Marasmioid and Gymnopoid Fungi of the Republic of Korea. 8. Gymnopus Section Levipeses

Rhim Ryoo¹, Vladimir Antoniò and Kang-Hyeon Ka³

¹Department of Forest Bioresources, National Institute of Forest Science, Suwon, Republic of Korea; ²Department of Botany, Moravian Museum, Brno, Czech Republic

ABSTRACT

Collections of Gymnopus sect. Levipeses from the Republic of Korea have been studied. Two new species, Gymnopus dryophiloides and G. brunneodiscus, are described based on their macro- and micromorphological and phylogenetic characteristics. Three other species, referred to as Gymnopus spp. 1, 2, and 3, are distinguished as separate taxa without formal descriptions. Taxonomic and phylogenetic positions of all taxa have been inferred and confirmed by analyses of ITS and LSU sequence data. Their detailed descriptions, illustrations and an identification key are provided.

1. Introduction

The genus Gymnopus (Pers.) Roussel belongs to the family Omphalotaceae, and is, according to Antonín and Noordeloos [1], divided into five sections. Species of sect. Levipeses (Fr.) Halling are characterized by a pileipellis composed of inflated, mostly irregular, lobed or coralloid elements (Dryophila-structure). Other Gymnopus sections have a pileipel-lis in the form of an (ixo)cutis or an irregular trichoderm [1,2]. There are about 45 species described worldwide and their distribution is very broad [1–8]. However, information from many parts of the world (e.g., Africa, South America) is missing or very incomplete.

None of the species belonging to Gymnopus sect. Levipeses had been recorded in the Republic of Korea until 2011 [9]. Jang et al. [10] published their own Korean sequence called G. dryophilus in the phylogeny tree (but see our results, Table 1, Figure 1).

Specimens of Gymnopus sect. Levipeses collected from various localities throughout the Republic of Korea since 2007 are evaluated in this study. This paper is one of a series of papers describing the diversity of marasmioid, marasmielloid, and gymnopoid fungi in the Republic of Korea, supported by the National Institute of Forest Science. Two papers dealing with sections Androsacei and Impudicae of the genus Gymnopus have already been published [11,12].

2. Material and Methods

2.1. Morphology

Macroscopic descriptions of collected specimens are based on fresh basidiomata. Color abbreviations follow Kornerup and Wanscher [13]. The authors of fungal names are cited according to the International Plant Names Index Authors website (http://www.ipni.org/ipni/authorsearchpage.do). Microscopic features were studied using dried material mounted in H₂O, approximately 5% KOH, Melzer’s reagent, and Congo Red (for recipes, see [14]) using an Olympus BX-50 light microscope (Tokyo, Japan) at 1000× magnification. For lamellae, L refers to the number of entire lamellae, while l refers to the number of lamellulae tiers between each pair of entire lamellae. For basidiospores, the factor E indicates the quotient of the length and width in any one basidiospore and Q is the mean of the E-values; the basidiospore values are based on 20 measurements in each collection. Specimens are preserved in the herbarium of the Moravian Museum, Brno, Czech Republic (BRNM). Cultures are housed in the herbarium of the National Institute of Forest Science (NIFoS), Republic of Korea.

2.2. Phylogenetic analyses

DNA extraction was performed by means of the modified method by Lee and Taylor [15]. The PCR primer used ITS1F, ITS1, ITS4B and ITS4 for the...
Table 1. The list on the GenBank accession number of nrITS and nrLSU sequences used for this study.

| Scientific name | Herbarium Number | Locality | ITS | LSU |
|-----------------|------------------|----------|-----|-----|
| Gymnopus alpinus | Duke15 | Sweden | DQ480101 | – |
| Gymnopus alpinus | Duke14 | U.K., Scotland | DQ480102 | – |
| Gymnopus dryophiloides | TENN 55,834 | U.K., Scotland | DQ480114 | – |
| Gymnopus dryophiloides | CB 16251 | Latvia | JX36168 | – |
| Gymnopus aquosus | TENN 55,883 | U.K., Scotland | DQ450003 | – |
| Gymnopus brunneodiscus | BRNM 710027 | Czech Republic | JX361670 | – |
| Gymnopus brunneodiscus | BRNM 670555 | Czech Republic | JX361671 | – |
| Gymnopus brunneodiscus | BRNM 695556 | Czech Republic | JX361673 | – |
| Gymnopus biderecous | SFUS-AWW118 | Java | AY263432 | – |
| Gymnopus biderecous | SFUS-AWW116 | Java | AY263432 | – |
| Gymnopus confluens | TENN F-059603 | Sweden | KF710313 | – |
| Gymnopus confluens | TENN F-059603 | Czech Republic | JX361564 | – |
| Gymnopus confluens | TENN F-059603 | Russia | KP710300 | – |
| Gymnopus confluens | TENN 57012 | Russia | AY640619 | – |
| Gymnopus congex | TENN 57012 | Germany | KY418871 | – |
| Gymnopus congex | TENN 57012 | Costa Rica | AF291305 | – |
| Gymnopus congex | TENN 57012 | USA | NGO27632 | – |
| Gymnopus congex | BRNM 670666 | Spain | JX361317 | – |
| Gymnopus congex | Duke 193411 | Sweden | JX361563 | – |
| Gymnopus congex | BRNM 718444 | Czech Republic | JX361564 | – |
| Gymnopus congex | BRNM 718448 | Korea | MHS98960 | – |
| Gymnopus congex | BRNM 718448 | Korea | MHS98962 | – |
| Gymnopus congex | BRNM 718450 | Korea | MHS98963 | – |
| Gymnopus congex | BRNM 718451 | Korea | MHS98964 | – |
| Gymnopus congex | BRNM 718453 | Korea | MHS98965 | – |
| Gymnopus congex | BRNM 718447 | Korea | MHS98967 | – |
| Gymnopus congex | BRNM 718452 | Korea | MHS98970 | – |
| Gymnopus congex | BRNM 718453 | Korea | MHS98972 | – |
| Gymnopus congex | BRNM 718449 | Korea | MHS98974 | – |
| Gymnopus congex | BRNM 718454 | Korea | MHS98975 | – |
| Gymnopus congex | BRNM 718456 | Korea | MHS98982 | – |
| Gymnopus congex | BRNM 718457 | USA, OR | AY256694 | – |
| Gymnopus congex | TENN 59457 | USA, OR | AY256694 | – |
| Gymnopus congex | TENN 59467 | USA, OR | AY256694 | – |
| Gymnopus congex | BRNM 705224 | Czech Republic | JX361313 | – |
| Gymnopus congex | BRNM 664995 | Czech Republic | JX361313 | – |
| Gymnopus congex | BRNM 693553 | Switzerland | JX361315 | – |
| Gymnopus congex | GLM 45932 | – | DQ71804 | – |
| Gymnopus congex | BRNM 712422 | Czech Republic | JX36125 | – |
| Gymnopus congex | BRNM 712407 | Czech Republic | JX36126 | – |
| Gymnopus congex | BRNM 691489 | Czech Republic | JX36128 | – |
| Gymnopus congex | Dvorák 138/02, BRNU | Czech Republic | JX36175 | – |
| Gymnopus congex | Dvorák 393/07, BRNU | Czech Republic | JX36176 | – |
| Gymnopus congex | BRNM 659773 | Italy | JX36177 | – |
| Gymnopus congex | AW2125 | AY263424 | AY639419 | – |
| Gymnopus congex | SC 8-4065 | Spain | JN247551 | JN247555 |
| Gymnopus congex | SC 8-4057 | Spain | JN247552 | JN247556 |
| Gymnopus congex | SC 8-4058 | Spain | JN247553 | JN247557 |
| Gymnopus congex | BRNM 737257 | Hungary | – | JN247558 |
| Gymnopus congex | TENN 59532 | USA, TN | AY256693 | – |
| Gymnopus congex | TENN 58090 | Costa Rica | AF055788 | – |
| Gymnopus congex | TENN 56636 | Costa Rica | DQ499797 | – |
| Gymnopus congex | TENN 56619 | Costa Rica | DQ499797 | – |
| Gymnopus congex | NY REH290 | Costa Rica | AF055788 | – |
| Gymnopus congex | BRNM 728565 | Slovakia | JX36160 | – |
| Gymnopus congex | BRNM 737693 | Norway | JX36164 | – |
| Gymnopus congex | BRNM 699755 | Czech Republic | JX36166 | – |
| Gymnopus congex | AW2117 | Java | AY263448 | – |
| Gymnopus congex | AW2116 | – | AY639427 | – |
| Gymnopus congex | TENN 56718 | USA, NC | AY256692 | – |
| Gymnopus congex | TENN 56321 | USA, NC | DQ499797 | – |
| Gymnopus congex | TENN 59640 | USA, Tennessee | DQ480113 | – |

Entries in bold type were newly sequenced by the authors.
nuclear ribosomal internal transcribed spacer (nrITS) region and selected LR0R, and LR7 for the nuclear large subunit ribosomal DNA (nrLSU) region according to Gardes and Bruns [16]. PCR cycling condition and DNA sequencing was carried out according to the protocol described by Anton [12,17]. For the nrITS region, PCR was performed with a 30 s denaturation at 94 °C, a 30 s annealing at 56 °C and a 1 min extension at 72 °C and was run with 35 cycles in the first denaturation and the last extension. For the nrLSU region, PCR was carried out with a 30 s denaturation at 94 °C, a 45 s annealing at 45 °C and a 90 s extension at 72 °C and then 35 cycles were run with the first denaturation and the last extension. Forty nrITS sequences of 19 species and 12 nrLSU sequences of eight species belonging to section Levipedes were retrieved from GenBank [4,5,18]. Eighteen sequences of the nrITS dataset and 17 sequences of the nrLSU dataset were formed for this study. Gymnopus confluens belonging to section Vestipedes was selected as an outgroup [18]. GenBank accession numbers of all sequences for the phylogenetic trees are listed in Table 1. Both the nrITS and nrLSU datasets were aligned with Mega 6.06 [19] and Clustal X2 [20]. Each phylogenetic analysis was performed by MrBayes 3.1.2. [21]. In the nrITS and nrLSU datasets, the ends of them were trimmed to 714 and 882 characters including 492 and 796 constant, and 188 and 46 variable sites, respectively. Both Markov chains were run for 2,000,000 generations with a sample taken every 100th generation, discarding a burn-in of 1,000 generations. The general time reversible (GTR) was used with gamma-distributed
substitution for a given data set. The Bayesian branch supports were assigned as posterior probabilities (PP) according to the 50% majority-rule of the consensus trees. The PP values showed to be higher than 0.95, including 95% confidence intervals (CI).

3. Results

3.1. Phylogenetic analyses

The two newly described species, Gymnopus dryophiloides and G. brunneodiscus, and Gymnopus spp. 1, 2 and 3, are distinguished from morphologically similar species by phylogenetic analyses of nrITS and nrLSU (Figures 1 and 2). In two phylogenetic trees, taxa of the Gymnopus dryophilus complex collected in Korea showed a monophyletic clade (95% and 98%), and formed one other clade close to European and American taxa with high supporting values (100% and 100%). This clade is described as a new species, G. dryophiloides. In the nrITS region, this species have a sequence divergence of 1.3% and differ in 9 out of 714 nucleotide sequences from typical G. dryophilus (isolate; AFTOL_ID 559, GenBank; DQ241781). In the nrLSU region, this new species has different sequences within 3bp among 822bp in several isolations from other localities (China, Germany, USA). In the monoclade including holotype G. dryophiloides, the nrITS sequence (MH589967) of the G. dryophiloides holotype differs the only 1bp from KX513744, 2bp with MH589958, and the nrLSU sequences have the same base pair. Gymnopus brunneodiscus differs in 42 out of 714 nucleotide characters of the nrITS dataset from G. octor (Pers.) Antonín & Noordel. They have a sequence divergence of about 5.9%. The independent taxonomic positions of Gymnopus spp. 1 and 2 are supported by the nrITS and nrLSU sequences. Gymnopus sp. 1 and five sequences of G. aquosus (Bull.: Fr.) Antonín & Noordel., G. earleae Murill, G. fagiphilus (Velen.) Antonín, Halling & Noordel., G. hybridus (Kühner & Romagn.) Antonín & Noordel., G. inusitatus (Vila & Llimona) Vila & Llimona, G. spongiosus (Berk. & M.A. Curtis) Halling, and G. vitellinipes A.W. Wilson, Desjardin & E. Horak. This species forms also a significantly distant branch with G. earleae according to 20 base substitutions with 714 base pairs of nrITS sequences and has a sequence divergence of 2.8%.

3.2. Taxonomy

3.2.1. Species descriptions

Gymnopus dryophiloides Antonín, R. Ryoo & K.H. Ka, sp. nov.

Mycobank MB 828254

Diagnosis: Gymnopus dryophiloides differs from G. dryophilus by a more distinct orange tinge of the stipe, slightly smaller (shorter) basidiospores, shorter cheilocystidia with a larger variability in shape, and forms an independent monoclade in the ITS and LSU dataset. Gymnopus dryophiloides is

Figure 2. Phylogeny of Gymnopus sect. Levipedes based on the nrLSU (nuclear large subunit of ribosomal RNA gene) inferred from Bayesian analysis. Specimen names and their GenBank accession numbers in bold letters were newly sequenced for this study.
characterized by a pale to light yellow, orange or watery ochraceous yellow pileus. It has yellowish white lamellae, a pale to light yellow or orange stipe, (4.0)4.5–6.0(6.5) × 2.5–3.5(4.0) μm large basidiospores, and 17–38(50) × 4.5–10(17) μm large, clavate, (sub)cylindrical, fusoid, mostly lobate, irregular to coralloid cheilocystidia (Figures 3 and 4).

Holotype: Republic of Korea. Mt. Kariawangsan, Dae-hwa-myeon, Pyeongchang, 37°28′32″N, 128°30′11″E, alt. c. 1060–1080 m, 21 August 2012, V. Antonin 12.138 & K.-H. Ka (BRNM 781447, designated here).

Basidiomata single. Pileus 10–50 mm broad, convex to conical-convex with involute margin when young, then conical-convex to plano-convex with less distinct to absent broad umbo and inflexed to straight margin, often uplifted and undulate when old, hygrophanous, striate only at outer margin or not translucently striate, smooth or slightly rugulose, glabrous, pale to light yellow or orange (4–5A3–6, 6A–B5) or watery ochraceous yellow when moist, light yellow to yellowish white (3–4A2–3) when dry. Lamellae very close, L = (35)50–60, l = 3–4(6), emarginate and attached with small tooth, narrow, whitish then yellowish white (3A2–3(4)), with a concolorous, finely denticulate and pubescent edge. Stipe 30–75 × 1.5–5 mm, cylindrical or laterally compressed (sometimes with groove), slightly broadened at apex, slightly broader to subbulbose (up to 10 mm) at base, bulba more distinct in young basidiomata, glabrous or finely pruinose at apex, smooth or finely longitudinally fibrillose, concolorous with lamellae at apex, pale to light yellow or orange (4–5A3–6), sometimes darker, light orange or grayish orange (5A4, 6B6) in old basidiomata; with whitish to pale (pinkish) ochraceous basal rhizoids. Context membranaceous, concolorous with surface of basidiomata, hollow in stipe, with slightly fungoid smell and mild taste, sometimes with slightly acrid aftertaste.

Basidiospores (4.0)4.5–6.0(6.5) × 2.5–3.5(4.0) μm, average = 5.3 × 3.1 μm, E = 1.50–2.40, Q = 1.70–1.86, ellipsoid, ellipsoid-fusoid, pip-shaped, hyaline, thin-walled. Basidia 17–23(25) × 5.0–7.5 μm, 4-spored,
Figure 4. Gymnopus dryophiloides (BRNM 781447). (A) cheilocystidia; (B) basidiospores; (C) pileipellis cells. Scale bar = 20 μm.

clavate, sometimes subcapitate. Basidioides 12–25 × 3.0–8.0(9.0) μm, subcylindrical, clavate (and sometimes subcapitate), fusoid. Cheilocystidia 17–38(50) × 4.5–10(17) μm, variable in shape, clavate, (sub)cylindrical, fusoid, mostly lobate, irregular to coralloid, thin-walled. Pleurocystidia absent. Trama hyphae cylindrical or subinflated, ± thin-walled, branched, smooth or minutely incrusted, 4.0–15 μm wide. Pileipellis composed of cells forming a Dryophila-structure, up to 80 × 5.0–25 μm in size, cylindrical, fusoid or clavate, irregular, lobate, branched, subcoralloid, thin- to slightly thick-walled, smooth or incrusted, pale (dirty) yellow-brown in KOH. Pileocystidia absent. Stipitipellis a cutis of branched, subcoralloid, thin- to slightly thick-walled. Caulocystidia absent, scattered cylindrical, thin-walled terminal cells present. Clamp connections present in all tissues.

Ecology: On detritus and litter of Abies holophylla, Acer sp., Castanea crenata, Juglans mandshurica, Larix campestris, Pinus densiflora, P. koraiensis, P. rigida, Quercus acutissima, Q. mongolica, Q. serrata, Quercus sp. and Zelkova serrata.

Etymology: dryophiloides = similar to G. dryophilus.

Additional Specimens Examined: Republic of Korea. Inje, Buk-myeon, Seoraksan National Park, 38°09′51″N, 128°22′23″E, alt. c. 480 m, 27 June 2008, V. Antonín 08.39 (BRNM 781679); Chuncheon, Dongsan-myeon, Bongmyong-ri, 20 August 2007, R. Ryoo KG 139 (BRNM 781444); Deogyusan National Park, Cheoe-yeon falls, 24 August 2007, R. Ryoo KG 158 (BRNM 781446); Deogyusan National Park, Chilyeon falls, 23 August 2007, R. Ryoo KG 153 (BRNM 781446); Cheongiu, Songnisan-maltijae Recreational Forest, 37°29′33″N, 127°46′43″E, alt. c. 230 m, 27 August 2015, V. Antonín 15.106, K.-H. Ka, S.-K. Kim & J.-A. Kang (BRNM 781451); Chungju, Joryeongsan National Park, 36°48′43″N, 128°02′43″E, alt. c. 495 m, 28 August 2015, V. Antonín 15.117, K.-H. Ka, S.-K. Kim & J.-A. Kang (BRNM 781452); Chungju, Bonghwang Nature Forest, 37°03′20″N, 127°49′46″E, alt. c. 115 m, 29 August 2015, V. Antonín 15.125, K.-H. Ka, S.-K. Kim & J.-A. Kang (BRNM 781453); Youngdong, Mt. Minjooji Recreational Forest, 36°03′12″N, 127°49′50″E, alt. c. 620 m, 26 August 2015, V. Antonín 15.97, K.-H. Ka, S.-K. Kim & J.-A. Kang (BRNM 781450); Wonju, Mt. Chiaksan, 37°25′24″N, 128°04′16″E, alt. c. 290 m, 27 August 2015, V. Antonín 15.75, K.-H. Ka, S.-J. Yeong & E.-J. Wang (BRNM 781449); Jecheon, recreational forest, 37°08′42″N, 128°02′03″E, alt. c. 350 m, 21 August 2015, V. Antonín 15.65, K.-H. Ka, S.-J. Yeong & E.-J. Wang (BRNM 781448); Muju, Mt. Deogyu Recreational Forest, 35°54′26″N, 127°48′39″E, alt. c. 750 m, 30 August 2016, V. Antonín 16.130, K.-H. Ka & S.-H. Kim (BRNM 781454); ibid., 5 September 2016, V. Antonín 16.155, R. Ryoo, K.H. Wang & Y.S. Jang (BRNM 781456); Jangsu, Waryong National Recreational Forest, 35°40′45″N, 127°28′37″E, alt. 570 m, 1 September 2016, V. Antonín 16.145, K.-H. Ka & S.-H. Kim (BRNM 781455); Gyeongnam Prov., Geochang-gun, Geumwonsan Natural Recreational Forest, 35°43′55″N, 127°47′52″E, alt. 480 m, 11 July 2017, V. Antonín 17.25, K.-H. Ka, R. Ryoo & M.-H. Jeon (BRNM 808970).

Remarks: Gymnopus dryophiloides is characterized by having a small, light to grayish orange pileus, a light yellow to light orange, at base subbulbose stipe, small basidiospores, clavate, subcylindrical, fusoid, mostly lobate, irregular to coralloid cheilocystidia, and a pileipellis of the Dryophila-structure. A collection from Dongsan-myeon, Chuncheon (BRNM 781444) differs by smaller, broadly clavate, fusoid, utriform, only more or less regular cheilocystidia, and a collection from Deogyusan National Park, Chilyeon falls (BRNM 781446) also by mostly clavate, regular cheilocystidia.

Gymnopus brunneodiscus Antonín, R. Ryoo & K.-H. Ka, sp. nov.

MycoBank MB 828304

Diagnosis: Gymnopus brunneodiscus differs from G. ocior by a light brown to (chestnut) brown pileus...
with a paler, almost whitish margin, a pale brown stipe with an orange-brown tinge and larger cheilocystidia, forming an independent clade in the nrITS and nrLSU phylogeny. Pileus of Gymnopus brunneodiscus (BRNM 714970) brown, almost whitish margin; stipe pale brown with orange tinge to orange-brown with yellowish white apex; basidiospores (4.7)5.0–7.0 × 2.7–4.0 μm, average 5.6 × 3.3 μm; cheilocystidia 18–68 × 3.5–6.0(8.0) μm, cylindrical, (narrowly) clavate, irregular, lobed, branched to coralloid, thin-walled. Pleurocystidia absent. Trama hyphae cylindrical or subinflated, thin- to slightly thick-walled, branched, smooth or less frequently minutely incrusted, hyaline, 3.0–15 μm wide. Pileipellis composed of cells forming a Dryophila-structure, cells often relatively slender, irregular, lobate to coralloid, smooth or incrusted, ± thin-walled, 3.0–15 μm wide; incrustation ± hyaline (margin) to (dark) brown (center) in KOH. Pileocystidia absent. Stipitpellis a cutis of cylindrical, parallelly arranged, slightly thick-walled, smooth or minutely incrusted, 3.0–5.0(6.0) μm wide hyphae. Caulocystidia absent; scattered adpressed to suberect, clavate to cylindrical, ± thin-walled terminal cells present. Clamp connections present in all tissues.

Ecology: On detritus of Larix sibirica, Pinus densiflora, Acer palmatum, Ailanthus glandulosa, Castanea crenata, Quercus mongolica and Quercus sp. in mixed forests.

Etymology: brunneus = brown, discus = disk. Having a brown-colored pileus center.

Additional Specimens Examined: Republic of Korea. Chuncheon, Dongsan-myeon, Experimental forest of Kangwon National University, 37°46′46″N, 127°48′59″E, alt. c. 210 m, 22 July 2007, V. Antonín 07.102, H.D. Shin & R. Ryoo (BRNM 714970); Ibid., V. Antonín 07.108, H.D. Shin & R. Ryoo (BRNM 714974); Cheongju, Sangdang-sanseong Natural Recreation Forest, 36°40′48″N, 127°32′40″E, alt. c. 180 m, 27 August 2015, V. Antonín 15.112, K.-H. Ka, K.-S. Kim & J.A. Kang (BRNM 808971); Hongcheon, Dong-myeon, 37°41′07″N, 128°00′06″E, alt. 285 m, 17 August 2013, V. Antonín 13.175 & R. Ryoo (BRNM 808972); ibid., 37°42′08″N, 128°00′06″E, alt. c. 500 m, 17 August 2013, V. Antonín 13.173 & R. Ryoo (BRNM 808973); ibid., 37°41′10″N, 128°00′02″E, alt. c. 310 m, 17 August 2013, V. Antonín 13.180 & R. Ryoo (BRNM 808974); Tean, Anmyeon-do, 36°29′47″N, 126°21′36″E, alt. 40 m, 11 July 2014, V. Antonín
1. Pileus ochraceous to (chestnut) brown, with collection from Tean, Anmyeon-do (BRNM 808976).

2. Pileus milky white to pale yellow-white with paler margin (which seems to be a constant character), closely placed yellowish white lamellae, a smooth and glabrous stipe, (4.7)5.0–7.0 × 2.7–4.0 μm large basidiospores, and cylindrical, (narrowly) clavate, irregular, lobed to coralloid cheilocystidia. Our collection from Tean, Anmyeon-do (BRNM 808976) differs by having smaller basidiospores ((4.2)4.5–5.5(6.0) × 2.5–3.2 μm), and shorter cheilocystidia (18–35 × 4.0–7.0 μm).

3.2.2. Key to species of Gymnopus sect. Levipedes

1. Pileus light to grayish orange or watery ochraceous; stipe pale brownish with paler apex; basidiospores 5.0–6.0(6.5) × 2.7–3.5 μm, average 5.6 × 3.1 μm, Q = 1.83. ______________ Gymnopus brunneodiscus ______________

2. Pileus white, light to grayish orange or watery ochraceous, brownish, light or grayish orange; cheilocystidia up to 38(50) × 4.5–13(17) μm, more distinctly clavate; pileipellis of the typical Dryophila-structure. ______________ Gymnopus dryophiloides ______________

3. Pileus light to grayish orange or watery ochraceous yellow, ochraceous brownish, light or grayish orange; stipe light yellow to light orange, pale brownish or (orange) brown; basidiospores (4.0)4.5–6.5 × 2.5–3.5(4) μm, average less than 6.0 × 3.1 μm ______________ Gymnopus dryophiloides ______________

4. Pileus orangish ochraceous; stipe pale brownish with paler apex; basidiospores 5.0–6.0(6.5) × 2.7–3.5 μm, average 5.6 × 3.1 μm, Q = 2.03. ______________ Gymnopus sp. 2 ______________

4. Discussion

Species of Gymnopus sect. Levipedes from the Republic of Korea have been distinguished based on their macro- and micromorphology and molecular characteristics. The phylogenetic position of Gymnopus dryophiloides complex is similar in nrITS and nrLSU to that published in previous papers [5,18] but the Korean collections form an independent clade, a new species, G. dryophiloides. This study shows that G. nubicola Halling is a part of the G. dryophilus group in the nrITS phylogeny, although it has morphologically different characters [5]. The separate positions of G. brunneodiscus, Gymnopus spp. 1, 2 and 3 have been confirmed based on their morphological and molecular characterization. Although Gymnopus spp. 1, 2 and 3 represent both morphologically and phylogenetically separate new species, the collected material (only one collection, sometimes only one basidioma) is too poor for formal descriptions of these taxa. 

Gymnopus dryophiloides is morphologically and phylogenetically closely related to G. dryophilus, a species widely distributed throughout Europe [1]. It differs by a more distinct orange tinge of the stipe, sometimes distinctly yellow lamellae, slightly smaller (shorter) basidiospores and shorter cheilocystidia with a greater variability in shape [1,18]; for a detailed comparison, see Table 2. According to our phylogenetic studies, it seems that North American collections also form a separate clade. Gymnopus nubicola, described from Ecuador, should differ by a dark reddish brown pileus when young and fresh, eventually becoming brown to light brown, occasionally becoming grayish orange and then mostly at the margin, flesh with a pungent, almost waxy smell, and a mild to waxy taste, a brown to dark brown stipe toward base, and small, 10–20 × 3–5 μm, scattered and inconspicuous, irregularly lobed and knobbed cheilocystidia [3]. However, the phylogenetic placement of this collection supports the proposal by Matta et al. [5] to consider it merely a form of an (American) type of "G. dryophilus". Gymnopus sp. 2 (Yangyang, Michcheongol Natural Resort Forest, 26 June 2008, V. Antonín 08.29, BRNM 718669, Figures 3 and 6)
differs by a centrally ochraceous brownish and marginally pale cream pileus, an (orange) brown stipe toward base, larger basidiospores, 5.5–6.5 \( \times \) (2.5)–3.2 (3.5) \( \mu \)m, \( Q = 2.03 \), shorter basidia (18–21 \( \times \) 5.5–7.5 \( \mu \)m) and a pileipellis forming a transition between a Dryophila-structure and a cutis.

\textit{Gymnopus} sp. 3 (Hamyang, Macheon-myeon, 8 July 2008, V. Anton\n\textsc{ı}n 08.72 & R. Ryoo, BRNM 718701, Figures 3 and 7) differs by a milky white to pale yellow-white pileus with irregularly dispersed brown stains, brown stained lamellae, larger basidiospores, (6.0)–6.5–7.0 (7.5) \( \times \) 3.5–4.0 (4.5) \( \mu \)m, and smaller cheilocystidia (23–30 \( \times \) 6.0–10 \( \mu \)m).

The clade formed by \textit{Gymnopus brunneodiscus} has 1.00 posterior probabilities and shows one independent group phylogenetically. \textit{Gymnopus ocior} differs by a dark red- or orange-brown pileus sometimes with yellowish or yellow-red (never whitish) margin, a yellow to ochraceous or reddish brown stipe and smaller, 12–45 \( \times \) 3.0–9.0 \( \mu \)m cheilocystidia [1,18]. In the original description of \textit{Gymnopus sepiiconicus} (Corner) A.W. Wilson, Desjardin & E. Horak, Corner [22] mentioned smaller basidiomata (pileus up to 18 mm wide, stipe up to 50 \( \times \) 1.5 mm), and slightly smaller basidiospores (4.5–6.4 \( \times \) 2.4–4.4 \( \mu \)m) and shorter cheilocystidia (20–44 \( \times \) 3–7 \( \mu \)m), \textit{G. alpinus} (Vilgalys & O.K. Mill.) Antonin & Noordel. has a dark brown pileus and larger, (6.2)–6.5–8.5 \( \times \) 3.0–4.4 \( \mu \)m basidiospores and differently shaped cheilocystidia [1]. \textit{Gymnopus bicolor} A.W. Wilson, Desjardin & E. Horak also has a distinctly paler margin, but has larger, 5.2–8.0 \( \times \) 2.4–3.6 \( \mu \)m basidiospores and differently shaped cheilocystidia [4]. \textit{Gymnopus earleae} Murrill has a dark brown pileus, but differs by a basally

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**Table 2.** Differential macro- and micromorphological characters of \textit{G. dryophiloides} against similar species.

| Character                  | \textit{G. dryophiloides}                                                                 | \textit{G. dryophilus} [1,18]                                                                 |
|----------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Pileus                     | pale to light yellow or orange or watery ochraceous-yellow                               | pale colored, orange-brown or ochraceous brown, then ochraceous-brown, yellow-ochraceous to |
| Lamellae                   | whitish then yellowish white                                                            | pinkish ochraceous white, cream to yellow                                                  |
| Stipe                      | 30–75 \( \times \) 1.5–5 mm, concolorous with lamellae at apex, pale to light yellow or orange, sometimes darker, light orange or grayish orange | 30–120 \( \times \) 1–5 mm, yellowish with paler apex, sometimes somewhat darker ochraceous brown in basal part |
| Basidiospores              | (4.0)4.5–6.0(6.5) \( \times \) 2.5–3.5(4.0) \( \mu \)m                                | 5.0–7.0(8.0) \( \times \) (2.5)3.0–4.0(4.5) \( \mu \)m                                       |
| Cheilocystidia             | 17–38(50) \( \times \) 4.5–10(17) \( \mu \)m, variable in shape, clavate, (sub)cylindrical, fusoid, mostly lobate, irregular to coralloid | 17–55 \( \times \) 4.0–10 \( \mu \)m, (sub)cylindrical, narrowly clavate, mostly coralloid, also lobate or with apical projections |

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![Figure 6.](image-url) *Gymnopus* sp. 1 (BRNM 808978). (A) cheilocystidia; (B) basidiospores; (C) pileipellis cells. Scale bar = 20 \( \mu \)m.

![Figure 7.](image-url) *Gymnopus* sp. 2 (BRNM 718669). (A) cheilocystidia; (B) basidiospores; (C) pileipellis cells. Scale bar = 20 \( \mu \)m.
Table 3. Differential macro- and micromorphological characters of *G. brunneodiscus* against similar species.

| Character                  | *G. brunneodiscus* | *G. odor* [1,18] | *G. sepiiconicus* [4] | *G. alpinus* [2,17] | *G. bicolor* [4] | *G. earlei* [2] |
|----------------------------|-------------------|------------------|-----------------------|--------------------|-----------------|-----------------|
| **Pileus**                 | Light brown to (chestnut) brown, with paler, almost whitish margin | Dark red- or orange-brown, pallescent to reddish yellow or pinkish brownish | Brown to dark brown with beige yellow to white margin in age | Very dark red- to purplish brown, uniform, or only slightly paler at very margin | Brown with beige white margin | Dark brown when young and fresh, fading to an orangish buff |
| **Lamellae**               | Pale yellowish white, sometimes with brownish tinge when young | Very dark red- or orange-brown, pallescent to reddish yellow or pinkish brownish | Whitish or yellowish lamellae | White | White or cream colored | Pale orangish yellow, becoming orangish buff |
| **Stipe**                 | 35–70 × 1–3 mm, pale brown with orange tinge to orange-brown, with paler, yellowish white apex when young | 20–60 × 2–5 mm, yellow to orange or reddish brown | 40–52 × 1–2 mm, brownish orange to brown or creamy buff, with orange beige apex | 30–60 × 2.5–6 mm, pale yellow to orange-yellow to orange-brown below | 30–42 × 2–3 mm, reddish brown, becoming pale orange-brown, with white beige apex | 22–40(50) × 1–2(4) mm, orangish buff when young, becoming yellowish orange (ochraceous orange) at the apex and a tawny brown below with age |
| **Basidiospores**         | (4.7)5.0–7.0 × 2.7–4.0 μm | (5.0)5.5–6.5(7.0) × (2.5)2.75–3.5(4.0) μm | 4.8–6.4 × 2.4–4.4 μm | (6.2)6.5–8.5 × 3.0–4.4 μm | 5.2–8.0 × 2.4–3.6 μm | 5.6–7 × 2.8–3.5 μm |
| **Cheilocystidia**        | 18–68 × 3.5–6.0(8.0) μm, cylindrical, (narrowly) clavate, irregular, lobed, branched to coralloid, (5.6–6.4–8.3–5 μm) and smaller, usually absent or inconspicuous | 16–60 × 6.0–12 μm, clavate, subylindrical or subutriform, often lobed, branched, coralloid or with apical projections | 20–44 × 3–7 μm, irregularly cylindrical to obtuse clavate, contorted, lobulate | 16.5–30(44) × 6.0–11.5 μm, clavate, simple, irregular to coralloid | 17.5–25.5 × 6.5–9.5 μm, broadly clavate, lobulate, smooth | Usually absent, inconspicuous and rare when present, often collapsed, 24.5–30 × 2.0–2.8 μm, narrowly cylindrical to flexuous contorted, rarely diverticulate |

**Figure 8.** *Gymnopus* sp. 3 (BRNM 21870). (A) cheilocystidia; (B) basidiospores; (C) pileipellis cells. Scale bar = 20 μm.
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