



Floristic study of the bryophytes of an evergreen broad-leaved forest in the vicinity of Baekyaki Oreum in Gujwa-Seongsan Gotjawal, Jeju Island

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ABSTRACT: This study presents a survey of the bryophytes of evergreen broad-leaved forest near Baekyaki Oreum in Gujwa-Seongsan Gotjawal in the eastern part of Jeju Island, Korea. A total of 53 taxa belonging to Bryophyta (11 families 26 genera 39 species) and Marchantiophyta (9 families, 9 genera 14 species) were determined, and the liverwort index was found to be 26.4%. The predominant life-form was the mat type. The rates of bryophytes dominating at mesic to hygric sites were higher than those of bryophytes, which were mainly observed in xeric habitats. These values indicate that the forest areas in this study area have a high density level. Upon an investigation of the substrates, bryophytes on rocks were most diverse. It was also found that volcanic rock masses of various sizes lay scattered over the study area and offer numerous micro-habitats for bryophytes. This is related to the characteristics of Gotjawal. We consider that more detailed studies should be conducted on regional scales to establish the bryophyte flora of Gotjawal and the evergreen broad-leaved forests of Jeju Island.

Keywords: bryophyte, Gujwa-Seongsan Gotjawal, liverwort index, life-form

Jeju Island was formed by volcanic activity and has unique topological and geological features. In this unique volcanic terrain, forests established on lava flow are scattered around the island, known as “Gotjawal,” a newly coined compound word coming from dialects spoken on Jeju Island (Jeju Special Self-Governing Province, 2009; Yoon, 2014). Recently, it has become known that Gotjawal is an area inhabited by various plants and animals where unique and various types of ecosystems are also sustained; the area also contains natural waterways of the type necessary to recharge underground water, and it has high preservation value (Jeon et al., 2012; Kang et al., 2013; Yoon, 2014; Jeong, 2015). However, few floristic studies of bryophytes have been conducted, except for those concerning on Seonheul Gotjawal (Dongbaek-dongsan) in the northeastern part of the island by Yim et al. (2013), on Aewol Gotjawal (Subtropical Forest of Nabeup-ri) in the northwestern area by Yim and Hyun (2018), and on Hangyeong Gotjawal (Cheongsu-ri) in the southeastern part of the island by Yim et al. (2019).

The area and range of the Gotjawal terrain have not yet been established (Jeon et al., 2015). According to Song (2000), who first described Gotjawal, Gotjawal can be divided into four major types of terrains. These were termed Gujwa-Seongsan, Jocheon-Hamdeok, Hangyeong-Andeok, and Aewol. The Jeju Special Self-Government Province (2009) adds Gyoraehannam Gotjawal to the four terrains, making the total five (Fig. 1). Among them, the Gujwa-Seongsan Gotjawal terrain is suggested to be divided into four lava flow areas: Jongdal-Handong Gotjawal, Sehwa Gotjawal, Sangdo-Hado Gotjawal, and Susan Gotjawal (Song, 2000). It has been considered that these lava flows were formed by four corresponding Oreum (a small extinct volcanic cone in Jeju Island). The Jongdal-Handong Gotjawal lava flow is distributed from Donggeomun Oreum to the coastal lowlands 30 m above sea level toward Handong-ri, over a total length of 11 km. The Sehwa Gotjawal lava flow starts at Darangshi Oreum and is distributed over a total length of 4.7 km. The Sangdo-Hado Gotjawal lava flow is distributed over a total length of approximately 5.6 km,

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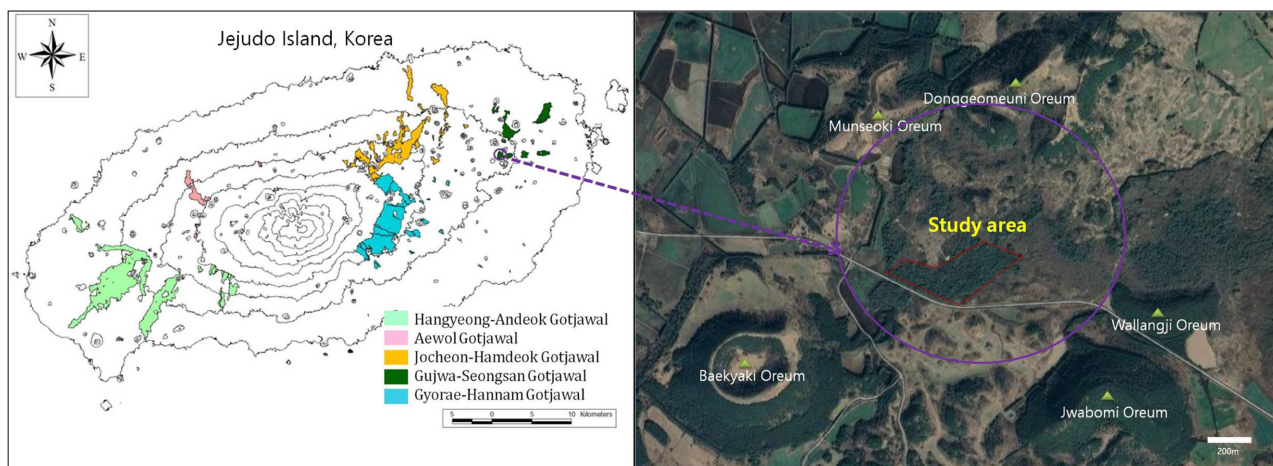


Fig. 1. Map showing the location of the study area and distribution of the Gotjawal terrains, Jeju Island, Korea. Gotjawal terrains designated by the Jeju Special Self-Governing Province (1997) are indicated by the colored areas.



Fig. 2. Pictures showing the characteristics of the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum in Gujwa-Seongsan Gotjawal, Jeju Island. **A.** Panoramic view of the evergreen forest from the top of Baekyaki Oreum. **B.** Vegetation. **C.** Bryophytes on rocks. **D.** Bryophytes on bark.

starting from Yongnuni Oreum and ending near Jimibong Oreum. Finally, the Susan Gotjawal lava flow starts around the vicinity of Gungdaek Oreum 50 m above sea level in the western area of the village of Susan-ri, running for more than 5.5 km (Song, 2000). However, Ahn et al. (2015) found that Gujwa-Seongsan Gotjawal was formed by four sequential eruptions at Donggeomun Oreum. The lava flows from the first eruption are distributed in parts of Jongdal-Handong Gotjawal, Sangdo-Hado Gotjawal, and Sehwa Gotjawal. The second flows are distributed along the direction of Sangdo-

Hado among the three forked flows of the first lava flows. The third flows are distributed from Jongdal-Handong Gotjawal to the vicinity of the Bijarim Forest, and the fourth flows are distributed from the south of Donggeomun Oreum toward the east. These lava flows are located in the vicinity of Baekyaki Oreum and are widely known as Baekyaki Oreum Gotjawal or Susan Gotjawal. In this area, evergreen broad-leaved forests are linearly distributed along the uneven terrain and unlike other Gotjawal terrains, the dominant tree species are not evergreen oaks but plants of the family Lauraceae. It has also

been found that the deciduous trees such as *Celtis sinensis* Pers. and *Mallotus japonicus* (L. f.) Mu?ll. are mixed throughout this forest. In addition, in the lower layer of the forest, the ratio of exposed rocks is high, and ferns, such as *Arachniodes aristata* (G. Forst.) Tindale, *A. standishii* (T. Moore) Ohwi, and *Crepidomanes latealatum* (Bosch) Copel grow, as do flowering plants such as *Ardisia crenata* Sims, *A. japonica* (Thunb.) Blume, and *Rubus buergeri* Miq. The adjacent area is used as pasture, where *Miscanthus sinensis* Andersson, *Ligustrum obtusifolium* Siebold & Zucc., *Euonymus alatus* (Thunb.) Siebold, and *M. japonicus* etc. are densely distributed. The secondary forest of deciduous broad-leaved trees formed around this area is dominated by *Pourthiaea villosa* (Thunb.) Decne., *Zelkova serrata* (Thunb.) Makino, and *C. sinensis*, among others (Fig. 2A, B).

The purpose of this study was to investigate the bryophyte flora of the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum in Gujwa-Seongsan Gotjawal. Furthermore, this study contributes to the literature on the bryophyte flora of Gotjawal and evergreen broad-leaved forests on a regional scale and provides basic data pertaining relevant indicator species.

Materials and Methods

Field surveys

Field surveys were conducted in an evergreen broad-leaved forest in the vicinity of Baekyaki Oreum in Gujwa-Seongsan Gotjawal, with an area of approximately 75,453 m² (Fig. 1), four times from August of 2011 to August of 2018. The study area is located between Donggeomeuni Oreum, Baekyaki Oreum, and Jwabomi Oreum and belongs to Jongdal-ri, Gujwa-eup, Jeju-si, and Seongeup-ri, Pyoseon-myeon, Seogwipo-si.

Identification, nomenclature and arrangement of taxa

The samples collected in the investigated area were identified at the species level with macroscopic morphology and microscopic features using relevant literature (Iwatsuki and Mizutani, 1972; Inoue, 1974, 1976; Choe, 1980; Noguchi, 1987, 1988, 1989, 1991, 1994; Gao et al., 1999; Iwatsuki, 2001; Li et al., 2001; Wu et al., 2002; Cao et al., 2003). Voucher specimens were deposited in the herbarium of the Warm Temperate and Subtropical Forest Research Center in Korea (WFRC). Only one collection number per taxon was cited to avoid repetition on the floristic list. The nomenclature and arrangement of the taxa utilize the systems proposed by Goffinet et al. (2009) and Crandall-Stotler et al. (2009) for mosses and liverworts, respectively.

Life-forms and substrates

The life-forms of the bryophytes in the study area were estimated using Mägdefrau (1982), and they were found to be on the floristic list for each taxon. The records of substrates for each taxon were included in this list.

Number of bryophyte taxa and liverwort index

We compared the number of taxa and the liverwort index of the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum with other localities based on the available literature [i.e., Deogyusan Mt. (Choi et al., 2010; Yoon et al., 2011), Sobaeksan Mt. (Korea National Park Research Institute, 2016a), Gayasan Mt. (Korea National Park Research Institute, 2016b), Taebaeksan Mt. (Korea National Park Research Institute, 2018), Jirisan Mt. (Korea National Park Research Institute, 2019a), Sokrisan Mt. (Korea National Park Research Institute, 2019b), Dongbaek-dongsan (Yim et al., 2013), Subtropical Forest of Nabeup-ri (Yim and Hyun, 2018), and the evergreen broad-leaved forest of Cheongsu-ri at Hangyeong Gotjawal (Yim et al., 2019)]. The liverwort index, which is based on the fact that liverworts and hornworts tend to prefer more humid conditions compared to mosses, was calculated as follows (Nakanishi, 2001):

$$\text{Liverwort index (\%)} = \frac{\text{No. of liverworts} + \text{No. of hornworts}}{\text{Total no. of liverworts}} \times 100$$

Results and Discussion

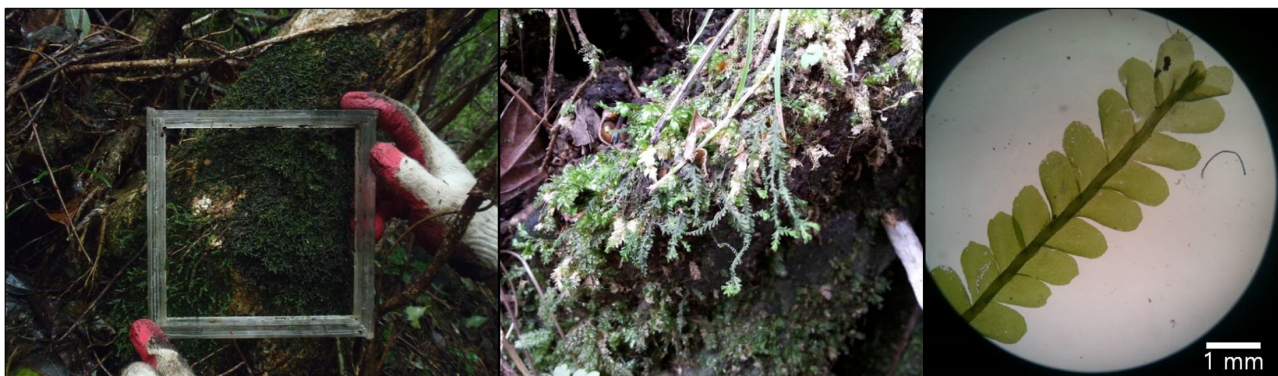
The number of taxa and the liverwort index

A total of 53 taxa belonging to Bryophyta (11 families 26 genera 39 species) and Marchantiophyta (9 families 9 genera 14 species) were determined (Appendix 1). A comparison of the results of the numbers of taxa indicated that the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum has a larger area than the Subtropical Forest of Nabeup-ri, but also has lower species diversity (Table 1).

The liverwort index is based on findings indicating that liverworts and hornworts tend to prefer more humid conditions than mosses. Therefore, it is useful to compare air humidity levels between different sites (Nakanishi, 2001). The liverwort index of the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum showed a humidity level of 26.4%, demonstrating that the air humidity of investigated area was lower than all of the mountain and Gotjawal areas, apart from the evergreen broad-leaved forest of Cheongsu-ri (Table 1). We consider that more detailed studies of the bryophyte flora of Korea should be conducted on a regional scale.

Table 1. Comparisons of the bryophyte species richness levels and liverwort indexes of the evergreen broad-leaved forest in the vicinity of Baekyaki Oreum and other localities.

Locality	Area (km ²)	No. of species	Liverwort index
Gotjawal area			
Evergreen broad-leaved forest in the vicinity of Baekyaki Oreum (Gujwa-Seongsan Gotjawal)	0.075	53	26.4
Dongbaek-dongsan (Seonheul Gotjawal)	1.420	85	27.0
Evergreen broad-leaved forest of Cheongsu-ri (Hangyeong Gotjawal)	0.501	72	23.6
Subtropical Forest of Nabeup-ri (Aewol Gotjawal)	0.034	63	30.2
Mountain area			
Jirisan Mt.	483.022	218	49.5
Sobaeksan Mt.	322.011	236	41.9
Deogyusan Mt.	231.650	311	40.8
Sokrisan Mt.	274.766	130	42.3
Gayasan Mt.	76.256	173	37.6
Taebaeksan Mt.	70.052	275	38.9

**Fig. 3.** *Plagiochila shangaica* Steph. found in the study area.

Remarkable species

Plagiochila shangaica Steph. (Hae-an-nal-gae-i-kki), Choi et al. (2012), newly reported from Korean flora, was found in this study area (Fig. 3). This liverwort inhabits moist rocks on Jeju Island, Oenarodo Island and Geojedo Island, among others, and is distributed in China, Japan, and Vietnam (Choi, 2013; Shu et al., 2017). The centers of diversity of *Plagiochila* are in Southeast Asia and the Neotropics (So, 2001). *P. shangaica* is designated and managed as a rare plant in Japan (Ministry of the Environment Government of Japan, 2020). The habitat of this species was unknown except for Andeok Valley on Jeju Island, and this marks the first time it has been found in Gotjawal terrains thus far. Therefore, it is considered that research on this species as a climate change indicator species and rare plant is necessary.

Life-forms

We estimated the life-forms for each taxon in the study area, as presented in Table 2. The predominant life-form was the mat type (19 species, 35.8%), followed by the weft (18 species, 34.0%), tall turf (10 species, 18.9%), fan (3 species, 5.7%), tail (2 species, 3.8%), and short turf types (1 species, 1.9%). We analyzed the results based on the relationship between the adaptive strategy and life-form of bryophytes according to Kürschner (2004), Uyar et al. (2007), and Glime (2017). As a result, the rates of mostly pleurocarpous bryophytes (the mat, weft, fan, and tail life forms) dominating at mesic to hygic sites amounted to 79.2%, whereas mostly acrocarpous bryophytes (the tall turf and short turf life forms), mainly observed in xeric habitats, amounted to 20.8% (Fig. 2, Appendix 1). These values indicate that the forests in this study area have high density levels.

Table 2. Number of taxa and percentage composition according to the life-forms of bryophytes in the study area.

Life-forms	No. of taxa (%)
Xeric habitat type	11 (20.8)
Short turfs	1 (1.9)
Tall turfs	10 (18.9)
Mesic to hygic site type	42 (79.2)
Tails	2 (3.8)
Fans	3 (5.7)
Mats	19 (35.8)
Wefts	18 (34.0)
Total	53 (100.0)

Table 3. The number of taxa according to the substrate in the study area.

Substrate	No. of taxa
Specific to only one substrate	
Epilithic	28
Epiphytic	1
Epixylous	1
On the soil	1
Common to two or more substrates	
Epilithic and epiphytic	9
Epilithic and on the soil	2
Epilithic and epixylous	1
Epiphytic and epixylous	1
Epilithic, epiphytic and epixylous	2
Epilithic, epiphytic and on the soil	2
Epilithic, epixylous and on the soil	1
Epilithic, epiphytic, epixylous and on the soil	4
Total	53

Substrate pattern

We estimated the substrates for each taxon to investigate the distribution pattern. The numbers of taxa according to the substrate are presented in Table 3. Upon an investigation of the substrates, bryophytes on the rocks were found to be most diverse, at 49 taxa, followed by bark (19 taxa) and decayed tree and soil (10 taxa, each). These results appear to stem from the fact that volcanic rock masses of various sizes are scattered over the study area, offering numerous micro-habitats for bryophytes due to one of the characteristics of Gotjawal, i.e., the presence of rocks of various sizes that are scattered randomly (Fig. 2C, D).

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Conflict of Interest

The authors declare that there are no conflict of interest.

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Appendix 1. Floristic list of bryophytes of evergreen broad-leaved forest in the vicinity of Baekyaki Oreum in Gujwa-Seongsan Gotjawal, Jeju Island.

Taxa	Korean name	Life form	Substrate	Voucher No. (Eun-Young Yim-)
Bryophyta Schimp. 선류식물문				
Fissidentaceae Schimp. 봉황이끼과				
<i>Fissidens gymnogynus</i> Besch.	작은봉황이끼	Tall turfs	L	SSG324
Bryaceae Schwägr. 은이끼과				
<i>Rosulabryum capillare</i> (Hedw.) J. R. Spence	철사이끼	Short turfs	L	SSG072
Mniaceae Schwägr. 참이끼과				
<i>Mnium ambiguum</i> H. Müll.	납작맥초롱이끼	Tall turfs	L	SSG178
<i>Plagiomnium acutum</i> (Lindb.) T. J. Kop.	아기들덩굴초롱이끼	Tall turfs	LS	SSG016
<i>Plagiomnium cuspidatum</i> (Hedw.) T. J. Kop.	들덩굴초롱이끼	Tall turfs	L	SSG006
<i>Plagiomnium vesicatum</i> (Besch.) T. J. Kop.	큰잎덩굴초롱이끼	Tall turfs	L	SSG095
<i>Trachycystis microphylla</i> (Dozy & Molk.) Lindb.	아기초롱이끼	Tall turfs	LP	SSG108
Bartramiaceae Schwägr. 구슬이끼과				
<i>Philonotis fontana</i> (Hedw.) Brid.	물가이끼	Tall turfs	S	SSG073
Thuidiaceae Schimp. 깃털이끼과				
<i>Anomodon minor</i> (Hedw.) Lindb.	푸른명주실이끼	Tails	LP	SSG168
<i>Claopodium aciculatum</i> (Broth.) Broth.	가시이끼	Wefts	L	SSG077
<i>Haplocladium angustifolium</i> (Hampe & Müll. Hal.) Broth.	침작은명주실이끼	Wefts	LPXS	SSG003
<i>Haplocladium microphyllum</i> (Hedw.) Broth.	작은명주실이끼	Wefts	LP	SSG078
<i>Pelekium versicolor</i> (Hornsch. ex Müll. Hal.) Touw	아기깃털이끼	Wefts	LPXS	SSG008
<i>Thuidium kanedae</i> Sakurai	깃털이끼	Wefts	LPS	SSG007
<i>Thuidium pristocalyx</i> (Müll. Hal.) A. Jaeger	푸른깃털이끼	Wefts	L	SSG081
<i>Thuidium subglauzinum</i> Cardot	큰푸른깃털이끼	Wefts	L	SSG111
Brachytheciaceae Schimp. 양털이끼과				
<i>Brachythecium buchananii</i> (Hook.) A. Jaeger	긴양털이끼	Wefts	L	SSG083
<i>Brachythecium helminthocladum</i> Broth. & Paris	끈양털이끼	Wefts	L	SSG261
<i>Brachythecium plumosum</i> (Hedw.) Schimp.	날개양털이끼	Wefts	LP	SSG033
<i>Brachythecium populeum</i> (Hedw.) Schimp.	양털이끼	Wefts	LXS	SSG005
<i>Bryhnia novae-angliae</i> (Sull. & Lesq.) Grout	세모양털이끼	Wefts	L	SSG018
<i>Cirriphyllum piliferum</i> (Hedw.) Grout	걸끈양털이끼	Wefts	L	SSG032
<i>Eurhynchium savatieri</i> Schimp. ex Besch.	가는부리이끼	Wefts	LPXS	SSG087
<i>Rhynchostegium pallidifolium</i> (Mitt.) A. Jaeger	아기양털부리이끼	Wefts	LP	SSG153
Hypnaceae Schimp. 털깃털이끼과				
<i>Callicladium haldanianum</i> (Grev.) H. A. Crum	풀이끼	Wefts	L	SSG048
<i>Pseudotaxiphyllum pohliaecarpum</i> (Sull. & Lesq.) Z. Iwats.	빨간걸주목이끼	Mats	LS	SSG096
<i>Pylaisiadelpha tenuirostris</i> (Bruch & Schimp. ex Sull.) W. R. Buck	무성아실이끼	Mats	P	SSG092
<i>Taxiphyllum aomoriense</i> (Besch.) Z. Iwats.	겹친주목이끼	Mats	L	SSG144
<i>Taxiphyllum taxirameum</i> (Mitt.) M. Fleisch.	주목이끼	Mats	LPX	SSG058

Appendix 1. Continued.

Plagiotheciaceae M. Fleisch. 산주목이끼과					
<i>Plagiothecium euryphyllum</i> (Cardot & Thér.) Z. Iwats.	넓은잎산주목이끼	Mats	L	SSG090	
<i>Plagiothecium nemorale</i> (Mitt.) A. Jaeger	산주목이끼	Mats	LPX	SSG002	
Entodontaceae Kindb. 윤이끼과					
<i>Entodon challengerii</i> (Paris) Cardot	넓은잎윤이끼	Wefts	L	SSG089	
<i>Entodon sullivantii</i> (Müll. Hal.) Lindb.	가는윤이끼	Wefts	LPXS	SSG009	
Sematophyllaceae Broth. 나무실이끼과					
<i>Sematophyllum subhumile</i> (Müll. Hal.) M. Fleisch.	나무실이끼	Mats	X	SSG093	
<i>Sematophyllum subpinatum</i> (Brid.) E. Britton	날개무성아실이끼	Mats	PX	SSG267	
Neckeraceae Schimp. 납작이끼과					
<i>Neckera humilis</i> Mitt.	아기납작이끼	Fans	LP	SSG013	
<i>Pseudanomodon giralduii</i> (Müll. Hal.) Ignatov & Fedosov	큰명주실이끼	Tails	L	SSG075	
<i>Thamnobryum plicatulum</i> (Sande Lac.) Z. Iwats.	그늘대호꼬리이끼	Fans	L	SSG088	
<i>Thamnobryum subseriatum</i> (Mitt. ex Sande Lac.) B. C. Tan	대호꼬리이끼	Fans	L	SSG004	
Marchantiophyta Stotler & Crand. -Stotl. 태류식물문					
Wiesnerellaceae Inoue 방울우산이끼과					
<i>Wiesnerella denudata</i> (Mitt.) Steph.	방울우산이끼	Mats	L	SSG102	
Dumortieraceae D. G. Long 털우산이끼과					
<i>Dumortiera hirsuta</i> (Sw.) Nees	털우산이끼	Mats	L	SSG103	
Metzgeriaceae H. Klinggr. 리본이끼과					
<i>Metzgeria lindbergii</i> Schiffn.	리본이끼	Mats	LP	SSG182	
Porellaceae Cavers 세줄이끼과					
<i>Porella gracillima</i> Mitt.	가는세줄이끼	Mats	L	SSG220	
<i>Porella grandiloba</i> Lindb.	큰세줄이끼	Mats	L	SSG143	
<i>Porella vernicosa</i> Lindb.	가시세줄이끼	Mats	L	SSG001	
Lejeuneaceae Cavers 작은귀이끼과					
<i>Lejeunea japonica</i> Mitt.	작은귀이끼	Mats	LPS	SSG204	
Lophocoleaceae Müll. Frib. ex Vanden Berghen 두끝벼슬이끼과					
<i>Heteroscyphus argutus</i> (Nees) Schiffn.	아기비늘이끼	Mats	L	SSG099	
<i>Heteroscyphus planus</i> (Mitt.) Schiffn.	비늘이끼	Mats	LP	SSG186	
Plagiochilaceae Müll. Frib. 날개이끼과					
<i>Plagiochila ovalifolia</i> Mitt.	둥근날개이끼	Tall turfs	L	SSG046	
<i>Plagiochila sciophila</i> Nees ex Lindenb.	아기날개이끼	Tall turfs	LX	SSG214	
<i>Plagiochila shangaica</i> Steph.	해안날개이끼	Tall turfs	LP	SSG107	
Cephaloziellaceae Douin 걸계밭이끼과					
<i>Cephaloziella spinicaulis</i> Douin	가시걸계밭이끼	Mats	L	SSG148	
Jungermanniaceae Rchb. 망울이끼과					
<i>Jungermannia infusca</i> (Mitt.) Steph.	큰망울이끼	Mats	L	SSG173	

L, epilithic; P, epiphytic; X, epixylous; S, on the soil.