





Jejulea byssolomoides gen. et sp. nov., a Remarkable *Pilocarpaceae* (Lichen-Forming Ascomycetes) from Jeju Island, South Korea

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ABSTRACT

The new genus and species, *Jejulea byssolomoides*, is described from Jeju Island, Korea. This lichen is characterized by saxicolous, crustose, pale greenish-gray, partly finely filamentous, matt, smooth thallus, prominent convex brown to dark brown ascomata with a concolorous margin constricted at the dark brown base, 300–800 µm diameter, 200–250 µm high, without a distinct proper margin, adhering to the substratum ending in a minute byssoid white external part of cylindrical cells, fusiform 3–5 septate ascospores (17–23 × 4–5 µm). Phylogenetic analyses using ITS and mtSSU sequences place *Jejulea* in the *Pilocarpaceae* (Lecanorales). The new taxon is closely related to *Byssoloma*, a cosmopolitan group of foliicolous lichens, which is most diverse in the tropics. Like *Byssoloma*, *Jejulea* also forms a byssoid apothecial margin.

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1. Introduction

Although Jeju Island is small in size (1826 km²), it is known for its high number of endemic lichens [1–4] and lichenicolous fungi [5]. Foliicolous lichens in the Gotjawal forest area on Jeju Island have also been described [6]. So far, lichen research has focused mainly on epiphytic, saxicolous [1,2,7], and foliicolous lichens [8,9]. The river valley formed by a solid basalt base can be surprisingly interesting. The discovery of the saxicolous “*Byssoloma*” is another example of a remarkable endemic species occurring on these islands of the East China Sea.

Pilocarpaceae is a crustose, cosmopolitan family comprising 29 genera, with 424 species [10]. Species are characterized by biatorine or lecideine apothecia and pycnidia or campylidia type of conidiomata. The family is distributed in the tropical zone, where most species grow on leaves. Research of that group has been very intensive recently and descriptions of the new species are not rare [11]. The closest relatives of the new genus *Jejulea* are the genera *Byssoloma*, *Sporopodium*, *Tapellaria*, *Fellhanera*, *Lasioloma*, and *Calopadia*. The genus *Byssoloma* Trevis. [12] recently comprises 93 cosmopolitan foliicolous lichen species [13] with the main distribution in tropical and subtropical zones. A few species extend to temperate zones [11]. The genus is

characterized by cortical crustose thalli, a byssoid apothecial margin, loosely intricate hyphae of proper exciple, asci with I+ darker, tubular structure, and colorless, 1–3 septate spores [14]. *Sporopodium* Mont. [15] is a genus that also occurs in tropical zones, the campylidia of these 11 species usually feature a distinct socle producing the conidia [14]. Some of the species contain secondary metabolites [16]. The genus *Tapellaria* [17] forms black, lecideine apothecia, anastomosing paraphyses, and campylidia producing filiform conidia. It is a predominantly foliicolous genus (25 species) with only a small number of the species growing on bark [18]. Most of the species are known from Neotropics, but *Tapellaria parvimuriformis* was newly described from East Asia [11]. *Fellhanera* Vězda [19] is a large polyphyletic genus among foliicolous lichens [11] which contains about 114 species [13]. Like the previous genera, it forms small apothecia with a thin margin, paraplectenchymatous excipulum, anastomosing paraphyses, *Byssoloma* type asci, ellipsoid ascospores, and pycnidial conidiomata [14]. There are other genera very close to *Fellhanera*: *Brasilicia* differs in its filiform ascospores, *Bapalmuia* Sérus [20] has the very same shape as ascospores but differs in its secondary chemistry [14]. *Lasioloma* [21] differs from *Tapellaria* and *Calopadia* in its woolly prothallus, the

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pilose apothecial margins, and the centrally branched conidia, whereas *Tapellaria* differs in its black apothecia with purple hypothecium and anastomosing paraphyses. 10 species are corticolous with Neotropical distribution and the rest are foliicolous species with a predominantly Paleotropical distribution [22].

2. Materials and methods

2.1. Morphological studies

Observations and measurements of photobiont cells, thallus and apothecium anatomy, asci and ascospores were made of hand-cut sections mounted in water and diluted KOH (K) solution. Asci were also observed in Lugol's Iodine (I), with and without pretreatment in K. Mean value (\bar{x}) and standard deviation (SD) were calculated, and the results are given as (minimum value observed) $\bar{x} \pm$ SD (maximum value observed). \bar{x} , SD, and n (the total number of ascospores measured) are given within parentheses. Thin-layer chromatography (TLC; Merck, Darmstadt, Germany) was carried out according to [23]. Macro images were captured with a Canon 5DSR digital SLR camera (Canon, Tokyo, Japan) and an Olympus Zuiko 20 mm macro lens (Olympus, Tokyo, Japan). Microscopic images were captured with a Canon 5DSR digital SLR camera (Canon, Tokyo, Japan) mounted on an Olympus BX41 DIC microscope (Olympus, Tokyo, Japan). Illustrations were prepared using Adobe Photoshop. Measurements of the hymenium, hypothecium, cortex, and spore size (30–50 spores per specimen) were made in water mounts. The voucher specimen was deposited in the Korean Lichen Research Institute, Suncheon National University, Suncheon, South Korea.

2.2. DNA extraction, amplification, and sequencing

Genomic DNA was extracted from the six fresh lichen specimens using the CTAB protocol [24]. The nuclear ribosomal internal transcribed spacer (nrITS) and mitochondrial small subunit ribosomal RNA (mtSSU) regions were amplified using AccuPower[®] PCR PreMix (Bioneer, Daejeon, South Korea). The primers used were ITS1F (5'-CTTGGTCATTTAGAGGAAGTAA-3') and ITS4 (5'-TCCTCCGCTTATTGATATGC-3') for ITS [25], mrSSU1 (5'-AGCAGTGAGGAATATTGGTC-3') and mrSSU3R (5'-ATGTGGCACGCTCTATAGCCC-3') for mtSSU [26]. PCR amplification was done using a T100[™] Thermal Cycler machine (Bio-Rad, Hercules, CA, USA) performed under the following conditions: an initial cycle of 5 min at 94 °C,

followed by 30 cycles of 30 s at 94 °C, 30 s at 55 °C, 10 min at 72 °C, and then finally 10 min at 72 °C for nrITS, and an initial cycle of 3 min at 94 °C, followed by 35 cycles of 1 min at 94 °C, 1 min at 52 °C, 1 min at 72 °C, and then finally 7 min at 72 °C for mtSSU.

2.3. Multiple sequence alignment

Six new sequences (nrITS and mtSSU) were obtained from this study, and their closest relatives (i.e., *Byssoloma* species) based on BLAST searches were retrieved from GenBank. Members representing all genera were currently accepted (Table 1). For phylogenetic analyses, sequences were assembled by ATGC version 1.03 (GENETYX Co., Tokyo, Japan) and multiple sequence alignment (MSA) was performed using MAFFT v. 7 with G-INS-1 algorithm for nrITS and L-INS-i algorithm for mtSSU [27]. Unclearly aligned position sequences were manually modified using MEGA v. 7 [28]. nrITS and mtSSU based on a combined phylogenetic tree were estimated based on Maximum-Likelihood (ML) and Bayesian Posterior Probabilities (PP). ML and PP best-fit model of nucleotide substitution and parameters were estimated by IQ-TREE 2.2.0 [29] based on Bayesian information criterion (BIC), and SYM+I+G4 model for nrITS and TVM+F+I+G4 for mtSSU were chosen. ML analysis was performed using IQ-TREE 2.2.0 [29] and 1000 bootstrap replications. Bayesian analysis was conducted based on the Markov chain Monte Carlo method (MCMC), 10 million generations with every 100th sampling using MrBayes v. 3.2.7 [30]. The first 25% sample of trees was discarded and visualized in Figtree v. 1.4.4. *Micarea micrococca* and *Micarea byssacea* located in *Pilocarpaceae* were chosen as outgroups.

3. Results

3.1. Phylogenetic analyses

The data set of nrITS and mtSSU consisted of 37 nrITS and 81 mtSSU sequences of *Pilocarpaceae* obtained from NCBI with six sequences of two-locus newly obtained from *Jejulea byssolomoides* (Table 1). Maximum-likelihood bootstrap value (ML) \geq 70% and Bayesian Posterior Probabilities (PP) \geq 95% were added above the branches. In the mtSSU phylogenetic tree, *J. byssolomoides* is closely located in a clade composed of four genera, *Bapalmuia*, *Byssolecania*, *Byssoloma*, *Tapellaria*, and formed an independent clade (Figure 1). In the nrITS phylogenetic tree, *J. byssolomoides* was clustered in the *Byssoloma* clade with *Bapalmuia palmularis* (Figure 2). The branch length indicates the

Table 1. List of species and DNA sequence information employed for phylogenetic analysis.

Species name	Voucher	GenBank accession no.	
		nrlTS	mtSSU
<i>Aquacidia atricola</i>	ALV4918		MH817969
<i>Aquacidia trachona</i>	Andersen 99 (BG)	AY756456	AY567784
<i>Bapalmuia palmularis</i>	Lücking 16003 (BG)	AY756457	AY567781
<i>Byssolecania hymenocarpa</i>	KYW0254	MK946965	MK957159
<i>Byssolecania hymenocarpa</i>	KYW0286	MK946957	MK957152
<i>Byssolecania</i> sp.	20180247	MK946973	MK957170
<i>Byssolecania variabilis</i>	Lücking 16033 b (BG)	AY756458	AY567780
<i>Byssoloma annuum</i>	KeM583		LC648424
<i>Byssoloma annuum</i>	HN20170295		MN043716
<i>Byssoloma brunneodiscum</i>	HN20170147		MN105603
<i>Byssoloma brunneodiscum</i>	HN20170165		MN105600
<i>Byssoloma</i> cf. <i>leucoblepharum</i>	KYW0184		MN043700
<i>Byssoloma</i> cf. <i>leucoblepharum</i>	KYW0445		MN043697
<i>Byssoloma chlorinum</i>	KeM575		LC648423
<i>Byssoloma chlorinum</i>	KeM372		LC648410
<i>Byssoloma citricola</i>	50677		MN043707
<i>Byssoloma leucoblepharum</i>	54740		MN105613
<i>Byssoloma leucoblepharum</i>	KYW0188		MN105612
<i>Byssoloma leucoblepharum</i>	HN20170108		MN043724
<i>Byssoloma leucoblepharum</i>	HN20170091		MN043720
<i>Byssoloma leucoblepharum</i>	KYW0422		MN043694
<i>Byssoloma leucoblepharum</i>	HN20170357	MK946977	MK957174
<i>Byssoloma leucoblepharum</i>	20180145	MK946971	MK957166
<i>Byssoloma leucoblepharum</i>	20180153	MK946970	MK957165
<i>Byssoloma leucoblepharum</i>	KYW0405	MK946966	MK957160
<i>Byssoloma leucoblepharum</i>	Ekman 3502 (BG)	AY756459	AY567778
<i>Byssoloma marginatum</i>	Tønsberg 27125 (BG)	AY756460	AY567777
<i>Byssoloma meadii</i>	Ekman L1130 (LD)		AY567776
<i>Byssoloma melanodiscocarpum</i>	HN20170148		MN105607
<i>Byssoloma melanodiscocarpum</i>	HN20170298		MN105601
<i>Byssoloma rubrofusum</i>	HN20170295		MN105599
<i>Byssoloma rubrofusum</i>	HN20170297		MN105602
<i>Byssoloma</i> sp.	20190551		MN105611
<i>Byssoloma</i> sp.	20190514		MN105610
<i>Byssoloma subdiscordans</i>	HN20170156		MN105609
<i>Byssoloma subdiscordans</i>	HN2014213		MN105606
<i>Byssoloma subdiscordans</i>	57021		MN043704
<i>Byssoloma subdiscordans</i>	57130		MN043703
<i>Byssoloma subdiscordans</i>	Tønsberg 25968 (BG)	AY756461	AY567779
<i>Byssoloma vanderystii</i>	KeM400		LC648411
<i>Byssoloma vanderystii</i>	HN20170227		MN043718
<i>Byssoloma vanderystii</i>	20180144		MN043710
<i>Byssoloma vanderystii</i>	KYW0060		MN043699
<i>Calopadia foliicola</i>	KYW0068		MK957146
<i>Calopadia foliicola</i>	Lücking 16011 (BG)		AY567782
<i>Calopadia puiggarii</i>	KYW0036_31764		MK957156
<i>Calopadia puiggarii</i>	20180158		MK957167
<i>Eugeniella micrommata</i>	KeM437		LC648413
<i>Eugeniella micrommata</i>	KYW0046		MK957161
<i>Fellhanera bouteillei</i>	AFTOL-ID 4917		KJ766392
<i>Fellhanera bouteillei</i>	KYW0558		MK957177
<i>Fellhanera bouteillei</i>	Ekman 3417 (BG)	AY756463	AY567787
<i>Fellhanera bouteillei</i>	LIFU082-16 (versA1)	KX132990	
<i>Fellhanera bouteillei</i>		AF414858	
<i>Fellhanera fuscata</i>	KYW0264	MK946967	MK957162
<i>Fellhanera fuscata</i>	KYW0336	MK946959	MK957154
<i>Fellhanera fuscata</i>	KYW0392	MK946956	
<i>Fellhanera fuscata</i>	KYW0462	MK946954	
<i>Fellhanera gyrophorica</i>	17826	MN387060	
<i>Fellhanera gyrophorica</i>	17746	MN387059	
<i>Fellhanera gyrophorica</i>	17744	MN387058	
<i>Fellhanera gyrophorica</i>	17267	MN387057	
<i>Fellhanera gyrophorica</i>	17094	MN387056	
<i>Fellhanera microdiscus</i>	HN20170313	MK946978	MK957175
<i>Fellhanera</i> sp.	20180167	MK946981	MK957169
<i>Fellhanera</i> sp.	20180166	MK946980	MK957168
<i>Fellhanera</i> sp.	20180146	MK946969	MK957164
<i>Fellhanera</i> sp.	20180711	MK946950	MK957145
<i>Fellhanera subtilis</i>	Tønsberg 28199 (BG)	AY756464	AY567786
<i>Fellhanera viridisorediata</i>	Tønsberg 27375 (BG)	AY756465	AY567775
<i>Fellhaneropsis myrtillicola</i>	Tønsberg 25311 (BG)	AY756466	AY756445
<i>Fellhaneropsis vezdae</i>	Knutsson 97-229 (hb Knutsson)		AY567744
<i>Jejulea byssolomoides</i>	KoLRI057219	OM044386	OM044380
<i>Jejulea byssolomoides</i>	KoLRI057220	OM044387	OM044381
<i>Jejulea byssolomoides</i>	KoLRI057221	OM044388	OM044382

(continued)

Table 1. Continued.

Species name	Voucher	GenBank accession no.	
		nrITS	mtSSU
<i>Jejulea byssolomoides</i>	KoLRI057222	OM044389	OM044383
<i>Jejulea byssolomoides</i>	KoLRI057223	OM044390	OM044384
<i>Jejulea byssolomoides</i>	KoLRI057224	OM044391	OM044385
<i>Lasioloma arachnoideum</i>	KYW0595		MK957155
<i>Lasioloma arachnoideum</i>	KYW0646		MK957158
<i>Lasioloma arachnoideum</i>	Lücking 16005 (BG)		AY567783
<i>Leimonis erratica</i>	AFTOL-ID 4988		KJ766425
<i>Leimonis erratica</i>	Arup 99192 (hb Arup)		AY567737
<i>Micarea byssacea</i>	289102_A97	MG521563	MG707769
<i>Micarea micrococca</i>	299101_A100	MG521552	MG707753
<i>Puttea margaritella</i>	M351		FJ006733
<i>Puttea margaritella</i>	M270		FJ006731
<i>Septotrapelia usnica</i>	26 Sept 01 Sudirman & Sipman		AY300894
<i>Sporopodium antoninianum</i>	Lücking 16002d (BG)		AY567785
<i>Sporopodium argillaceum</i>	HN20170022		MK957173
<i>Sporopodium argillaceum</i>	HN20170001		MK957171
<i>Szczawinskia tsugae</i>	Tønsberg 30044 (BG)		AY567746
<i>Tapellaria nana</i>	50677		MK957178
<i>Tapellaria nigrata</i>	KYW0539		MK957176
<i>Tapellaria nigrata</i>	KYW0602	MK946952	MK957147
<i>Tapellaria parvimuriformis</i>	KYW0181	MK946955	MK957150

DNA sequences for the new genus *Jejulea* (in bold) were generated in this study. All others were obtained from GenBank. The species names are followed by voucher information and GenBank accession numbers. Voucher: Specimen voucher information; nrITS: internal transcribed spacer; mtSSU: mitochondrial small subunit.

difference between the three genera. However, statistical support of the external node dividing the clustered three genera *Bapalmuia*, *Byssoloma*, and *Jejulea* in nrITS was not significant. Thus, the approximate taxonomic position of *J. byssolomoides* was confirmed in nrITS. Two genera *Byssolecania* and *Tapellaria* formed independent clades strongly supported by ML and PP.

3.2. Taxonomy

Jejulea byssolomoides J.P. Halda, J.-J. Woo & J.-S. Hur gen. et sp. nov. (Figure 3).

Mycobank No.: MB#842471 (genus) and MB#842472 (species).

Jejulea byssolomoides belongs to the *Pilocarpaceae* and is phylogenetically related to *Byssoloma leucoblepharum*, *Byssoloma subdiscordans*, *Byssoloma marginatum*, and *B. palmularis* but differs by the combination of the following characters: fusiform 3–5 septate ascospores (17–23 × 4–5 μm), an indistinct proper margin with a white byssoid external part of cylindrical cells (20–25 μm), dark brown hypothecium and absence of pycnidia.

3.3. Type

South Korea, Yeongcheon-dong, Seogwipo, Jeju-si, Jeju-do, 33°18′0.79″N 126°34′34.54″E, alt. 307 m, on the vertical face of a sheltered basalt rock along a stream, 18 August 2015, J. P. Halda, S.-O. Oh & D. Liu 152633 (KoLRI 036855 – *Holotype*, KoLRI 036876, 036882, 036883, 036886, 036887, 036888,

036889, 036891, 036893, 057219, 057220, 057221, 057222, 057223, 057224 – *Isotypes*).

3.4. Etymology

The name of the genus refers to Jeju Island, the type locality. The epithet “*byssolomoides*” points to the closest relative genus, *Byssoloma*.

3.5. Morphology

Thallus thin, crustose, superficial, spreading, 1–8 cm diameter, 20–40 μm thick, spreading, pale greenish-gray, partly finely filamentous, matt, smooth; hypothallus indistinct. Algal cells chlorococcoid, spherical 6–15(–17) μm diameter interstitial hyphae short-celled, 2–3 μm thick. Apothecia biatorine, applanate, orbicular, 300–800 μm diameter, 200–250 μm high, often grows in small groups of 2–4 ascomata. Excipulum well-developed, margin indistinct, becoming thinner outwards and adhering to the substratum ending in a minute white external part of cylindrical cells (20–25 μm); disk 250–750 μm diameter, almost flat, not elevated at the margin, brown to dark brown, blackish from the center, epruinose. Proper exciple obviously thinner or tapering outwards as a minute white hyphal rim, colorless, subgelatinous; hyphae branched and anastomosing, uninflated (ca. 2 μm wide lumina), embedded in a gelatinous matrix, generally oriented toward the tapering edge. Hypothecium ca. 100 μm thick at the center, dark brown to partly black, subparaplectenchymatous, composed of more or less vertically



Figure 1. The phylogenetic tree was based on mtSSU sequences. Maximum-likelihood bootstrap value (ML) $\geq 70\%$ and Bayesian Posterior Probabilities (PP) $\geq 95\%$ were marked above branches. Thickened branches indicate ML/PP = 100/1.00. The newly obtained sequence of *Jeulea byssolomoides* used in this study is shown in bold.

arranged cells, darker than subhymenium. Subhymenium 15–20 μm thick, brown. Hymenium 40–75 μm thick, pale brown, dark brown below; paraphyses sparsely branched and anastomosing, with 1–2 μm diameter lumina. Asci clavate, with a blurred IKI+ layer and a tholus with an IKI+ blue inner

tube (*Byssoloma*-type), ca. 35 \times 12 μm . Ascospores 8 per ascus, fusiform, 3–5 septate sometimes with perispore 1–2 μm thick, (14–)17–23(–26) \times (3–)4–5(–6) μm [$x = 19.6 \times 4.4 \mu\text{m}$; SD 3.3; 0.6 μm ; $n = 48$; l/w ratio = 4.5], colorless, sometimes slightly constricted at the septa. Pycnidia not observed.

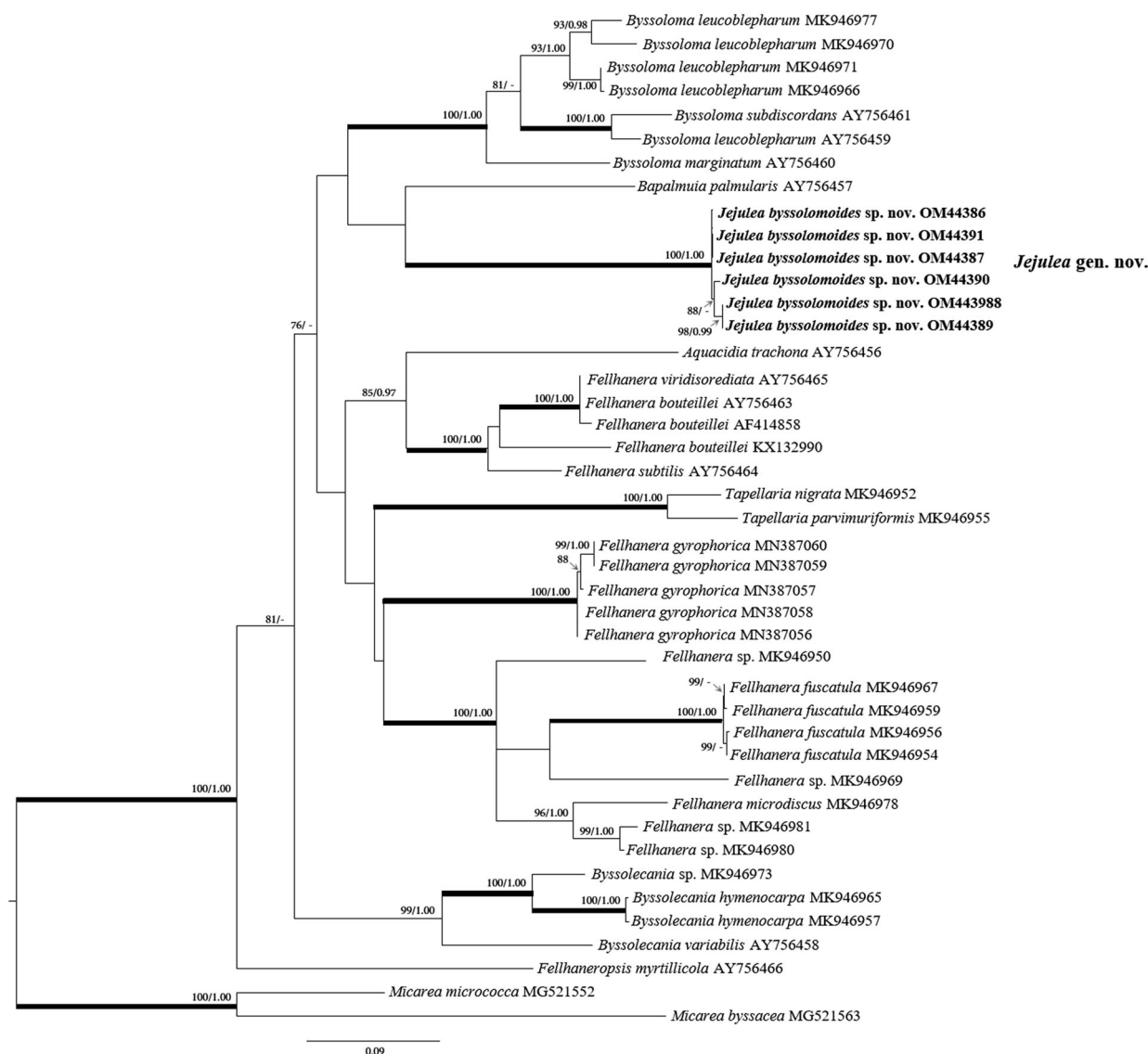


Figure 2. The phylogenetic tree was based on nrITS sequences. Maximum-likelihood bootstrap value (ML) $\geq 70\%$ and Bayesian Posterior Probabilities (PP) $\geq 95\%$ were marked above branches. Thickened branches indicate ML/PP = 100/1.00. The newly obtained sequence of *Jejeulea byssolomoides* used in this study is shown in bold.

3.6. Chemistry

No lichen product was detected by TLC.

3.7. Ecology and distribution

Known from the type locality in Seogwipo, Jeju Island, South Korea. The species was found growing on shaded volcanic rocks (basalt) along a stream protected by the forest's margin together with *Coenogonium lueckingii*, *Flakea papillata*, *Porina curnowii*, *P. eminentior*, *P. leptalea*, *P. mastoidea*, *Strigula nipponica*, *Verrucaria aethiobola*, and *Willeya iwatsukii*. Jeju Island is a shield volcano that is composed of basaltic lava flows and minor pyroclastic rocks. The climate is characterized by hot humid summers and cool winters as a result of the influence of the East Asian monsoon.

3.8. Remarks

Jejeulea byssolomoides superficially resembles *Byssoloma* (see above) with its white byssoid margin of apothecia and septate ascospores but differs in the different ascus type and in having a true exciple of palisade plectenchyma. No species of the genus *Byssoloma* have been confirmed from Korea. Among saxicolous East-Asian species *Gyalideopsis lunata* [31] differs in its colorless hymenium and hypothecium, hyaline proper margin, and shorter submuriform to muriform ascospores ($12\text{--}17 \times 7\text{--}10 \mu\text{m}$ vs. $3\text{--}5$ septate, $17\text{--}23 \times 4\text{--}5 \mu\text{m}$ in *J. byssolomoides*).

The closest related species *B. leucoblepharum* and *B. subdiscordans* differ in ecology: they grow especially on leaves of evergreen shrubs and trees, and also in morphology: thinner thallus, smaller pale to black apothecia $300\text{--}600 \mu\text{m}$ diameter, disk plane, with a persistent densely byssoid white margin.

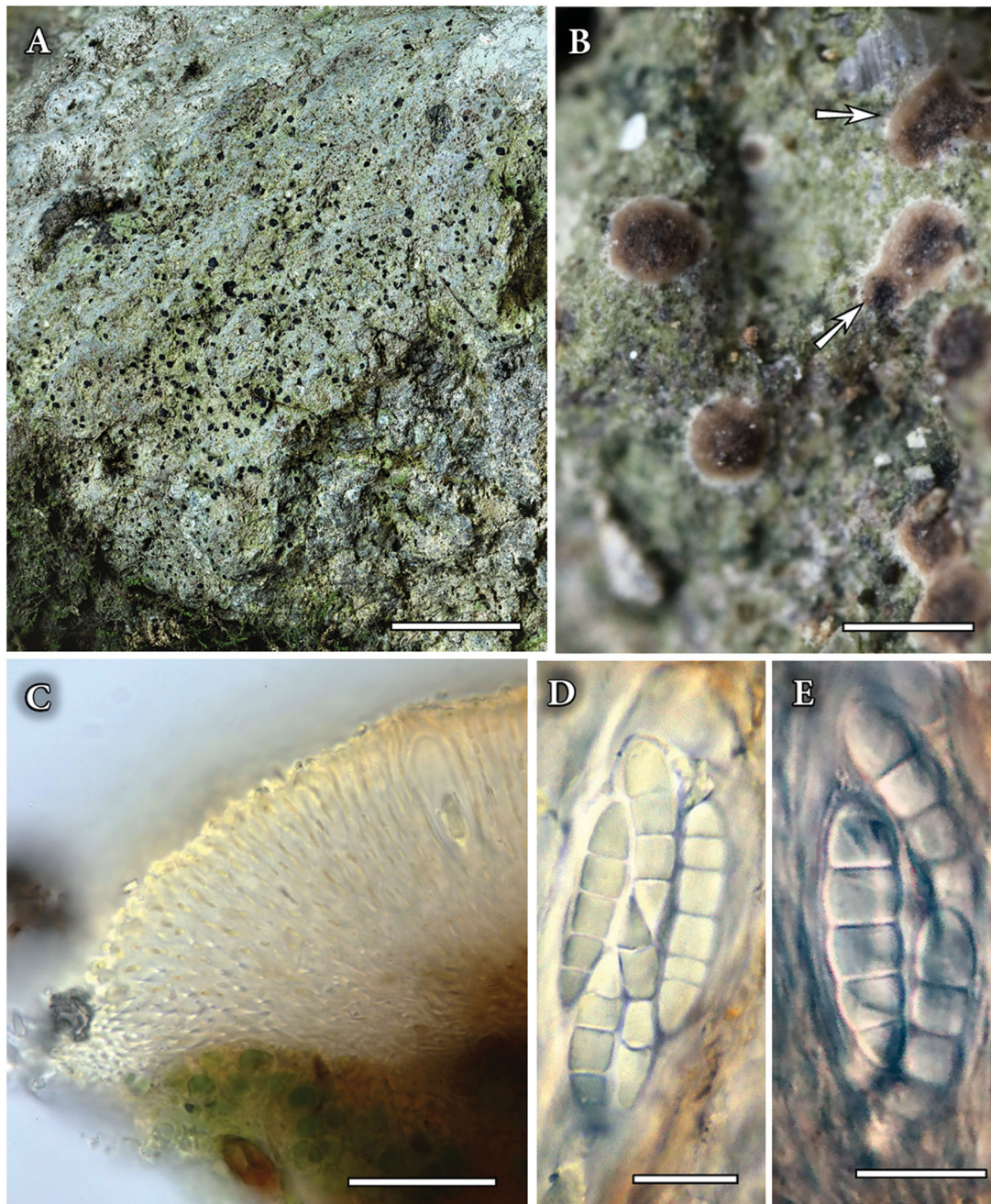


Figure 3. *Jejelea byssolomoides* (KoLRI 36855, holotype). (A, B) Thallus with ascomata (arrows); (C) Cross section of ascoma; (D, E) Detail of mature ascospores in ascus (mounted in water). Scales: (A) – 10 mm, (B) – 1000 μm , (C) – 50 μm , (D, E) – 10 μm .

Excipulum made of colorless loosely woven hyphae, 50–150 μm broad. Hypothecium 20–50 μm high, light to dark brown. Apothecial base aeruginous. Hymenium 45–60 μm high, colorless. Asci 35–55 \times 9–12 μm . Ascospores oblong, 3-septate, without constrictions at the septa, 10–18 \times 2.5–3.5 μm (3–5 μm in *B. subdiscordans*), colorless. Pycnidia subglobose to cup-shaped, 0.1–0.15 mm diameter, brownish-gray with a black center. Conidia pyriform, non-septate, 4–5 \times 1.2–1.8 μm , colorless. *Byssoloma marginatum* forms a compact apothecial margin because the excipulum is composed of hyphae embedded in the gelatinous matrix. The apothecial disk is colored dark grayish brown and ascospores (10–16 \times 3–4 μm), 3-septate, colorless.

4. Discussion

Its geographical isolation and the special climatic conditions on Jeju Island are the main factors determining the emergence of new species of lichenized fungi, of which several dozen have been described herein in recent years (e.g., *Caloplaca chejuensis*, *Fellhanera chejuensis*, *Fauriea jejuensis*, *Graphis jejuensis*, *Orientophila chejuensis*, and *Protoparmeliopsis chejuensis*).

Jejelea byssolomoides is a distinct and mainly lichen-inhabiting lineage in the *Pilocarpaceae* characterized by its saxicolous thallus having a larger and wide 3–5 septate, 17–23 \times 4–5 μm ascospores so it cannot be confused with any other species of *Pilocarpaceae*. Other lichen genera with a byssaceous

ascomata growth form and a chlorococcoid photobiont such as *Byssoloma* Trevis., *Bapalmuia* Sérus., *Sporopodium* Mont., *Tapellaria* Müll. Arg., *Fellhanera* Vězda, *Lasioloma* Santesson, and *Calopadia* Vězda are phylogenetically unrelated, with different types of fruiting bodies and sizes of ascospores. The new species also resembles the saxicolous *Septotrappelia usnica* known from Indonesia, Singapore, and Sri Lanka [32], but the species contains usnic acid and zeorin and forms a granulose thallus, slightly bent, 3-septate ascospores not constricted at the septa (21–27 × 5–6 μm) [33].

Ascomata with hairy margins are not common among lichens. They are known in some species in the family *Porinaceae* which produce hairy perithecial ascomata (*Trichothelium*) and in *Pilocarpaceae* (*Lasioloma*, *Byssoloma*) [14]. The saxicolous *Gyalidea* species, also known from coastal Korea, differ in the absence of white cylindrical cells growing from the margin of the excipulum, a different type of ascus (lightly thickened apical tholus, KI-, a small ocular chamber) [34] and in the different shape and size of the ascospores (1-septate to muriform) [2,35].

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References

- [1] Kondratyuk SY, Lőkös L, Halda JP, et al. New and noteworthy lichen-forming and lichenicolous fungi 7. *Acta Bot Hungarica*. 2018;60(1–2):115–184.
- [2] Kondratyuk SY, Halda JP, Lőkös L, et al. New and noteworthy lichen-forming and lichenicolous fungi 8. *Acta Bot Hungarica*. 2019;61(1–2):101–135.
- [3] Moon KH, Nakanishi M, Kashiwandani H. New or noteworthy species of Graphidaceae (Ostropales, Ascomycota) in Korea. *Jap J Bot*. 2012;87(5):320–325.
- [4] Wang XY, Liu D, Lőkös L, et al. New species and new records of *Buellia* (lichenized ascomycetes) from Jeju province, South Korea. *Mycobiology*. 2016;44(1):14–20.
- [5] Joshi Y, Kondratyuk S, Lokos L, et al. New species and new records of lichenicolous fungi from South Korea. *Mycosphere*. 2015;6(2):195–200.
- [6] Woo J-J, Lücking R, Oh S-Y, et al. Two new foliicolous species of *Strigula* (Strigulaceae, Strigulales) in Korea offer an insight into phorophyte-dependent variation of thallus morphology. *Phytotaxa*. 2020;443(1):1–12.
- [7] Aptroot A, Moon KH. 114 New reports of microlichens from Korea, including a description of five new species, show that the microlichen flora is predominantly Eurasian. *Herzogia*. 2014;27(2):347–365.
- [8] Jayalal U, Oh SO, Lücking R, et al. Contributions to the foliicolous lichens flora of South Korea. *Mycobiology*. 2013;41(4):202–209.
- [9] Oh S-Y, Woo J-J, Hur J-S. Distribution of foliicolous lichen *Strigula* and genetic structure of *S. multififormis* on Jeju Island, South Korea. *Microorganisms*. 2019;7(10):430.
- [10] Lücking R, Hodkinson BP, Leavitt SD. Corrections and amendments to the 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota. *Bryologist*. 2017;120(1):58–69.
- [11] Wang WC, van den Boom P, Sangvichien E, et al. A molecular study of the lichen genus *Byssoloma trevisan* (Pilocarpaceae) with descriptions of three new species from China. *Lichenologist*. 2020;52(5):387–396.
- [12] Trevisan V. *Spighe e paglie*. Padova (Italy): Fasc. primo.; 1853. p. 1–64.
- [13] Robert V, Stegehuis G, Stalpers J. The MycoBank engine and related databases [Internet]; 2005 [cited 2022 Feb 8]. Available from: <https://www.mycobank.org/>.
- [14] Lücking R. Follicolous lichenized fungi. *Flora Neotropica Monograph*. 2008;103:1–866.
- [15] Montagne C. *Cryptogamia guyanensis seu plantarum cellularium in Guyana gallica annis 1835–1849 a cl. Leprieur collectarum enumeratio universalis*. *Ann Des Sci Naturel Trois sér Bot*. 1851;16:47–81.
- [16] Lücking R, Lumbsch HT. New species or interesting records of foliicolous lichens. VI. *Sporopodium aeruginascens* (Lecanorales), with notes on the chemistry of *Sporopodium*. *Mycotaxon*. 2001;78:23–27.
- [17] Müller J. *Lichenes epiphylli novi*. Basel (Switzerland): H. Georg; 1890. p. 1–22.
- [18] Neuwirth G, Stocker-Worgotter E. *Tapellaria palaeotropica* (Pilocarpaceae), a new foliicolous lichen species from the Seychelles, and a world key to the genus. *Lichenologist*. 2017;49(3):253–258.
- [19] Vězda A. Neue gattungen der familie *Lecideaceae* s. lat. (lichenes). *Folia Geobot Phytotax*. 1986;21(2):199–219.
- [20] Sérusiaux E. New taxa of foliicolous lichens from Western Europe and Macronesia. *Nordic J Bot*. 1993;13(4):447–461.

- [21] Santesson R. Foliicolous lichens I. A revision of the taxonomy of obligately foliicolous, lichenized fungi. *Symbolae Bot Upsal.* 1952;12(1):1–590.
- [22] McCarthy PM. A new corticolous species of *Lasioloma* (lichenized Ascomycota, Pilocarpaceae) from North-Eastern Queensland. *Australasian Lichenol.* 2020;87:58–61.
- [23] Orange A, James PW, White FJ. Microchemical methods for the identification of lichens. London (UK): British Lichen Society; 2001.
- [24] Doyle JJ, Doyle JL. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochem Bull.* 1987;19:11–15.
- [25] White TJ, Bruns TD, Lee SB, et al. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. PCR protocols. Part three. Genetics and evolution. Waltham (MA): Academic Press; 1990. p. 315–322.
- [26] Zoller S, Scheidegger C, Sperisen C. PCR primers for the amplification of mitochondrial small subunit ribosomal DNA of lichen-forming ascomycetes. *Lichenologist.* 1999;31(5):511–516.
- [27] Katoh K, Standley DM. MAFFT multiple sequence alignment software version 7: improvements in performance and usability. *Mol Biol Evol.* 2013; 30(4):772–780.
- [28] Kumar S, Stecher G, Tamura K. MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Mol Biol Evol.* 2016;33(7): 1870–1874.
- [29] Minh BQ, Schmidt HA, Chernomor O, et al. IQ-TREE 2: new models and efficient methods for phylogenetic inference in the genomic era. *Mol Biol Evol.* 2020;37(5):1530–1534.
- [30] Ronquist F, Teslenko M, van der Mark P, et al. MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. *Syst Biol.* 2012;61(3):539–542.
- [31] Harada H, Kawakami S. *Gyalideopsis lunata* sp. nov. (lichenized Ascomycota, Gomphillaceae) with rudimentary hyphophores, from gifuken, Central Japan. *Lichenology.* 2011;10(1):23–28.
- [32] Kukwa M, Piątek M. First records of the lichen *Septotrapelia usnica* (Lecanorales, Ascomycota) from West Africa. *Polish Bot J.* 2014;59(1): 105–108.
- [33] Bungartz F, Hillmann G, Kalb K, et al. Leprose and leproid lichens of the Galapagos, with a particular focus on *Lepraria* (Stereocaulaceae) and *Septotrapelia* (Pilocarpaceae). *Phytotaxa.* 2013; 150(1):1–28.
- [34] Henssen A, Lücking R. Morphology, anatomy, and ontogeny in the Asterothyriaceae (Ascomycota: Ostropales), a misunderstood group of lichenized fungi. *Ann Bot Fennici.* 2002;39: 273–299.
- [35] Kondratyuk SY, Lőkös L, Halda JP, et al. New and noteworthy lichen-forming and lichenicolous fungi 5*. *Acta Bot Hungarica.* 2016;58(3–4): 319–396.