed, with eight species matching those previously recorded. Seven species in five genera were shown to be new records in Korea: *Galerina marginata*, *Gymnopilus crociphyllus*, *Gymnopilus picreus*, *Hebeloma birrus*, *Hebeloma cavipes*, *Pholiota multicingulata*, and *Psilocybe thaizapoteca*. In this study, we provide detailed morphological descriptions of these species and investigate their evolutionary relationships by constructing phylogenetic trees.

**Keywords** Indigenous fungal species, ITS, New records, Strophariaceae

The family Strophariaceae in the order Agaricales was first described by Singer and Smith [1]. Approximately 18 genera and 1,316 species in the family Strophariaceae have been reported worldwide [2]. The family Strophariaceae is characterized by a monomitic hyphal system with clamps, cylindrical to narrowly clavate basidia with two to four spores, and violaceous spores with germ pores. Strophariaceae are found on various substrates such as soil, dung, plant litter, and grass roots [3]. Most species in this family are saprotrophs and found on various kinds of decaying organic matter while several species are ectomycorrhizal fungi [4, 5]. Some species of Strophariaceae have potential positive medicinal attributes such as anticancer agents [6].

Traditionally, identification of fungal species has been based on morphological characters; however, because morphology can vary depending on environmental conditions, identification of fungal species based on morphology alone is often unreliable [7]. The introduction of molecular phylogenetics to fungal taxonomy and evolution has been crucial in shedding light on the phylogenetic relationships of the Strophariaceae [5, 8]. For example, phylogenetic studies using the internal transcribed spacer regions (ITS) clarified the evolutionary relationships in the genera *Galerina* and *Gymnopilus* [9, 10]. Recently, additional loci have been included in phylogeny studies of fungi. For example, three loci were used to investigate phylogenetic relationships in the *Psilocybe*: the ITS, the large subunit rRNA, and the elongation factor 1-α [11]. Accumulated DNA sequence information, in particular DNA barcoding using the ITS region, has greatly improved accuracy in identification of fungi at the species level and improved our understanding of fungal phylogenetic relationships [8, 12, 13]. Specifically, many Asian species have been re-evaluated by molecular analysis, primarily using the ITS [14-16].

Since the first reports of *Hypholoma* and *Pholiota* species in 1940 [17], 10 additional genera, including 53 species in the family Strophariaceae, have been reported in Korea [18]. Until recently, most species of Korean Strophariaceae were reported based on simple morphological identifications without detailed descriptions or molecular data. Thus, it is necessary to re-evaluate the family Strophariaceae in Korea. To this aim, the National Institute of Biological Resources (NIBR) of Korea and the Korea National Arboretum (KNA)

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have begun a comprehensive investigation of the biodiversity of indigenous fungal species in Korea. As a part of the many projects these agencies have initiated, many fungal species indigenous to Korea have been collected from 2012 to 2016. Through the efforts of these surveys, seven new records in the Strophariaceae were discovered by morphological and ITS sequence analysis. Here, we provide their morphological characteristics in detail as well as ITS phylogenetic analysis.

## MATERIALS AND METHODS

**Specimens.** Fruiting bodies were collected from locations throughout South Korea from 2012 to 2016 and specimens were dried and deposited in the Seoul National University Fungal Collection (SFC) (Table 1). Specimens were initially assigned to species according to field guides [19-22]. The putatively identified specimens were then re-examined using molecular analysis as well as macro- and microscopic characteristics as described in previous studies for more accurate species classification.

To observe microscopic characteristics, dried tissue from specimens was rehydrated in 3% (w/v) KOH and stained in 1% (w/v) phloxine. Microscopy was performed using an Eclipse 80i light microscope (Nikon, Tokyo, Japan). We measured basidia (20 per specimen), cystidia (20 per specimen), and basidiospores (20 per specimen). Q refers to the length/width ratio of an individual basidiospore. The morphological features were characterized in detail with specimens that had confirmed identity based on DNA sequence analyses (described below).

**DNA sequencing and phylogenetic reconstruction.** DNA was extracted using a modified cetyltrimethylammonium bromide extraction protocol [23]. The ITS region was amplified with ITS1F and ITS4B [24] using previously described methods [25]. The amplicons were Sanger-sequenced in both forward and reverse directions using the PCR primers. Sequencing was performed by Macrogen (Seoul, Korea) using an automated DNA sequencer (ABI3700; Applied Biosystems, Foster City, CA, USA).

DNA sequences were proofread using MEGA program ver. 5.0 [26] and aligned with *Galerina*, *Gymnopilus*, *Pholiota*, and *Psilocybe* ITS sequences downloaded from GenBank using MAFFT [27]. Alignments were checked by eye and

**Table 1.** Korean Strophariaceae species, collection information, and GenBank accession numbers used in this study

| Species | Specimen code | Substrate | Locality | Accession No. |
|---|---|---|---|---|
| ***Galerina marginata* (Batsch) Kühner**[a] | SFC20140530-09 | Conifer | Jangsu-gun, Jeollabuk-do | KX773866 |
| | SFC20140703-11 | Conifer | Jeju-si, Jeju-do | KX773867 |
| ***Gymnopilus crociphyllus* (Sacc.) Pegler**[a] | SFC20140702-15 | Conifer | Seogwipo-si, Jeju-do | KX773868 |
| | SFC20150701-05 | Broad leaved tree | Jeju-si, Jeju-do | KX773869 |
| ***Gy. picreus* (Pers.) P. Karst.**[a] | SFC20120919-41 | Conifer | Gongju-si, Chungcheongnam-do | KX773870 |
| | SFC20140724-07 | Conifer | Jangsu-gun, Jeollabuk-do | - |
| | SFC20140828-25 | Conifer | Cheongyang-gun, Chungcheongnam-do | KX773871 |
| | SFC20140921-27 | Conifer | Jangsu-gun, Jeollabuk-do | - |
| *Gy. sapineus* (Fr.) Murrill | SFC20150904-45 | Conifer | Gurye-gun, Jeollanam-do | KX773872 |
| | SFC20150904-47 | Conifer | Gurye-gun, Jeollanam-do | KX773873 |
| ***Hebeloma birrus* (Fr.) Sacc.**[a] | SFC20160721-06 | - | Inje-gun, Gangwon-do | KX773875 |
| | SFC20140701-43 | - | Gapyeong-gun, Gyeonggi-do | KX773874 |
| *H. cavipes* Huijsman[a] | SFC20160512-25 | On ground | Goyang-si, Gyeonggi-do | KX773876 |
| *H. vinosophyllum* Hongo | SFC20160708-46 | On ground | Guri-si, Gyeonggi-do | - |
| | SFC20160512-19 | On ground | Guri-si, Gyeonggi-do | KX773877 |
| | SFC20150813-53 | - | Goyang-si, Gyeonggi-do | - |
| | SFC20150811-77 | On ground | Guri-si, Gyeonggi-do | - |
| *Pholiota alnicola* (Fr.) Singer | SFC20140626-16 | On ground | Guri-si, Gyeonggi-do | KX773878 |
| | SFC20150915-04 | Conifer | Goyang-si, Gyeonggi-do | KX773879 |
| | SFC20150917-03 | Broad leaved tree | Guri-si, Gyeonggi-do | KX773880 |
| *Ph. limonella* (Peck) Sacc. | SFC20130730-74 | Broad leaved tree | Guri-si, Gyeonggi-do | KX773881 |
| | SFC20150707-19 | Broad leaved tree | Guri-si, Gyeonggi-do | KX773882 |
| *Ph. lubrica* (Pers.) Singer | SFC20111015-10 | Conifer | Hoengseong-gun, Gangwon-do | KX773883 |
| ***Ph. multicingulata* E. Horak**[a] | SFC20140826-06 | Conifer | Wanju-gun, Jeollabuk-do | KX773884 |
| | SFC20140826-12 | On ground | Wanju-gun, Jeollabuk-do | KX773885 |
| *Ph. squarrosa* (Vahl) P. Kumm. | SFC20140912-I01 | Broad leaved tree | Inje-gun, Gangwon-do | KX773886 |
| *Ph. squarrosoides* (Peck) Sacc. | SFC20120814-45 | Broad leaved tree | Ulleung-gun, Gyeongsangbuk-do | KX773887 |
| *Ph. terrestris* Overh. | SFC20151120-02 | - | Seoul | KX773888 |
| ***Psilocybe thaizapoteca* Guzmán, Karun. & Ram.-Guill.**[a] | SFC20140723-26 | On ground | Jinan-gun, Jeollabuk-do | KX773889 |

[a]New to record in Korea.

ambiguous positions were adjusted manually. Neighbor-joining tree were constructed using the ITS dataset with MEGA with 1,000 bootstrap replicates. For the outgroup species, *Cortinarius carneipallidus* and *Simocybe serrulata* were selected based on a previous study [5, 9]. Intraspecific dissimilarity was calculated using MEGA.

## RESULTS AND DISCUSSION

During the survey of indigenous fungal species in Korea from 2012 to 2016, 29 specimens were identified as members of the Strophariaceae. These specimens were grouped into fifteen taxa in five genera according to their macroscopic

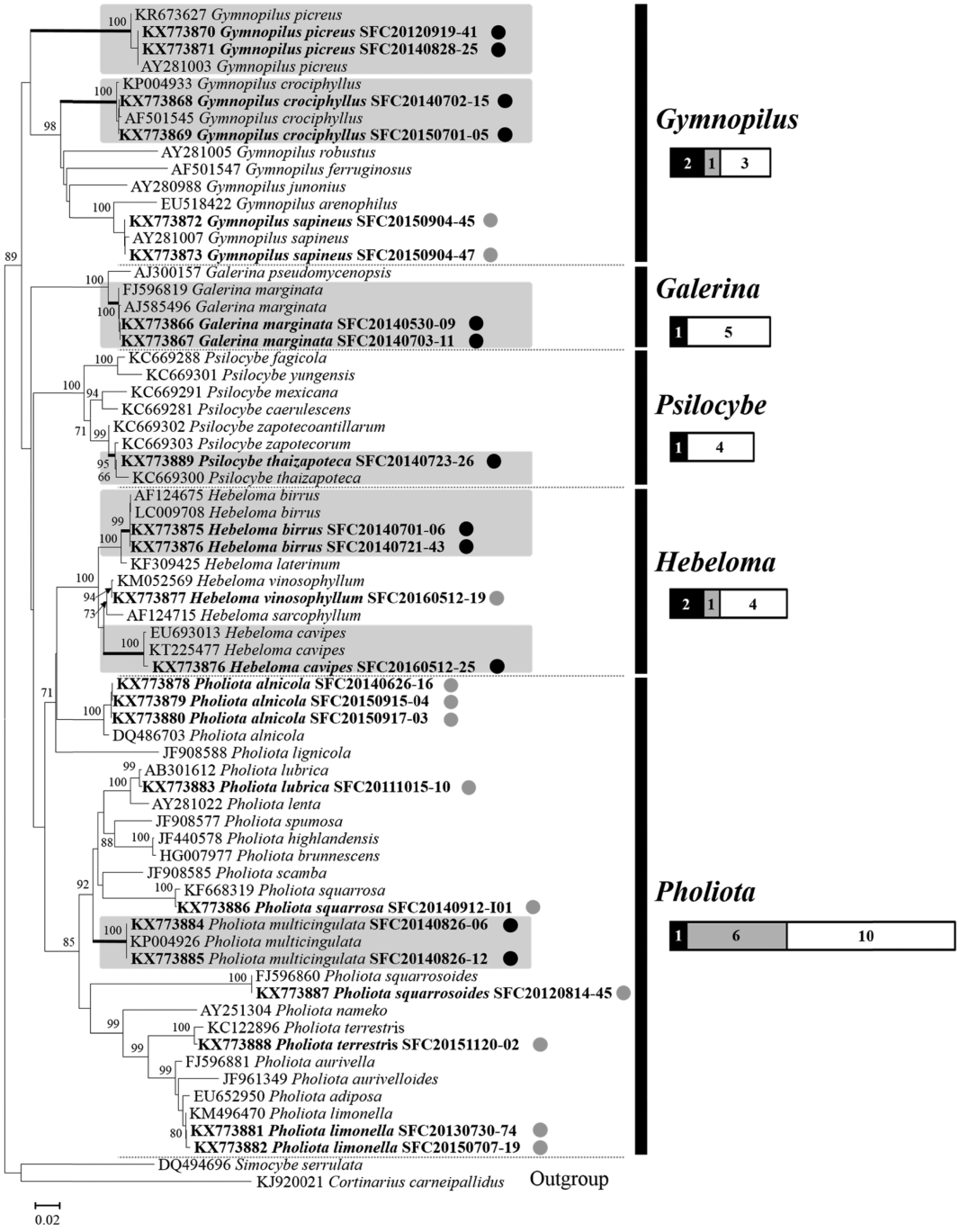


**Fig. 1.** Phylogenetic trees for Strophariaceae species based on neighbor-joining analysis of the internal transcribed spacer. Bootstrap scores of > 70 are presented at the nodes. The scale bar indicates the number of nucleotide substitutions per site. Bold letters represent the specimens which were used in this study. Square boxes under genus names: number in black, new records species; number in gray, recorded species; number in white, previously recorded species which were not found in this study.

and microscopic features. The specimens were identified to the species level by molecular analysis and were verified using morphological characters. By combining morphological and molecular approaches, eight previously reported Korean species and seven newly recorded Korean species were identified: *Galerina marginata*, *Gymnopilus crociphyllus*, *Gymnopilus picreus*, *Hebeloma birrus*, *Hebeloma cavipes*, *Pholiota multicingulata*, and *Psilocybe thaizapoteca* (Table 1, Figs. 1 and 2).

**Genus *Galerina*.** Two specimens (SFC20140530-09 and SFC20140703-11) were assigned to *Galerina* on the basis of the ITS sequences. They formed a monophyletic clade with reference sequences of *Ga. marginata* (bootstrap support, 99%) and had high sequence similarity with *Ga. marginata* (99.8~100.0%). *Ga. marginata* had high sequence identity with *Ga. pseudomycenopsis* (AJ300157, 97.1%) and the two appear as sister species in the phylogram (bootstrap support, 100%) (Fig. 1).

*Galerina* is a genus of saprobic mushrooms with over 250 species reported worldwide [2] and are characterized by yellow to brown bell-shape membranous pileus and ornamented spores with plage [20]. *Galerina vittiformis* is the type species of this genus [28, 29]. The genus *Galerina*

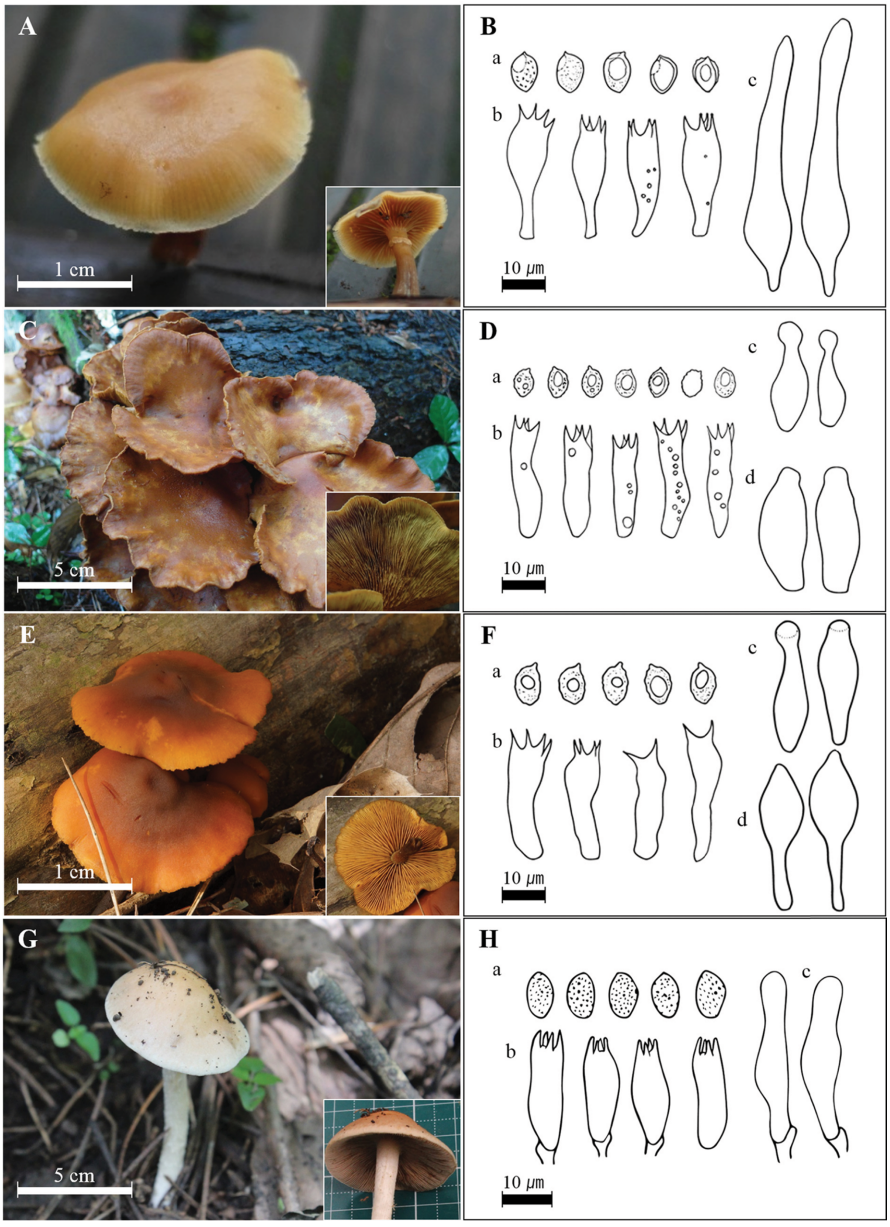


**Fig. 2.** Image and microscopic features of five new record species in Korea: A, B, *Galerina marginata* (SFC20140703-11); C, D, *Gymnopilus crociphyllus* (SFC20140702-15); E, F, *Gymnopilus picreus* (SFC20120919-41); G, H, *Hebeloma birrus* (SFC20160721-43); I, J, *Hebeloma cavipes* (SFC20160512-25); K, L, *Pholiota multicingulata* (SFC20140826-06); M, N, *Psilocybe thaizapoteca* (SFC20140723-26). a, basidiospore; b, basidia; c, cheilocystidia; d, pleurocysidia.

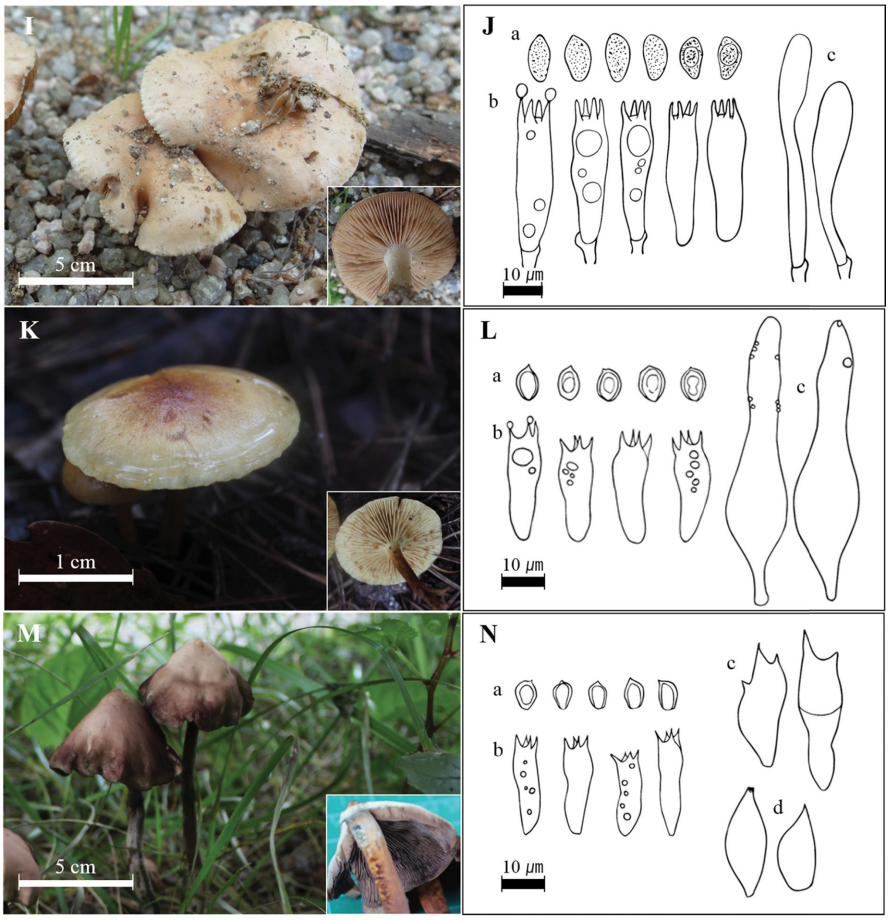


**Fig. 2.** Continued.

has been shown to be polyphyletic [28]. Five species were previously recorded in Korea (*Ga. calyptrata*, *Ga. fasciculata*, *Ga. helvoliceps*, *Ga. sideroides*, and *Ga. vittiformis*) [18]. Among these species, only *Ga. sideroides* has been described using both morphology and molecular data [30]. Our analysis shows that one species of the genus *Glaerina*, *Ga. marginata*, is a new report for Korea (black circle in Fig. 1, Fig. 2A and 2B).

**Genus *Gymnopilus*.** Eight specimens were confirmed as three species of *Gymnopilus*: *Gy. crociphyllus*, *Gy. picreus*, and *Gy. sapineus*. Among these, two (SFC20140702-15 and SFC20150701-05) clustered as a monophyletic group with reference sequences of *Gy. crociphyllus* (bootstrap support, 100%). Two specimens (SFC20120919-41 and SFC20140828-25) clustered with *Gy. picreus* (bootstrap support, 100%) (Fig. 1). The other specimens (SFC20150904-45 and SFC201509004-47) grouped with *Gy. sapineus* (bootstrap support, 100%) (Fig. 1).

Species in the genus *Gymnopilus* have fruiting bodies that are reddish brown to rusty orange/yellow and grow on wood. This group is comprised of more than 200 species [2] and *Gymnopilus liquiritiae* is the type species in of this genus [31]. The phylogeny for this genus was constructed using molecular analysis and with the exception of *Gy. picreus*, *Gymnopilus* has five well-supported clades with 91% bootstrap support [9]. Four *Gymnopilus* species have previously been reported in Korea (*Gy. aeruginosus*, *Gy. junonius*, *Gy. liquiritiae*, and *Gy. sapineus*) [18]. Only *Gy. sapineus* was confirmed in this study and two species were new reports to Korea: *Gy. crociphyllus* and *Gy. picreus*. In the phylogram of *Gymnopilus*, *Gy. picreus* was placed at the basal positon of this genus (Fig. 1). Other species in this group usually have basidia with 4-sterigmata while *Gy. picreus* has basidia with 2- or 4-sterigmata (Fig. 2E and 2F).

**Genus *Hebeloma*.** Seven specimens were identified to 3 species of *Hebeloma*: *H. birrus*, *H. cavipes*, and *H. vinosophyllum*. Two specimens (SFC20160721-43 and SFC20140701-06) clustered with *H. birrus* (bootstrap support, 97%), SFC20160512-25 was grouped with *H. cavipes* (bootstrap support, 100%). The other specimens (SFC20160708-46, SFC20160512-19, SFC20150813-53, and SFC20180811-77) grouped with *H. vinosophyllum* (bootstrap support, 96%) (Fig. 1).

Most species in the genus *Hebeolma* have pale to deep brown spores. Many species have gelatinized caps with pileipelles and cheilocystidia which are key characters for distinguishing specimens to the species level [20, 32]. The

species in this genus are mostly ectomycorrhizal fungi, and more than 150 species have been described worldwide [2]. *Hebeloma fastibile* is the type species in this genus [33]. According to molecular-based phylogenies there are several subsections in this genus [7]. Until now, five species were reported previously in Korea (*H. crustuliniforme*, *H. mesophaeum*, *H. radicosum*, *H. spoliatum*, and *H. vinosophyllum*) [18]. Among these, three species matched with the reference sequences (Fig. 1). The results of this study show that one species was recorded previously in Korea (*H. vinosophyllum*) and two species are new records to Korea: *H. birrus* and *H. cavipes* (Figs. 1 and 2).

**Genus *Pholiota*.** Eleven specimens were assigned to seven species of *Pholiota*: *Ph. alnicola*, *Ph. limonella*, *Ph. lubrica*, *Ph. multicingulata*, *Ph. squarrosa*, *Ph. squarrosoides*, and *Ph. terrestris*. Three specimens (SFC20140626-16, SFC20150915-04 and SFC20150917-03) clustered with *Ph. alnicola* (DQ486703) (bootstrap support, 100%), two specimens (SFC20130730-74 and SFC20150707-19) were identified as *Ph. limonella* (bootstrap support, 78%), specimen SFC20111015-10 was identified as *Ph. lubrica* (bootstrap support, 99%), two specimens (SFC20140826-06 and SFC20140826-12) were identified as *Ph. multicingulata* (bootstrap support, 100%), specimen SFC20140912-I01 was identified as *Ph. squarrosa* (bootstrap support, 100%), specimen SFC20120814-45 was identified as *Ph. squarrosoides* (bootstrap support, 100%), and specimen SFC20151120-02 was *Ph. terrestris* (bootstrap support, 100%). *Ph. multicingulata* was shown to be a new record to Korea (Fig. 1).

The genus *Pholiota* contains saprobes that typically live on dead wood and are comprised of about 150 species [2]. *Ph. squarrosa* is the type species for this genus [22]. Species of this genus have scaly, glutinous to dry cap surfaces and spores that are brown, light brown, or yellowish brown in deposit. All species of this genus have smooth spores and a germ pore [22]. *Pholiota* specimens that were collected shared these morphological characters but separated distantly from other *Pholiota* based on the ITS sequence analysis (Fig. 1). According to a previous study [34], the genus *Pholiota* is paraphyletic and divided into several subgenera. In order to determine the phylogenetic relationships within the *Pholiota*, further study is needed. Sixteen *Pholiota* species have been previously reported in Korea (*Ph. adiposa*, *Ph. alnicola*, *Ph. astragalina*, *Ph. aurivella*, *Ph. brunnescens*, *Ph. flammans*, *Ph. highlandensis*, *Ph. lenta*, *Ph. limonella*, *Ph. lubrica*, *Ph. microspora*, *Ph. spumosa*, *Ph. squarrosa*, *Ph. squarrosoides*, *Ph. terrestris*, and *Ph. tuberculosa*) [18]. In this study, we found only six recorded species and one species previously unrecorded in Korea (*Ph. multicingulata*).

**Genus *Psilocybe*.** One specimen (SFC20140723-26) of *Psilocybe* was confirmed as *Ps. thaizapoteca* (KC669300) (bootstrap support, 66%) (Fig. 1). *Ps. thaizapoteca* formed a sister clade with *Ps. zapotecorum* (KC669303), and two species had very high similarity (99.6%) (Fig. 1).

Species in the genus *Psilocybe* are found throughout the world and live in various habitats such as mossy, grassy, or forest humus soils [19]. *Ps. semilanceata* is the type species for this genus [35]. Fruiting bodies of *Psilocybe* are typically small with a hygrophanous cap and have a lilac- to dark purple-brown spore print-color [36]. A recent study using a multigene phylogeny showed that this genus formed a monophyletic group; however, some of the species were reassigned to the genus *Deconica* [37]. Four species were recorded previously in Korea (*Ps. argentipes*, *Ps. coprophila*, *Ps. merdaria*, and *Ps. xeroderma*) [18]. In this study, we found only one *Psilocybe* species (*Ps. thaizapoteca*) which is an unrecorded species to Korea.

## Taxonomy.

***Galerina marginata* (Batsch) Kühner**, Encyclop. Mycol. 7: 225 (1935).

Pileus 15~35 mm, convex or conical when young, then expanded, piano-convex or flattened when mature, lubricous to subviscid when moist, smooth, hygrophanous, apricot (5B6) to raw sienna (6D7), margin cream (4A3). Lamellae crowded, subdecurrent, cream to light brown, lamellulae abundant. Stipe 20~40 × 4~8 mm, cream to light brown, cylindrical to slightly clavate, hollow, whitish yellow or pale brown membranous ring is situated on the upper part of the stipe. Spores 9.4~9.7~10.2 × 5.6~6.1~6.7 μm, Q = 1.47~1.60~1.72, ellipsoidal to oval. Basidia with 4 sterigmata, 27.7~35.3 × 7.8~10.4 μm, clavate. Pleurocystidia 52.4~77.2 × 11.4~13.9 μm, fusiform-ventricose to obclavate, abundant. Cheilocystidia 51.3~62.2 × 8.2~9.1 μm, similar to pleurocystidia, abundant.

**Specimens examined:** Korea, Jeollabuk-do, Jangsu-gun, Mt. Palgong, 35°36′09.2″ N, 127°27′20.2″ E, on the branch of *Pinus densiflora*, 30 May 2014, J. Y. Park, H. Lee, H. J. Cho, SFC20140530-09 (GenBank accession No. KX773866); Korea, Jeju-do, Jeju-si, Jeolmul natural forest, 33°26′13.1″ N, 126°37′41.4″ E, on the branch of coniferous tree, 3 Jul 2014, M. S. Park, H. Lee, S.-Y. Oh, SFC20140703-11 (GenBank accession No. KX773867).

**Remarks:** *Ga. marginata* is distinguished by its membranous ring on the stipe, subdecurrent lamellae, and thin and translucent pileus margin. This species is very closely related to *Ga. pseudomycenopsis* according to morphological and molecular data. However, they were distinguished by mating test and morphological characteristics [28, 38]. *Ga. pseudomycenopsis* has a more vividly brown colored pileus, wide spores and grows in moist to wet mossy habitats, while *Ga. marginata* has a less vividly brown colored of pileus, narrower spores and some of the specimens were found on wood [38].

***Gymnopilus crociphyllus* (Sacc.) Pegler**, Aust. J. Bot. 13: 329 (1965).

Pileus 45~80 (~115) mm, first convex, then expanded, margin rumpled, hygrophanous, oxide yellow (5C7) to light brown (6D8), sometimes mustard yellowish (3B6) smudges. Lamellae

very crowded, light yellow to orange yellow, rusty staining, crowded. Stipe 30~60 × 8~20 mm, pale orange to Persian orange, cylindrical to slightly clavate, tough, fasciculate, veil absent. Spores 6.4~7.0~7.3 × 4.4~4.9~5.1 μm, Q = 1.31~1.43~1.58, ellipsoidal, germ pore absent. Basidia with 4 sterigmata, 25.4~27.8~30.9 × 5.5~6.3~7.5 μm, clavate. Cheilocystidia 19.8~23.3~26.9 × 5.5~6.7~8.7 μm tibiform, abundant. Clamp connection present.

**Specimens examined:** Korea, Jeju-do, Seogwipo-si, Andeok Valley, 33°15′26.0″ N, 126°21′10.0″ E, on the dead coniferous trees, 2 Jul 2014, M. S. Park, H. Lee, S.-Y. Oh, SFC20140702-15 (GenBank accession No. KX773868); Korea, Jeju-do, Jeju-si, Dongbaekdongsan Geopark, 33°30′51.2″ N, 126°43′07.6″ E, on the dead broad leaved tree, 1 Jul 2015, Y. W. Lim, N. K. Kim, H Lee, SFC20150701-05 (GenBank accession No. KX773869).

**Remarks:** *Gy. crociphyllus* has distinctive characters such as a fasciculate fruiting body, large pileus size, and a rumpled pileus margin. This species is easily misidentified as *Gy. ferruginosus* in the field [39]; however, *Gy. ferruginosus* has distinct differences in both morphological and molecular characters [39, 40]. *Gy. ferruginosus* has a deeper pileus surface color, and larger, more heavily ornamented spores than *Gy. crociphyllus* [39]. In the sequence analysis, our specimens of *Gy. crociphyllus* had a sequence dissimilarity of 12.9% with *Gy. ferruginosus* (AY501547).

***Gymnopilus picreus* (Fr.) Karst.**, Bidr. Finl. Nat. Folk 32: 400 (1879).

Pileus 15~25 (~50) mm, first campanulate-convex, then expanded, not viscid, hygrophanous, squamulose, golden yellow (5B7) to burnt sienna (7DB), center dark brown (8F8). Lamellae very crowded, sunflower to light orange, crowded, lamellulae abundant. Stipe 20~35 × 3~5 mm, light brown to dark brown, darkening from the base up, white pulverulent, cylindrical, hollow, veil absent. Spores 8.2~8.7~9.2 × 4.9~5.1~5.5 μm, Q = 1.57~1.69~1.86, ellipsoidal to subovoid, germ pore absent. Basidia with 2~4 sterigmata, 22.8~26.7~30.3 × 6.0~6.6~7.9 μm, cylindrical to clavate. Cheilocystidia 21.5~26.1~32.2 × 6.0~7.8~9.6 μm, abundant. Pleurocystidia, 18.3~23.3~28.2 × 6.2~7.3~8.2 μm, abundant. Clamp connection present.

**Specimens examined:** Korea, Chungcheongnam-do, Gongju-si, Mt. Museong, 36°31′04.2″ N, 127°05′07.5″ E, on the dead coniferous trees, 19 Sep 2012, H. Lee, W. D. Lee, W. J. Kim, SFC20120919-41 (GenBank accession No. KX773870); Korea, Jeollabuk-do, Jangsu-gun, Mt. Palgong, 35°37′16.0″ N, 127°28′46.0″ E, on the dead coniferous trees, 24 Jul 2014, J. Y. Park, H. Lee, H. J. Cho, SFC20140724-07; Korea, Chungcheongnam-do, Cheongyang-gun, Mt. Chilgap, 36°24′48.1″ N, 126°53′03.4″ E, on the dead coniferous trees, 28 Aug 2014, M. S. Park, Jonathan Julio Fong, SFC20140828-25 (GenBank accession No. KX773871); Korea, Jeollabuk-do, Jangsu-gun, Mt. Jangan, 35°37′47.8″ N, 127°35′45.3″ E, on the dead coniferous trees, 21 Sep 2014, J. Y. Park, SFC20140921-27.

**Remarks:** *Gy. picreus* is distinguished by its orange brown color, squamulose pileus, rusty-staining lamellae, dark brown stipe with white pulverulence.

***Hebeloma birrus* (Fr.) Sacc.**, Syll. Fung. (Abellini) 5: 794 (1887).

Pileus 20~50 mm, hemispherical when young, then convex or flattened with slightly overturned margin when matured, smooth, non-hygrophanous, lubricous to subviscid when moist, ivory (4B3) to reddish brown (8D8). Lamellae subcrowded, adnexed, beige to light greyish brown, lamellulae abundant. Stipe 40~70 × 5~13 mm, whitish and darkening at the base, cylindrical, white-pruinose, hairy at base. Spores 9.0~9.4~10.0 × 5.3~5.7~6.2 μm, Q = 1.59~1.72~1.81, ellipsoidal to oval. Basidia with 4 sterigmata, 21.5~23.0 × 6.5~7.9 μm, subcylindrical to clavate. Pleurocystidia not seen. Cheilocystidia 28.4~39.0 × 6.1~8.5 μm, clavate, sometimes lecthyform, abundant.

**Specimens examined:** Korea, Gangwon-do, Inje-gun, Yongdae National Recreation Forest, 37°54′25.3″ N, 127°27′27.8″ E, on the ground of broad leaved forest, 1 Jul 2014, Y. W. Lim, H. J. Cho, SFC20140701-06 (GenBank accession No. KX773875); Korea, Gyeonggi-do, Gapyeong-gun, Mt. Yeonin, 37°54′25.3″ N, 127°27′27.8″ E, on the ground of oak forest, 12 May 2016, M. S. Park, S.-Y. Oh, Y. J. Min, M. J. So, SFC20160721-43 (GenBank accession No. KX773874).

**Remarks:** *H. birrus* is easily identified by its reddish brown pileus, ellipsoidal spores with a small Q value (1.59~1.81), and a long and hairy stipe base. Many specimens of *H. birrus* were collected in regions after forest fires or in mining regions [41]. Our specimen of *H. birrus* (SFC20160721-43) was collected in a famous charcoal production region (Gapyeong-gun) and the other specimen (SFC20140701-06) was collected in a camp site (Yongdae National Recreation Forest).

***Hebeloma cavipes* Huijsman**, Persoonia 2: 97 (1961).

Pileus 20~65 mm, hemispherical when young, then convex or flattened when matured, slightly brown dots when young, smooth, non-hygrophanous, lubricous when moist, yellowish white (2A2) to cream (4A3). Lamellae subcrowded, narrowly attached, cream to light pinkish brown, lamellulae abundant. Stipe 25~45 × 6~14 mm, slightly paler color than pileus, cylindrical, hollow in age, surface more umbonated than pileus when young, then whitish fibrillose longitudinally. Spores 10.9~11.7~12.8 × 5.6~6.1~6.7 μm, Q = 1.81~1.90~2.14, oval. Basidia with 4 sterigmata, 32~41.4 × 8.0~10.7 μm, subcylindrical to clavate. Pleurocystidia not seen. Cheilocystidia 33.0~65.7 × 7.3~10.9 μm, clavate, uniform, abundant.

**Specimens examined:** Korea, Gyeonggi-do, Goyang-si, West Five Royal Tombs, 37°37′40.5″ N, 126°53′51.4″ E, on the ground of oak forest, 12 May 2016, H. Lee, S. Jargalmaa, K. H. Park, SFC20160512-19 (GenBank accession No. KX773876).

**Remarks:** *H. cavipes* is distinguished by its oval spores and brown dots on the pileus and stipe when young. It is very closely related to *H. vaccinum* according to macro- and micro-morphological features; however, two species

could be distinguished by the width of spores. According to Eberhardt *et al.* [42], *H. vaccinum* has a bigger spore width (6.6~7.9) than *H. cavipes* (5.6~6.7). Most specimens of *H. vaccinum* were collected on calcareus ground and known to a symbiont of *Salix* or *Populus* [43, 44] while. *H. cavipes* was collected on mostly soil types [42].

***Pholiota multicingulata* Horak**, Aust. J. Bot. Suppl. 10: 33 (1983).

Pileus 15~45 (~55) mm, campanulate-convex to convex when young, then expanded, piano-convex when matured, subumbonate, viscid when moist, smooth and hairless, cream (4A3) to cocoa brown (6E6), center dark brown (7F7). Lamellae crowded, cream to pale brown, rusty-staining when old, 3~5 lamellulae between 2 lamellae. Stipe 25~50 × 3~6 mm, cream to brown, darkening from the base up, cylindrical, hollow when old, veil absent. Spores 7.3~7.8~8.2 × 4.7~5.1~5.4 µm, Q = 1.44~1.54~1.68, ellipsoidal to oval. Basidia with 4 sterigmata, 23.2~29.7 × 7.3~9.2 µm, clavate. Pleurocystidia 62.6~67.34~72.9 × 5.9~6.8~7.8 µm, fusiform-lageniform, abundant. Cheilocystidia, 63.4~70.9~76.9 × 11.3~14.9~19.6 µm, similar to Pleurocystidia, abundant.

**Specimens examined:** Korea, Jeollabuk-do, Wanju-gun, Mt. Moak, 35°43′38.4″ N, 127°06′20.7″ E, on the log of coniferous tree, 26 Aug 2014, J. Y. Park, H. Lee, P. R. Noh, SFC20140826-06 (GenBank accession No. KX773884); Korea, Jeollabuk-do, Wanju-gun, Mt. Moak, 35°43′38.1″ N, 127°06′21.2″ E, on the ground of coniferous forest, 26 Aug 2014, J. Y. Park, H. Lee, P. R. Noh, SFC20140826-12 (GenBank accession No. KX773885).

**Remarks:** *Ph. multicingulata* is distinguished by its smooth and hairless pileus, viscid like slime when rainy, not hygrophanous, and fusiform-lageniform cystidia. This species has similar features to *Ph. scamba*—small cap size, whitish to yellow lamellae, overlapped size and shape of basidiospores and basidia except for cheilocystidia and pleurocystidia. However, *Ph. multicingulata* differs from *Ph. scamba* which is smaller and the ventricose cystidia [19].

***Psilocybe thaizapoteca* Guzmán, Karun. & Ram.-Guill.**, Mycotaxon 119: 77 (2012).

Pileus 30~85 mm, convex or conical to campanulate, subumbonate, smooth, sublubricous when moist, hygrophanous, pale yellow (3A3) to cocoa brown (6A6), sometimes irregular margin, white and thin veil present when young. Lamellae crowded, reddish brown to greyish brown, lamellulae present. Stipe 80~170 × 7~15 mm, tapering upward, hollow when old, fibrous, concolorous with pileus, floccose. Spores 6.4~6.7~7.2 × 4.0~4.2~4.4 µm, Q = 1.52~1.60~1.70, ellipsoidal to oval. Basidia with 4 sterigmata, 25.3~29.4~32.9 × 7.4~9.0~11.2 µm, clavate. Cheilocystidia 25.3~29.4~32.9 × 7.4~8.6~11.2 µm, generally polymorphous, regular or irregular branched or lobulated, abundant. Pseudocystidia absent.

**Specimens examined:** Korea, Jeollabuk-do, Jinan-gun, Mt. Unjang, 35°53′37″ N, 127°25′41″ E, on the ground of grassland with shrubs, 23 Jul 2014, J. Y. Park, H. Lee, H. J. Cho, SFC20140723-26 (GenBank accession No. KX773889).

**Remarks:** *Ps. thaizapoteca* is distinguished by its large and campanulate pileus, long and floccose stipe, branched or lobulated cystidia, and absence of pseudocystidia. This species is very closely related to *Ps. zapotecorum* according to ITS sequence analysis; however, *Ps. thaizapoteca* has a distinctly different morphology than *Ps. zapotecorum*. *Ps. thaizapoteca* has scales on the stipe surface while *Ps. zapotecorum* does not have scales. *Ps. zapotecorum* has pseudocystidia while *Ps. thaizapoteca* does not have pseudocystidia [45, 46]. In addition, all specimens of *Ps. zapotecorum* are from neotropic regions (Mexico to Argentina) while *Ps. thaizapoteca* has only been reported in Asia (Thailand) [45, 46].

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