

# Notes on the Lichen Genus *Leptogium* (Collemaataceae, Ascomycota) in South Korea

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**Abstract** *Leptogium* (Ach.) Gray is distributed throughout South Korea; however, for nearly two decades no detailed taxonomic or revisionary research on this lichen genus has been conducted. This study examined the specimens deposited in the lichen herbarium at the Korean Lichen Research Institute, and samples were identified using descriptions recently published in the scientific literature. In this revisionary study, a total of fourteen species of *Leptogium* were documented, including new records of *Leptogium delavayi* Hue, *Leptogium denticulatum* Nyl., and *Leptogium trichophoroides* P. M. Jørg. & A. K. Wallace. Detailed descriptions of each species are given, including their morphological, anatomical, and chemical characteristics. A key to all *Leptogium* species known to occur in South Korea is also presented.

**Keywords** *Leptogium*, Lichens, New record, South Korea, Taxonomic key

*Leptogium* (Ach.) Gray is a well-known lichen genus distributed throughout the tropical regions of the world. This genus is classified in the family Collemaataceae, which was divided into seven sections [1] on the basis of habit and anatomy of the thallus, nature of the cortex, presence or absence of tomentum, and the nature of spores [2]. Among the seven sections, Sect. *Mallotium* (Ach.) Vain and Sect. *Leptogium* are known to occur in South Korea. The section *Mallotium* is distinguished by the presence of a tomentum on the surface of a well-developed and foliose thallus, while the section *Leptogium* lacks tomentum on either surface and has muriform spores [1].

The genus *Leptogium* is characterized by a foliose to subsquamulose thallus, which can be gelatinous, blue-grey to brown or blackish, adnate to loosely adnate, with isidia or lobules; flat to plicate, spreading to erect lobes; non-layered medulla with an outer cortex of isodiametric cells in a single layer; smooth, wrinkled or ridged, glabrous or

non-glabrous surfaces; lower surface with simple rhizines, irregular holdfasts, and hairs; interwoven, or columnar paraplectenchymatous, medullary hyphae; presence of the cyanobacterial photobiont (*Nostoc*); lecanorine, laminal to marginal, sessile to short stalked apothecia; ascospores colorless, ovoid, ellipsoid or fusiform, septate, submuriform to muriform, acute, acuminate or obtuse; and laminal or marginal pycnidia with bacilliform, simple, colorless conidia [1, 3-5]. This genus comprises many species, which are widely distributed in tropical and temperate regions, with a few species distributed in Arctic and sub-Antarctic regions [4, 6, 7]. The genus *Collema* closely resembles the genus *Leptogium* in external appearance, but the former is distinguished by the absence of cortical layers on either side of the thallus [8, 9]. Furthermore, recent phylogenetic studies revealed that *Collema* and *Leptogium* are not monophyletic genera [10, 11].

Several studies have investigated the taxonomy, ecology, and distribution of *Leptogium* [2, 3, 5, 8, 12-16]; however, the reported number of known species comprising this genus varies among these publications, ranging from 150 to 400 [9, 17, 18]. In South Korea, no comprehensive study of *Leptogium* has been conducted to date, and existing information is based on scant data from different reports. According to previous studies, eleven species have been reported, including one variety [19, 20]. These species include *Leptogium azureum* (Sw. ex Ach.) Mont., *Leptogium burnetiae* C. W. Dodge, *Leptogium cochleatum* (Dicks.) P. M. Jørg. & P. James, *Leptogium cyanescens* (Pers.) Körb., *Leptogium hildenbrandii* (Garov.) Nyl., *Leptogium hirsutum* Sierk, *Leptogium lichenoides* (L.) Zahlbr., *Leptogium moluccanum* (Pers.) Vain., *Leptogium moluccanum* var. *myriophyllum* (Müll. Arg.) Asahina, *Leptogium pedicellatum*

Mycobiology 2014 June, 42(2): 120-131  
<http://dx.doi.org/10.5941/MYCO.2014.42.2.120>  
pISSN 1229-8093 • eISSN 2092-9323  
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**Received** February 18, 2014

**Revised** March 20, 2014

**Accepted** May 3, 2014

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P. M. Jørg., *Leptogium rugosum* Sierk, and *Leptogium saturninum* (Dicks.) Nyl. The present study reports three additional species: *Leptogium delavayi* Hue, *Leptogium denticulatum* Nyl., and *Leptogium trichophoroides* P. M. Jørg. & A. K. Wallace. A revised key to all species of *Leptogium* from South Korea is provided based on the current study and data from the scientific literature.

## MATERIALS AND METHODS

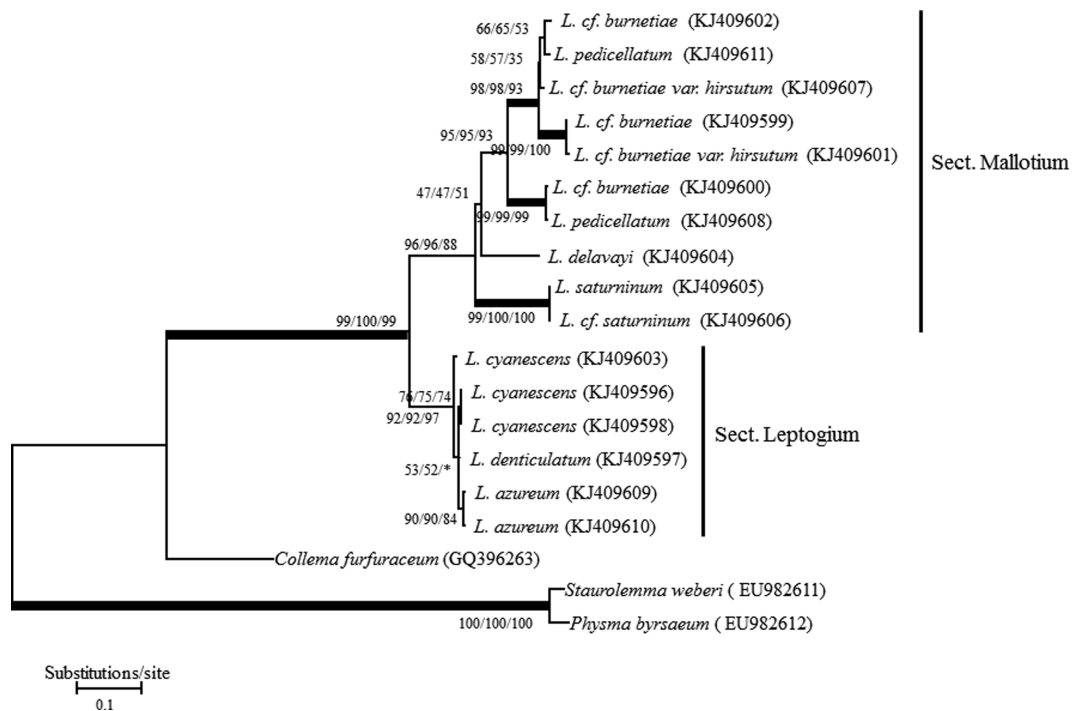
The study was based on specimens collected from South Korea over the past ten years. A Nikon SMZ645 dissecting microscope (Nikon Corp., Tokyo, Japan) was used for identifying morphological characteristics of the thallus and reproductive structures, including color, size, and shapes, and a Zeiss Scope, A1 compound microscope (Carl Zeiss, Oberkochen, Germany) was used for studying the anatomy of thalli and ascomata. Spot test reactions were performed on thalli under a compound microscope.

Chemicals were extracted in analytical grade acetone in a 1 mL Eppendorf tube. Thin layer chromatography (TLC) was performed using a glass plate coated with TLC Silica gel 60, in solvent system A (toluene : dioxin : acetic acid = 180 : 45 : 5) [21]. Acetone extracts of lichen thalli were also subjected to high performance liquid chromatography (HPLC) analyses (LC-20A; Shimadzu, Kyoto, Japan) on a YMC-Pack ODS-A (150 × 3.9 mm I.D.) reversed-phase column containing fully end-capped C18 material (particle

size, 5 µm; pore size, 12 nm). Elution was performed at a flow rate of 1 mL/min under the following conditions before subsequent injection: column temperature, 40°C; solvent system, methanol : water : phosphoric acid (80 : 20 : 1, v/v/v). Analyses were monitored by a photodiode array detector (SPD-M20A; Shimadzu) with a range of 190~800 nm throughout the HPLC run. Observed peaks were scanned between 190 and 400 nm. Voucher specimens were deposited in the herbarium of the Lichen & Allied Bio-resource Centre at the Korean Lichen Research Institute, Sunchon National University, South Korea.

**Molecular methods.** Total DNA was extracted directly from the thalli of selected specimens according to Ekman [22], and was purified with a DNeasy Plant Mini Kit (Qiagen, Hilden, Germany). The nuclear ribosomal RNA gene, including the internal transcribed spacers (ITS) 1 and 2 and the 5.8S subunit, was amplified using the primers ITS1F [23] and LR5 [24]. Amplifications were performed using a TaKaRa JP/TP600 PCR thermal cycler (TaKaRa Bio Inc., Otsu, Japan). PCR products were then sent to the sequencing facilities of the Genotech Cooperation (Seoul, South Korea) for purification and sequencing.

Alignment of DNA sequences was performed using BioEdit [25]. Ambiguous regions were delimited [26] and excluded from the alignment. Three species (*Collema furfuraceum* Du Rietz, *Staurolemma weberi* Henssen & P. M. Jørg., and *Physma byrsaenum* (Ach.) Tuck.) were selected



**Fig. 1.** Phylogenetic relationships among species of *Leptogium* for which molecular data are currently available in GenBank. This phylogeny was constructed using ITS-5.8S rDNA sequences. The tree was inferred by neighbor joining (NJ), minimum evolution (ME), and maximum likelihood (ML) analyses using the software MEGA 5. Bootstrap values are shown near the corresponding branch (NJ/ME/ML), and bold lines indicate values greater than 95%.

as outgroups based on BLAST sequence similarity searches in GenBank. Phylogenetic relationships among taxa were investigated using MEGA 5.2 software [27]. Phylogenetic trees were constructed using neighbor joining (NJ), minimum evolution, and maximum likelihood methods. Bootstrap support values were obtained with 1,000 pseudoreplicates.

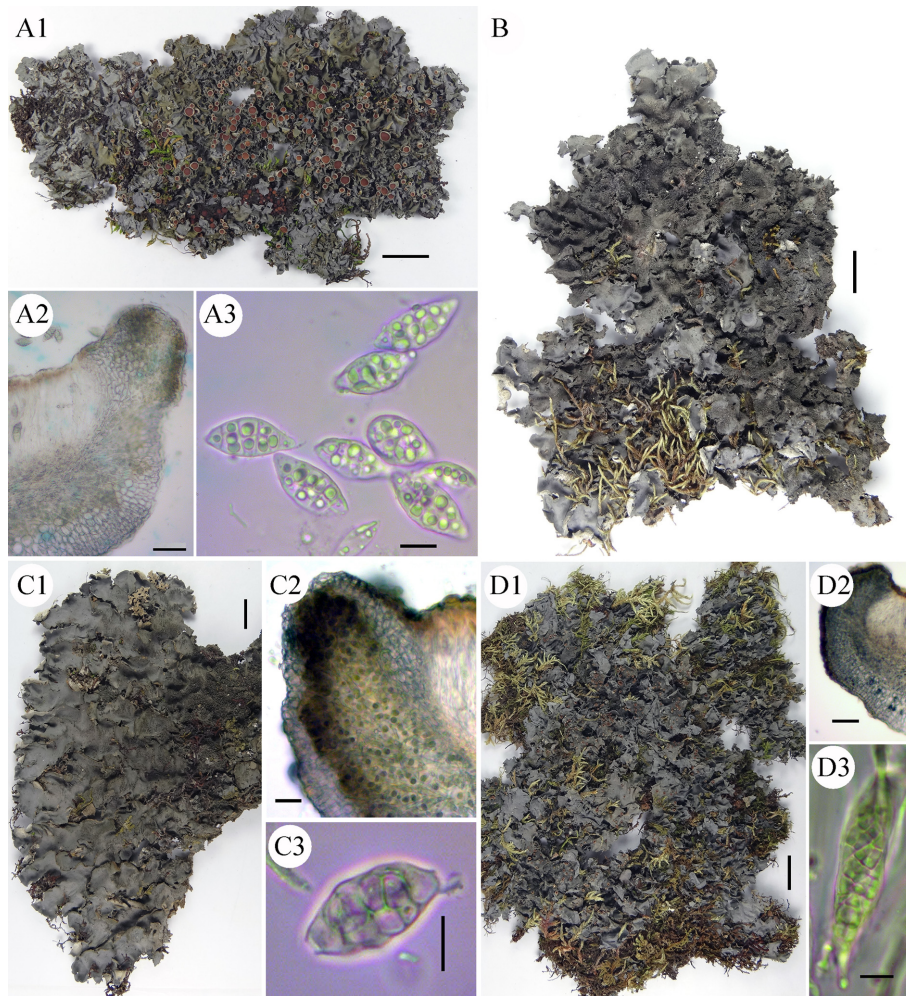
**RESULTS AND DISCUSSION**

**Phylogenetic analysis.** The final alignment included 1,165 characters, 648 of which were variable. The NJ tree shows that the *Leptogium* species comprised two main clades, supported by bootstrap values of 99% (Fig. 1). All species within the clade comprising Sect. *Leptogium* have no tomentum on the thallus surface, while species clustered within the clade Sect. *Mallotium* have tomentum on the lower surface of the thallus. The Sect. *Leptogium* and Sect. *Mallotium* have a monophyletic origin. *Leptogium delavayi* is a sister group to *L. saturninum*. As some specimens are

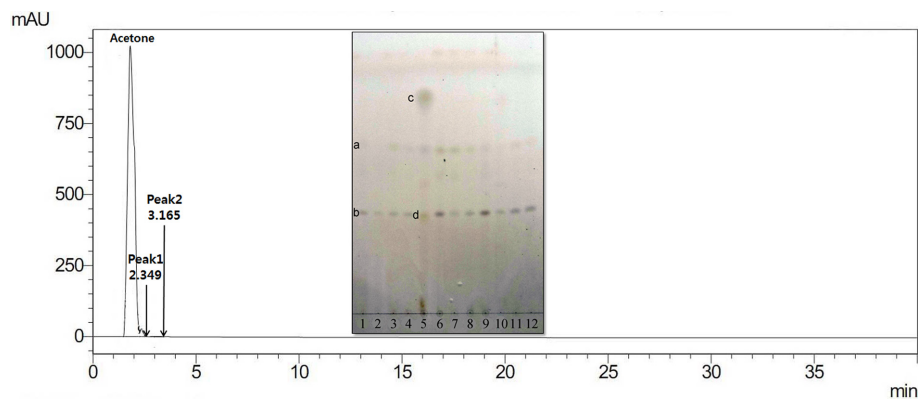
somewhat old, it was difficult to extract the total DNA from these thalli, thus limiting the number of specimens used in the phylogenetic analysis.

**Key to species of *Leptogium* from South Korea**

- 1. Thallus isidiate ..... 2
- 1a. Thallus not isidiate, sometimes lobulate ..... 5
- 2. Lower surface of lobes without white-gray tomentum .. 3
- 2a. Lower surface of lobes with white-grey tomentum ..... 4
- 3. Isidia squamuliform, never cylindrical ..... *L. denticulatum*
- 3a. Isidia granular to cylindrical, occasionally squamuliform ..... *L. cyanescens*
- 4. Thallus olivaceous-blackish, isidia usually granular ..... *L. saturninum*
- 4a. Thallus and isidia blue-grey, isidia cylindrical coralloid, apothecia pedicellate ..... *L. burnetiae*
- 5. Lower surface of lobes with white-grey tomentum ..... 6
- 5a. Lower surface of lobes without white-grey tomentum



**Fig. 2.** A, *Leptogium azureum*, A1: Habitus, A2: Section through apothecium margin, A3: Ascospores; B, *Leptogium burnetiae* habitus; C, *Leptogium burnetiae* var. *hirsutum*, C1: Habitus, C2: Section through apothecium margin, C3: Ascospores; D, *L. cyanescens*, D1: Habitus, D2: Section through apothecium margin, D3: Ascus with ascospores (scale bars: A1, B, C1, D1 = 1 cm, A2, D2 = 50 µm, C2 = 20 µm, A3, C3, D3 = 10 µm).



**Fig. 3.** High performance liquid chromatography and thin layer chromatography (solvent system A) profiles of *Leptogium* species. 1, *Leptogium azureum* with unknown chemicals 1 (a) and 2 (b); 2, *Leptogium burnetiae*; 3, *Leptogium burnetiae* var. *hirsutum*; 4, *Leptogium cyanescens*; 5, Control [*Lethariella cladonioides* (Nyl.) Krog] with atranorin (c), norstictic acid (d); 6, *Leptogium delavayi*; 7, *Leptogium denticulatum*; 8, *Leptogium hildenbrandii*; 9, *Leptogium moluccanum*; 10, *Leptogium pedicellatum*; 11, *Leptogium saturninum*; 12, *Leptogium trichophoroides*.

- ..... 10  
 6. Thallus smooth, apothecia prominently stalked  
 ..... *L. pedicellatum*  
 6a. Thallus wrinkled ..... 7  
 7. Thallus with distant wrinkles, euparaplectenchymatous  
 layer above the cyanobiont layer ..... 8  
 7a. Thallus densely wrinkled, apothecia with supporting  
 layer below the cyanobiont layer ..... 9  
 8. Thallus olivaceous, apothecia on stalks, without long  
 marginal hairs, spores  $30\sim 38 \times 8\sim 12 \mu\text{m}$  ..... *L. delavayi*  
 8a. Thallus dark greenish, apothecia on stalks, whitish  
 marginal hairs on young apothecia, spores  $19\sim 24 \times 8\sim$   
 $11 \mu\text{m}$  ..... *L. trichophoroides*  
 9. Thallus very heavily wrinkled, spores fusiform  
 ..... *L. rugosum*  
 9a. Thallus moderately wrinkled, spores ellipsoid  
 ..... *L. hildenbrandii*  
 10. Thallus wrinkled, isidia-like marginal outgrowth  
 ..... *L. lichenoides*  
 10a. Thallus not wrinkled ..... 11  
 11. Thallus dark leaden grey, thalline exciple wrinkled  
 ..... *L. cochleatum*  
 11a. Thallus bluish or olivaceous, thalline exciple smooth  
 ..... 12  
 12. Thallus bluish, thick ( $50\sim 100 \mu\text{m}$ ) ..... *L. azureum*  
 12a. Thallus olivaceous, thin ( $30\sim 60 \mu\text{m}$ ) ... *L. moluccanum*

### Species description.

***Leptogium azureum*** (Sw. ex Ach.) Mont., in Webb & Berthelot, Hist. Nat. Iles Canar. (Paris) 3: 129 (1840).

Thallus foliose, closely to loosely adnate, 1~6 cm wide, 70~120  $\mu\text{m}$  thick, dark grey to bluish. Lobes round to oblong, 2~5 mm wide; margins entire; surface smooth, isidia absent. Lower surface with sparse, tufted rhizines. Apothecia laminal, sessile to shortly pedicellate, 1~2 mm wide; disc concave to flat, pale to dark red-brown; thalline exciple smooth, pale brown, pedicel wrinkled, to 0.5 mm

long. Ascospores ellipsoid, muriform,  $20\sim 30 \times 10\sim 15 \mu\text{m}$ ; pycnidia submarginal. Conidia 1~3  $\mu\text{m}$  long (Fig. 2A).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium azureum* is characterized by the presence of smooth thallus without isidia. This species is similar to *L. cyanescens* in external appearance, but the latter species differs in having isidia on the thallus. According to Sierk [8], this species closely resembles *L. tremelloides* Mont., but the latter species has well-developed proper exciple and slightly larger spores.

**Selected specimens examined:** Mt. Deogyu, on bark,  $35^{\circ}48'32.5''$  N,  $127^{\circ}43'36.3''$  E, elev. 1,320 m, J. S. Hur, 050198, 30 Apr 2005; Mt. Halla, on bark,  $33^{\circ}22'6.77''$  N,  $126^{\circ}34'38.0''$  E, elev. 1,158 m, S. Y. Kondratyuk, L. Lökös, S. O. Oh, S. Joshi, 121469, 6 Jul 2012; on bark,  $33^{\circ}22'13.0''$  N,  $126^{\circ}31'49.0''$  E, elev. 1,530 m, S. O. Oh, U. Jayalal, S. Joshi, J. S. Park, F. H. Tian, J. S. Hur, 121101, 19 Jun 2012; Mt. Jogae, on bark,  $34^{\circ}59'27.9''$  N,  $127^{\circ}20'01.8''$  E, elev. 201 m, J. S. Hur, 040007, 31 Jan 2004; on bark,  $34^{\circ}59'23.6''$  N,  $127^{\circ}20'23.5''$  E, elev. 201 m, J. S. Hur, 040001, 31 Jan 2004.

**Ecology and distribution:** According to Park [28], *L. azureum* is a common species on the bark of *Abies* sp. and deciduous trees. This species has been recorded in different elevation ranges in South Korea. Many reports are from Halla Mountain on Jeju Island (Fig. 4A). In East Asia, this species has also been reported from North Korea [29], China, Taiwan [30], and Japan [31].

***Leptogium burnetiae*** C. W. Dodge, Beih. Nova Hedwigia 12: 120 (1964).

Thallus foliose, closely to loosely adnate, 1~6 cm wide, 70~150  $\mu\text{m}$  thick, grey to bluish grey. Lobes round to oblong, 4~10 mm wide; upper surface smooth to roughened, isidiate; isidia dense, clustered, coralloid, width 0.07~0.09 mm, height 0.2~0.7 mm, laminal, slightly darker than thallus;

sometimes phyllidiate, phyllidia laminal. Lower surface pale, long-celled white hairs, up to 1~1.5 mm long. Apothecia and pycnidia not seen (Fig. 2B).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium burnetiae* is characterized by the presence of gray thallus with the clustered coralloid isidia. This species closely resembles *L. sphaerosporum* P. M. Jørg. & L. Olley in external appearance, but the latter species differs in always having phyllidia on the thallus [32]. *Leptogium hirsutum* is also closely related to *L. burnetiae*, but the former species differs by the presence of gray thallus, and the cylindrical to granular, branched, somewhat large isidia. *Leptogium saturninum* differs from *L. burnetiae* by the presence of darker to blackish, thick thallus, and the short to flattened isidia.

**Selected specimens examined:** Mt. Baekseokbong, on rock, 37°28'7.39" N, 128°39'7.60" E, elev. 494 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090433, 090509, 16 May 2009; Mt. Hambaek, on bark (*Quercus* sp.), 37°10'23.5" N, 128°54'56.0" E, elev. 1,403 m, J. S. Hur, 070726, 19 Jun 2007; Mt. Jiri, on rock, 35°20'04.6" N, 127°42'50.6" E, elev. 1,547 m, J. S. Hur, 060730, 16 Sep 2006; on bark (*Betula* sp.), 35°17'52.7" N, 127°33'19.9" E, elev. 1,360 m, J. S. Hur, 060247, 17 Jun 2006; on bark (*Quercus* sp.), 35°17'8.39" N, 127°33'19.8" E, elev. 1,364 m, Y. Joshi, X. Y. Wang, J. Y. Hur, 091095, 13 Oct 2009; Mt. Jumbong, on bark (*Quercus* sp.), 38°03'46.7" N, 128°26'44.6" E, elev. 680 m, J. S. Hur, 041329, 9 Oct 2004; Mt. Maebong, on bark (*Quercus* sp.), 37°54'6.98" N, 127°58'9.92" E, elev. 617 m, X. Y. Wang, H. S. Jeon, L. V. Lei, J. A. Ryu, 100602, 26 May 2010; Mt. Sobaek, on a mossy rock, 36°57'21.3" N, 128°26'02.5" E, elev. 495 m, J. S. Hur, 030695, 1 Oct 2003; Mt. Songni, on rock, 36°32'43.6" N, 127°51'31.5" E, elev. 470 m, J. S. Hur, 060032, 21 Apr 2006; Mt. Sorak, on rock, 38°11'16.4" N, 128°21'42.7" E, elev. 450 m, J. S. Hur, 041504, 041521, 11 Oct 2004; Micheongol Valley, on rock, 37°56'10.6" N, 128°31'8.77" E, elev. 420 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090327, 14 May 2009.

**Ecology and distribution:** *Leptogium burnetiae* is a common species on bark and rock at higher elevations (greater than 1,200 m), with few specimens recorded at lower elevations (400~500 m) (Fig. 4B). This species was reported for the first time in South Korea by Park [33]. In East Asia, this species has also been reported from Japan [31] and Taiwan [34].

*Leptogium burnetiae* C. W. Dodge var. *hirsutum* (Sierk) P. M. Jørg., Herzogia 2: 457 (1973).

According to Jørgensen [3], specimens of *L. hirsutum* are classified a variety of *L. burnetiae* due to the absence of euparaplectenchymatous proper exciple. Awasthi and Akhtar [2] followed the same method, and all the specimens belong to *L. hirsutum* have been classified as a variety of *L. burnetiae*. Our specimens show the following characters.

Thallus foliose, closely to loosely adnate, 1~6 cm wide,

70~150 µm thick, grey to bluish grey. Lobes round to oblong, 4~10 mm wide; upper surface smooth to roughened, isidiate; isidia dense, clustered, coralloid, width 0.07~0.09 mm, height 0.2~0.7 mm, laminal, slightly darker than thallus, isidioid lobules on the surface and the margin. Lower surface pale, sometimes with partly pinkish, long-celled white hairs, up to 1~1.5 mm long. Apothecia somewhat rare; laminal 0.5~1.5 mm wide, shortly pedicellate, 1~1.5 mm high; disc concave to flat, reddish to dark brown; thalline exciple entire, smooth. Ascospores oval to ellipsoid, muriform, 25~30 × 12~15 µm; pycnidia not seen (Fig. 2C).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

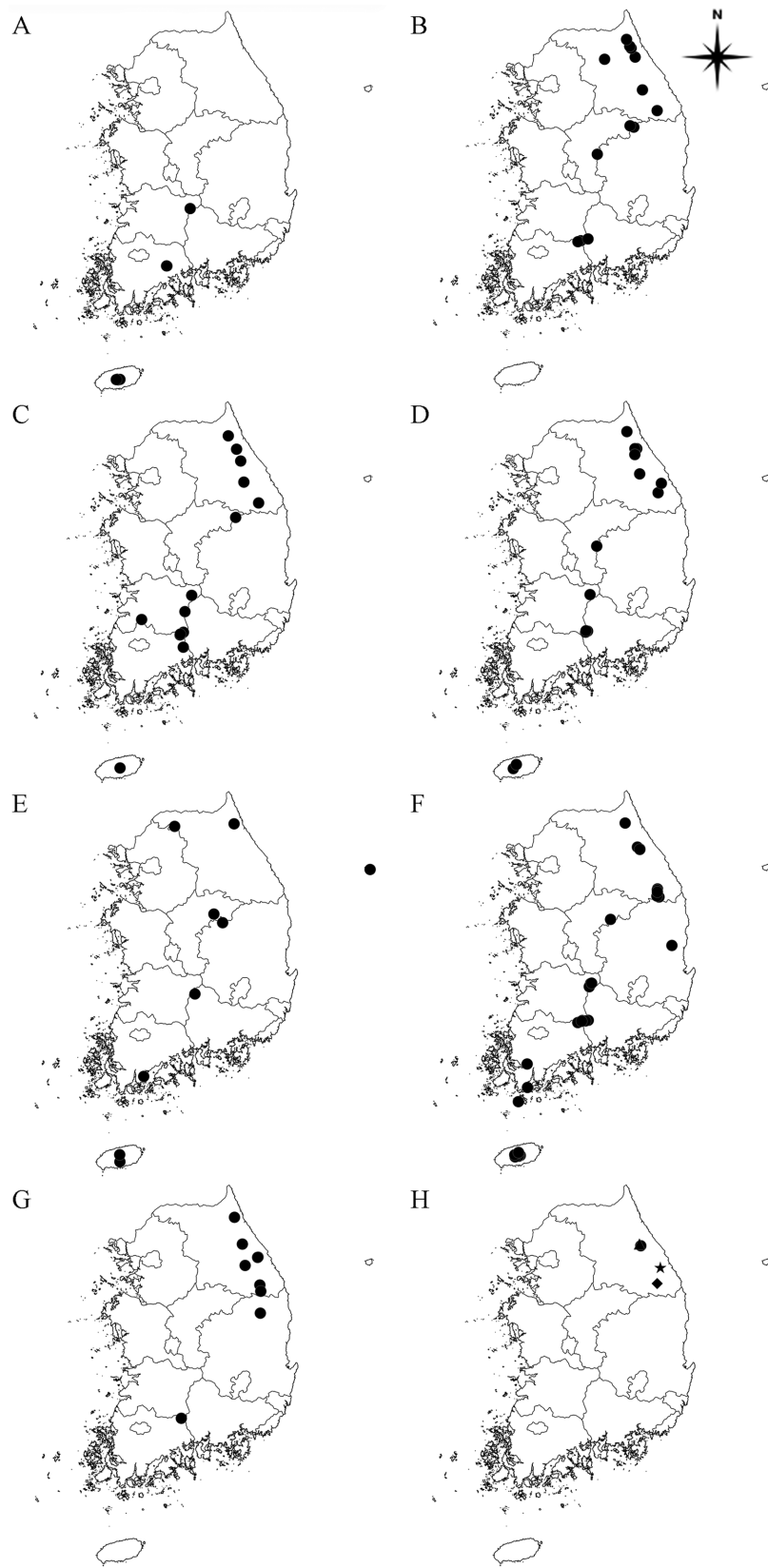
**Remarks:** This species was reported for the first time in South Korea by Park [28]. According to his descriptions, isidioid lobules and lobes with partly pinkish lower surface were present. Further, we suggest all species recorded as *L. hirsutum* to be treated as a variety of *L. burnetiae*.

**Selected specimens examined:** Mt. Baekseokbong, on rock, 37°28'7.39" N, 128°39'7.60" E, elev. 494 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090506, 16 May 2009; Mt. Baekwoon, on bark, 35°06'44.6" N, 127°36'51.1" E, elev. 1,068 m, J. S. Hur 060437, 27 Jun 2006; Mt. Baekwoon, on bark (*Quercus* sp.), 35°37'08.5" N, 127°38'04.9" E, elev. 1,169 m, J. S. Hur, 060622, 17 Aug 2006; Mt. Deogyo, on bark (*Quercus* sp.), 35°51'05.3" N, 127°44'55.4" E, elev. 1,576 m, J. S. Hur, 060508, 10 Aug 2006; Mt. Halla, on bark, 33°22'38.8" N, 126°34'16.4" E, elev. 1,181 m, S. Y. Kondratyuk, S. O. Oh, Y. Kusama, J. S. Hur, 121663, 7 Aug 2012; Mt. Hambaek, on bark (*Quercus* sp.), 37°10'23.5" N, 128°54'56.0" E, elev. 1,403 m, J. S. Hur, 070725, 19 Jun 2007; Mt. Jiri, on bark (*Quercus* sp.), 35°17'8.39" N, 127°33'19.8" E, elev. 1,364 m, Y. Joshi, X. Y. Wang, J. Y. Hur, 091112, 13 Oct 2009; Mt. Naejang, on bark, 35°29'44.3" N, 126°53'02.4" E, elev. 632 m, J. S. Hur, 030615, 8 Aug 2003; Mt. Odae, on bark, 37°46'06.9" N, 128°35'38.7" E, elev. 1,240 m, J. S. Hur, 040491, 8 May 2004; Mt. Sobaek, on bark (*Quercus* sp.), 36°57'57.8" N, 128°30'31.8" E, elev. 1,331 m, J. S. Hur, 070511, 11 Jun 2007; Mt. Sorak, on a mossy rock, 38°07'31.7" N, 128°22'09.0" E, elev. 1,310 m, J. S. Hur, 041496, 10 Oct 2004; Micheongol Valley, on rock, 37°56'10.6" N, 128°31'8.77" E, elev. 420 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090322, 14 May 2009.

**Ecology and distribution:** *Leptogium burnetiae* var. *hirsutum* is a common species on bark and rock at higher elevations (> 1,000 m), with few specimens recorded at lower elevations (400~500 m) (Fig. 4C).

*Leptogium cyanescens* (Pers.) Körb., Syst. Lich. Germ. (Breslau): 420 (1855).

Thallus foliose, closely to loosely adnate, 5~10 cm wide, 70~120 µm thick, dark grey to bluish. Lobes round to broadly oblong, 2~5 mm wide; margins entire with isidia; upper surface smooth, shiny, isidiate; isidia dense, cylindrical, simple, same color as thallus or darker. Lower surface with sparse, tufted rhizines. Apothecia very rare; laminal, sessile



**Fig. 4.** Distribution of *Leptogium* species in South Korea. A, *Leptogium azureum*; B, *Leptogium burnetiae*; C, *Leptogium burnetiae* var. *hirsutum*; D, *Leptogium cyanescens*; E, *Leptogium denticulatum*; F, *Leptogium pedicellatum*; G, *Leptogium saturninum*; H, *Leptogium delavayi* (●), *Leptogium hildenbrandii* (▲), *Leptogium moluccanum* (◆), *Leptogium trichophoroides* (★).

to shortly pedicellate, 1–2 mm wide; disc concave to flat, pale to dark red–brown; thalline exciple smooth, pale brown. Ascospores ellipsoid, muriform, 20–30 × 6–12 µm; pycnidia not seen (Fig. 2D).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium cyanescens* is characterized by the presence of smooth thallus with dense, simple, and cylindrical isidia. This species is quite similar to *L. azureum* in external appearance, but the latter species differs in not having isidia on the thallus. According to Sierk [8], this species closely resembles *L. dactylinum* Tuck., but the latter species has olivaceous to brownish thallus, and very small, squamuliform lobes with abundant apothecia.

**Selected specimens examined:** Mt. Deogyu, on bark, 35°51'15.9" N, 127°44'55.9" E, elev. 1,557 m, J. S. Hur, 050163, 30 Apr 2005; Mt. Duta, on moss (rock), 37°34'39.0" N, 128°36'23.3" E, elev. 989 m, X. Y. Wang, H. S. Jeon, L. Lei, J. A. Ryu, 100769, 27 May 2010; Mt. Eungbok, on moss (rock), 37°51'6.92" N, 128°31'5.22" E, elev. 706 m, Y. Joshi, X. Y. Wang, J. A. Ryu, 090724, 23 May 2009; Mt. Gitdaebong, on moss (rock), 37°18'36.7" N, 128°56'7.66" E, elev. 1,222 m, J. S. Hur, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090404, 090383, 090386, 15 May 2009; Mt. Halla, on rock, 35°20'20.0" N, 127°41'09.9" E, elev. 755 m, J. S. Hur, 040946, 4 Sep 2004; Mt. Jobong, on moss (rock), 37°56'10.7" N, 128°33'7.47" E, elev. 980 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090318, 14 May 2009; Mt. Seorak, on bark (*Quercus* sp.), 38°09'9.81" N, 128°27'26.7" E, elev. 463 m, Y. Joshi, X. Y. Wang, J. A. Ryu, 090779, 24 May 2009; Mt. Songni, on a moss (rock), 36°32'41.6" N, 127°51'19.0" E, elev. 440 m, J. S. Hur, 060027, 21 Apr 2006; Backdam Temple, on rock, 38°10'40.9" N, 128°22'23.2" E, elev. 455 m, J. S. Hur, 041550, 11 Oct 2004; Kwaneum Temple, on bark (*Quercus* sp.), 33°25'6.78" N, 126°32'9.38" E, elev. 565 m, J. S. Hur, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090070, 19 Apr 2009; Micheongol Valley, on moss (rock), 37°56'10.6" N, 128°31'8.77" E, elev. 420 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090318, 14 May 2009.

**Ecology and distribution:** This species is distributed in different altitudes in South Korea. Most of the species were collected from mossy rock surfaces, and a few specimens were collected from tree bark (Fig. 4D). This species was reported for the first time in South Korea by Kim [35]. In East Asia, this species has also been reported from North Korea [29], China, Taiwan [30], and Japan [31].

***Leptogium delavayi*** Hue, Bull. Soc. Bot. Fr., 36: 25 (1889). Thallus foliose, closely to loosely adnate, 3–5 cm wide, 100–130 µm thick, dark grey to olivaceous. Lobes round to orbicular, 4–7 mm wide; margins entire to crenate without isidia or phyllidiate; upper surface dull, wrinkled. Lower surface pale, with dense, long-celled white hairs, up to 1 mm long. Apothecia common; laminal 0.5–1 mm wide, shortly pedicellate, 1–1.5 mm in height; disc concave to

flat, reddish brown; thalline exciple entire to wrinkled without white hairs. Ascospores ellipsoid with acute ends, muriform, 30–38 × 8–12 µm; pycnidia not seen (Fig. 5A).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium delavayi* is characterized by the presence of olivaceous, wrinkled thallus with pedicellate apothecia. This species closely resembles *L. arisanense* Asah., which has sessile apothecia and long marginal hairs [13]. This is the first record for the lichen mycota of South Korea.

**Specimens examined:** Mt. Hwangbyeng, on moss (bark), 37°44'47.6" N, 128°37'31.5" E, elev. 772 m, J. S. Hur, 080442, 14 Jul 2008.

**Ecology and distribution:** This species was recorded at a mid-elevation range (c. 772 m) in South Korea (Fig. 4H). In East Asia, this species has also been reported from Taiwan, China [30], and Japan [31].

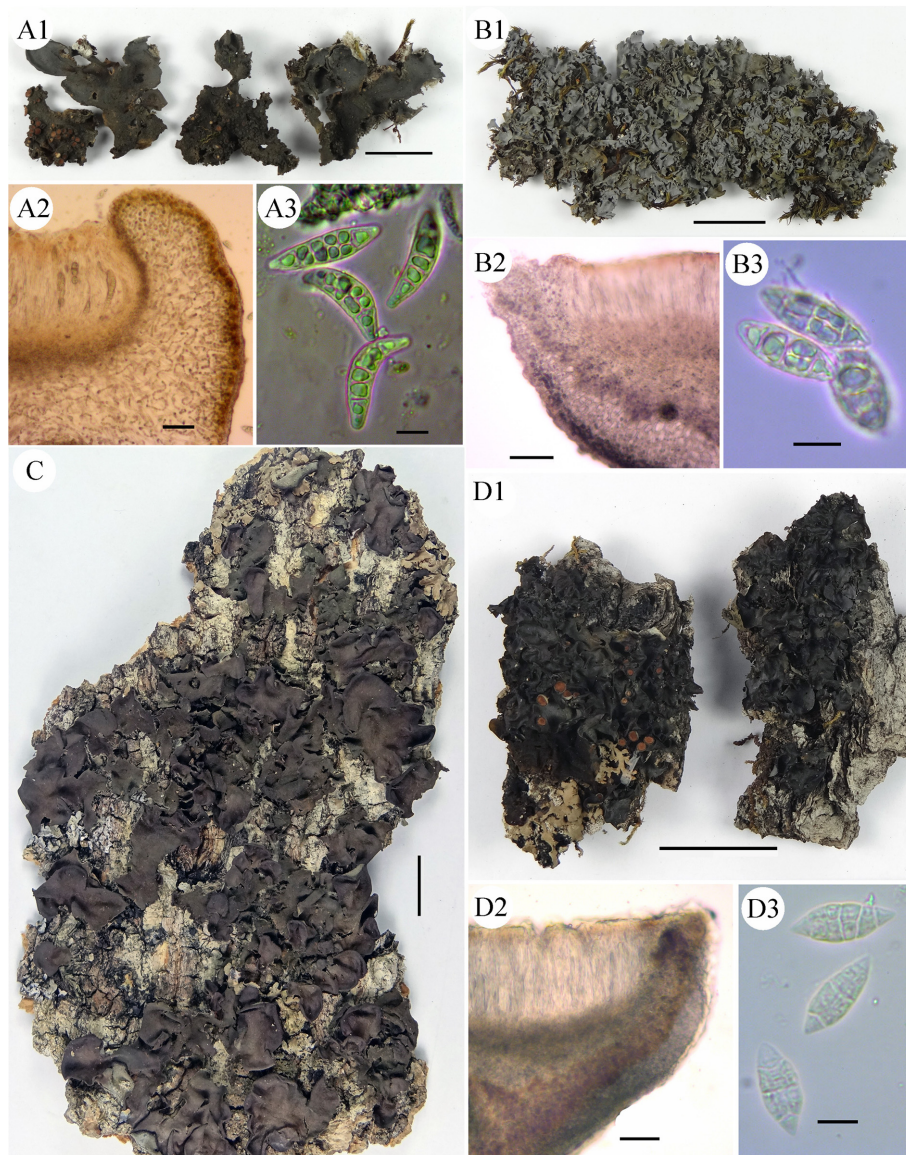
***Leptogium denticulatum*** Nyl., Ann. Sci. Nat., Bot., Sér. 5 7: 302 (1867).

Thallus foliose, closely to loosely adnate, 3–10 cm wide, 70–120 µm thick, dark grey to bluish. Lobes round to broadly oblong, 2–5 mm wide; margins entire, dentate or phyllidiate, often ascending; upper surface smooth, shiny, phyllidiate, never isidiolate; phyllidia granular-flattened at first, becoming coralloid-squamuliform to expanded-lobulate, laminal and marginal. Lower surface naked with sparse, tufted rhizines. Apothecia rare; laminal, sessile to shortly pedicellate, 1–2 mm wide; disc concave to flat, pale to dark red–brown; thalline exciple smooth to lobulate, pale brown. Ascospores ellipsoidal, muriform, 15–30 × 7–12 µm; pycnidia not seen (Fig. 5B).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium denticulatum* is characterized by the presence of smooth, non-wrinkled thallus, with well-defined phyllidia (never isidioid) on the margins and upper surface. This species closely resembles *L. cyanescens*, but the latter species has isidia on the thallus and margins. *Leptogium azureum* closely resembles *L. denticulatum* in external appearance, but the former species differs in having neither isidia nor phyllidia on the thallus.

**Selected specimens examined:** Mt. Baeka, on rock, 34°32'33.1" N, 126°55'46.7" E, elev. 334 m, J. S. Hur, 050561, 8 Oct 2005; Mt. Gakhuel, on rock, 38°06'24.8" N, 127°23'20.5" E, elev. 535 m, J. S. Hur, 080339, 28 Jul 2008; Mt. Geumwon, on rock, 35°43'39.0" N, 127°47'31.4" E, elev. 704 m, X. Y. Wang, H. S. Jeon, G. S. Han, 100559, 25 Jun 2010; Mt. Halla, on bark, 33°19'16.0" N, 126°33'21.0" E, elev. 957 m, S. O. Oh, U. Jayalal, S. Joshi, J. S. Park, F. H. Tian, J. S. Hur, 121268, 121259, 20 Jun 2012; Mt. Taebaek, on rock, 36°44'42.5" N, 128°15'54.6" E, elev. 1,118 m, J. S. Hur, 070833, 18 Jun 2007; Mt. Worak, on rock, 36°52'01.3" N, 128°06'34.3" E, J. S. Hur, 041248, 19 Sep 2004; Ulleung Island, on rock, 37°29'21.8" N, 130°53'15.2" E, elev. 545 m,



**Fig. 5.** A, *Leptogium delavayi*, A1: Habitus, A2: Section through apothecium margin, A3: Ascospores; B, *Leptogium denticulatum*, B1: Habitus, B2: Section through apothecium margin, B3: Ascospores; C, *Leptogium hildenbrandii* habitus; D, *Leptogium moluccanum*, D1: Habitus, D2: Section through apothecium margin, D3: Ascospores (scale bars: A1, B1, C, D1 = 1 cm, A2, B2, D2 = 50  $\mu$ m, A3, B3, D3 = 10  $\mu$ m).

J. S. Hur, 050322, 22 Jun 2005.

**Ecology and distribution:** This species is distributed in different altitude ranges in South Korea. Most of the species were collected from mossy rock surfaces, and a few specimens were collected from tree bark (Fig. 4E). This is the first report of this species from South Korea. In East Asia, this species has also been reported from China [30], Taiwan [34], and Japan [31].

*Leptogium hildenbrandii* (Garov.) Nyl., Act. Soc. Linn. Bordeaux, Trois. Sér. 21: 272 (1856).

Thallus foliose, closely to loosely adnate, often forming rounded patches, 3~12 cm wide, 70~150  $\mu$ m thick, black gray to brownish. Lobes rounded to orbicular, 5~10 mm

wide, margins entire to wavy; upper surface wrinkled, rough, isidia and phyllidia absent. Lower surface pale, with long-celled white hairs, up to 1~1.5 mm long. Apothecia not seen. Pycnidia immersed on thallus, marginal to sub-marginal, 0.1~0.3 mm wide. Conidia bacilliform, apices swollen, 4.3~5.5  $\times$  1.3~1.6  $\mu$ m (Fig. 5C).

**Chemistry:** Two unknown chemicals were detected using TLC (Fig. 3).

**Remarks:** *Leptogium hildenbrandii* is characterized by the presence of black gray to brownish, wrinkled, thallus, which often forms rounded patches. According to Jørgensen [3], this species is distinguished by the presence of euparaplectenchymatous supporting tissue in the lower part of the apothecium, below the algal layer in the cortical



region. This species closely resembles *Leptogium rugosum* Sierk, but the latter species is distinguished by the presence of heavily wrinkled thallus, fusiform, somewhat large spores, and absence of the thallus forming rounded patches [13].

**Specimens examined:** Mt. Odae, on bark, 37°46'22.4" N, 128°36'05.8" E, elev. 1,450 m, J. S. Hur, 040507, 8 May 2004.

**Ecology and distribution:** *Leptogium hildenbrandii* is a rare species, and is found on bark at higher elevations (> 1,000 m) (Fig. 4H). The species has been reported from South Korea by Moon [36]. In East Asia, this species has also been reported from China [30] and Japan [31].

***Leptogium moluccanum*** (Pers.) Vain., Acta Soc. Fauna Flora Fenn. 7: 223 (1890).

Thallus foliose, closely to loosely adnate, 2–3 cm wide, 50–70 µm thick, dark grey to olivaceous. Lobes round to broadly oblong, 1–3 mm wide; margins entire, confluent; upper surface smooth, shiny, without isidia or phyllidia. Lower surface lighter than the upper surface, without hairs. Apothecia rare; laminal, sessile to shortly pedicellate, 0.5–1.5 mm wide; disc concave to flat, pale to dark red-brown; thalline exciple smooth to wavy, upper most margin same as thallus color. Ascospores ellipsoid, submuriform, 20–30 × 6–12 µm; pycnidia not seen (Fig. 5D).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** This species is characterized by the presence of leaden grey to olivaceous, thin thallus with smooth apothecial disc. *Leptogium azureum* closely resembles *L. moluccanum*, but the former species has a grayish, comparatively thick thallus [4]. *Leptogium moluccanum* var. *myriophyllum* (Müll. Arg.) Asahina, another variety of the same species, has also been reported from South Korea by Park [28]. In East Asia, the same variety has also been reported from North Korea [29] and Japan [31].

**Specimens examined:** Mt. Duryun (Daeheung Temple), on moss (rock), GPS data not given, J. S. Hur, 030103, 030311, 4 Apr 2003; Mt. Taebaek, on bark, 37°12'35.3" N, 128°55'11.9" E, elev. 1,399 m, J. S. Hur, 080267, 25 May 2008.

**Ecology and distribution:** This species was reported from South Korea by Kashiwadani and Moon [37], and is distributed at higher elevations (Fig. 4H). In East Asia, this species has also been reported from China, Taiwan [30], Japan [31], and North Korea [29].

***Leptogium pedicellatum*** P. M. Jørg., Herzogia 3: 448 (1975).

Thallus foliose, closely to loosely adnate, 10–15 cm wide, 70–120 µm thick, dark grey to bluish. Lobes round to broadly orbicular, 5–10 mm wide; margins entire without isidia. Sometime phyllidiate; upper surface smooth, dull. Lower surface pale, with dense, long-celled white hairs, up to 1 mm long. Apothecia common; laminal 0.5–2 mm wide, shortly pedicellate, 1–1.5 mm height; disc concave to

flat, reddish brown; thalline exciple entire, smooth, young apothecial margins with white hairs. Ascospores ellipsoidal, muriform, 27–30 × 12–15 µm; pycnidia not seen (Fig. 6A).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium pedicellatum* is characterized by the presence of grayish, smooth, thallus with pedicellate apothecia. This species closely resembles *L. menziesii* (Ach.) Mont., which has sessile apothecia and smaller spores [2]. According to Jørgensen and Olley [32], this species is closely related to *L. sphaerosporum* due to the occasional production of phyllidia; however, the latter species always produces phyllidia. In South Korea, this species was identified as *L. menziesii* by Kim [35]. According to the lichen checklist prepared by Hur *et al.* [19], all previously reported species of *L. menziesii* were classified as *L. pedicellatum*.

**Selected specimens examined:** Mt. Deogyu, on bark (Oak sp.), 35°51'23.2" N, 127°45'02.5" E, elev. 1,560 m, J. S. Hur, 050105, 3 Apr 2005; Mt. Gyeongja, on rock, 34°08'50.4" N, 126°32'9.06" E, elev. 368 m, J. S. Hur, 100151, 5 Feb 2010; Mt. Halla, on bark, 33°23'54.0" N, 126°32'21.0" E, elev. 942 m, S. O. Oh, U. Jayalal, J. S. Park, J. S. Hur, 121031, 121055, 1 Jun 2012; Mt. Hambaek, on bark (*Acer* sp.), 37°11'28.1" N, 128°54'53.2" E, elev. 1,456 m, J. S. Hur, 070685, 19 Jun 2007; Mt. Hugseok, on bark, 34°41'16.7" N, 126°40'18.1" E, elev. 456 m, J. S. Hur, 050511, 23 Sep 2005; Mt. Jiri, on bark, 35°19'38.5" N, 127°42'59.4" E, elev. 1,660 m, J. S. Hur 040388, 24 Apr 2004; Mt. Juhul, on mossy rock, 36°46'16.9" N, 128°05'16.1" E, elev. 480 m, J. S. Hur 040129, 29 Feb 2004; Mt. Juwang, on rock, 36°24'09.6" N, 129°10'27.0" E, elev. 380 m, J. S. Hur, 050603, 15 Oct 2005; Mt. Odae, on bark, 37°46'51.4" N, 128°36'13.3" E, elev. 1,435 m, J. S. Hur, 040525, 8 May 2004; Mt. Sorak, on mossy bark, 38°08'53.5" N, 128°20'05.3" E, elev. 1,010 m, J. S. Hur, 050277, 16 Jun 2005; Mt. Taebaek, on bark, 37°06'31.0" N, 128°54'33.0" E, elev. 1,235 m, J. S. Hur, 040177, 040178, 24 Apr 2004; Wando Arboretum, on mossy bark, 34°21'10.3" N, 126°41'10.9" E, elev. 535 m, J. S. Hur, 050149, 13 Apr 2005; Singaemul Park, on rock, 33°30'31.3" N, 126°10'13.1" E, elev. 19 m, S. Y. Kondratyuk, L. Lökös, S. O. Oh, U. Jayalal, S. Joshi, J. S. Park, J. S. Hur, 121412, 121387, 5 Jul 2012; Gwanum Temple, on rock, 33°25'21.5" N, 126°33'34.8" E, elev. 615 m, S. Y. Kondratyuk, L. Lökös, 121917, 7 Jul 2012.

**Ecology and distribution:** This species is distributed in both low (c. 400 m) and high elevations (> 1,000 m) in South Korea (Fig. 4F). This species was reported for the first time in South Korea by Kim [35]. In East Asia, this species has also been reported from North Korea [38], China [2], and Japan [31].

***Leptogium saturninum*** (Dicks.) Nyl., Act. Soc. Linn. Bordeaux, Trois. Sér. 21: 272 (1856).

Thallus foliose, closely to loosely adnate, 1–6 cm wide, 70–150 µm thick, brownish black to olivaceous black. Lobes round to orbicular, 4–8 mm wide, confluent in the central

part of the thallus, margins entire to wavy; upper surface smooth to roughened, isidiate; isidia granular to coralloid, width 0.03~0.07 mm, height 0.1~0.3 mm, sparse to dense. Lower surface pale, long-celled white hairs, up to 1~1.5 mm long. Apothecia and pycnidia not seen (Fig. 6B).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium saturninum* is characterized by the presence of olivaceous black, thick thallus with short to flattened, granular isidia. This species closely resembles *L. burnetiae* in external appearance, but the latter species differs in having large coralloid isidia, and thin, bluish thallus. According to Awasthi and Akhtar [2], coralloid isidia are also present in *L. burnetiae*, and some parts of such thallus may become blackened; therefore, it may be difficult to distinguish such specimens from *L. saturninum*.

**Selected specimens examined:** Mt. Baekseokbong, on a mossy rock, 37°28'7.39" N, 128°39'7.60" E, elev. 494 m, Y. Joshi, X. Y. Wang, J. A. Ryu, J. Y. Hur, 090492, 16 May 2009; Mt. Cheongryang, on bark, 36°47'25.2" N, 128°55'25.4" E, elev. 885 m, J. S. Hur, 040105, 28 Feb 2004; Mt. Hambae, on bark, 37°11'27.3" N, 128°54'52.9" E, elev. 1,445 m, J. S. Hur, 070689, 19 Jun 2007; Mt. Odae, on bark, 37°46'17.2" N, 128°36'04.1" E, elev. 1,454 m, J. S. Hur, 080550, 15 Jul 2008; Mt. Seok-byeong, on bark, 37°35'14.7" N, 128°52'57.1" E, elev. 969 m, J. S. Hur, 080244, 24 May 2008; on bark, 37°35'02.2" N, 128°52'29.1" E, elev. 901 m, J. S. Hur, 080232, 24 May 2008; Mt. Seorak, on bark (*Quercus* sp.), 38°09'9.81" N, 128°27'26.7" E, elev. 463 m, Y. Joshi, X. Y. Wang, J. A. Ryu,

090777, 24 May 2009; Mt. Taebaek, on bark, 37°06'08.2" N, 128°55'53.1" E, elev. 1,349 m, J. S. Hur, 030668, 20 Aug 2003.

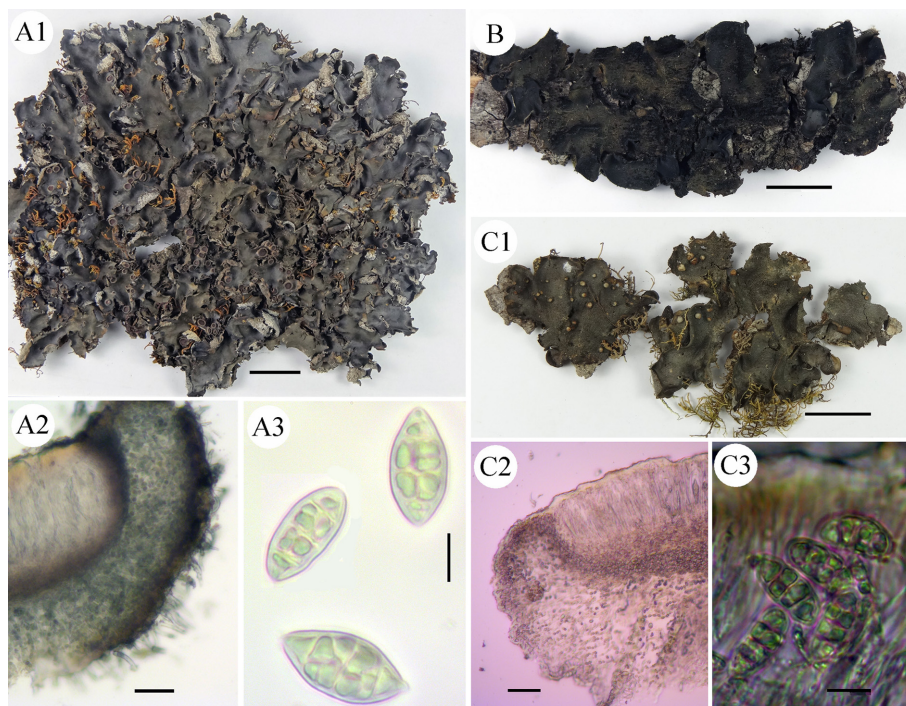
**Ecology and distribution:** *Leptogium saturninum* is a common species on bark and rock at higher elevations (> 1,000 m), and few specimens were recorded at lower elevations (400~500 m) (Fig. 4G). This species was reported for the first time in South Korea by Park [28]. In East Asia, this species has also been reported from North Korea [29], China [30], and Japan [31].

***Leptogium trichophoroides*** P. M. Jørg. & A. K. Wallace, in Jørgensen, Symb. Bot. Ups. 32: 123 (1997).

Thallus foliose, closely to loosely adnate, 3~5 cm wide, 130~170  $\mu$ m thick, brownish to blackish grey. Lobes round to orbicular, 3~8 mm wide; margins entire to crenate without isidia or phyllidia; upper surface dull, wrinkled. Lower surface pale, with dense, long-celled white hairs, up to 1 mm long. Apothecia common; marginal to sub-marginal, 0.3~1.5 mm wide, shortly pedicellate; disc concave to flat, reddish brown; thalline exciple entire to wrinkled with white hairs on young apothecia. Ascospores ellipsoidal with somewhat round ends, muriform, 19~24  $\times$  8~11  $\mu$ m; pycnidia not seen (Fig. 6C).

**Chemistry:** Two unknown chemicals were detected using HPLC and TLC (Fig. 3).

**Remarks:** *Leptogium trichophoroides* is characterized by the presence of brownish to blackish grey wrinkled thallus with pedicellate apothecia. This species closely resembles



**Fig. 6.** A, *Leptogium pedicellatum*, A1: Habitus, A2: Section through apothecium margin, A3: Ascospores; B, *Leptogium saturninum* habitus; C, *Leptogium trichophoroides*, C1: Habitus, C2: Section through apothecium margin, C3: Ascospores (scale bars: A1, B, C1 = 1 cm, A2, C2 = 50  $\mu$ m, A3, C3 = 10  $\mu$ m).

*L. trichophorum* Müll. Arg., but the latter species is distinguished by the presence of sessile apothecia with blackish hairs and large spores [13]. This is the first record for the lichen mycota of South Korea.

**Specimens examined:** Mt. Duta, on moss (bark), 37°25'54.4" N, 128°58'33.6" E, elev. 1,352 m, J. S. Hur, 080166, 11 May 2008.

**Ecology and distribution:** This species was recorded at higher elevations (c. 1,300 m) in South Korea (Fig. 4H). In East Asia, this species has also been reported from Taiwan [13] and Japan [13, 31].

The following species were not traceable; therefore, the descriptions were based on the published literature.

***Leptogium cochleatum*** (Dicks.) P. M. Jørg. & P. James, *Lichenologist* 15: 113 (1983).

This species has leaden grey thallus without isidia. It has sessile apothecia and wrinkled thalline exciple. This species closely resembles *L. moluccanum* and *L. azureum*, but both of the latter species have smooth thalline exciple [4].

This species was reported for the first time in South Korea by Park [33]. In East Asia, this species has also been reported from North Korea [29] and Japan [31].

***Leptogium lichenoides*** (L.) Zahlbr., *Cat. Lich. Univ.* 3: 136 (1924).

This species has small, dark brown to red brown cushion-like thallus. Lobes wrinkled, upright, and edges with finely divided, cylindrical isidia-like outgrowths [39].

The species was reported from South Korea by Park [40]. In East Asia, this species has also been reported from China [30] and Japan [31].

***Leptogium rugosum*** Sierk, *Bryologist* 67: 265 (1964).

This species is distinguished by the presence of dark gray to olivaceous thallus, with the surface covered by deep wrinkles without isidia or lobules [39].

This species was reported for the first time in South Korea by Moon [36]. In East Asia, this species has also been reported from Japan [31].

## ACKNOWLEDGEMENTS

This work was supported by a grant from the Korean Forest Service Program (KNA 2013) through the Korea National Arboretum and the Korean National Research Resource Center Program (NRF, 2012M3A9B8021726).

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