Notes on *Allium* section *Rhizirideum* (Amaryllidaceae) in South Korea and northeastern China: with a new species from Ulleungdo Island

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Abstract

*Allium* section *Rhizirideum* is reviewed for South Korea and neighboring northeastern China based on critical observation of wild populations and herbarium materials. Species delimitations are re-evaluated on the basis of morphological and somatic chromosome numbers, resulting in the recognition of five species. *Allium dumebuchum* from Ulleungdo Island, South Korea, is described as a new species. This species is most similar to *A. senescens* due to its habits, but is clearly distinguished particularly by its rhomboid scapes in cross-section, light purple perianth color, entire and narrowly triangular inner filaments, and flowering season from late September. One previously recognized species is placed into synonymy: *A. pseudosenescens* (under *A. senescens*). Photographs and a key to species of *Allium* section *Rhizirideum* in South Korea and northeastern China are provided in addition to information on nomenclatural types, synonymies, chromosome numbers, distribution, and specimens examined.

Keywords

Chromosome number, DNA barcode, distribution, morphology, new species, synonym, taxonomy
Introduction

With over 900 species (Seregin et al. 2015), Allium L. is one of the largest genera in the Amaryllidaceae (Friesen et al. 2006; Fritsch et al. 2010; Li et al. 2010). It is characterized by bulbs enclosed in membranous to fibrous tunics, free or almost free tepals, and often a subgynobasic style (Friesen et al. 2006). Most taxa produce remarkable amounts of cysteine sulphoxides causing the well-known characteristic odor and taste (Friesen et al. 2006). Allium is distributed naturally in the northern hemisphere and in South Africa, mostly in regions with dry seasons (De Sarker et al. 1997; Friesen et al. 2006; Nguyen et al. 2008; Neshati and Fritsch 2009). The classification of Allium by Friesen et al. (2006) based on molecular phylogenetic analyses includes 15 subgenera and 56 sections. About 23 taxa, excluding cultivated species, are known from the Korean peninsula and neighboring northeastern China (Choi and Oh 2011; Shukherdorj et al. 2018; Choi et al. 2019).

Allium section Rhizirideum G.Don ex W.D.J.Koch is the typical section of subgenus Rhizirideum (G.Don ex W.D.J.Koch) Wendelbo and characterized by having bulbs enclosed in membranous tunics and attached to horizontal rhizomes, a leaf shape ranging from hemicylindrical to plain, and a flower color from white to purple (Sinitsyna et al. 2016). Section Rhizirideum consists of 24 species and is part of the third of three main evolutionary lines of Allium (Fritsch 2001; Fritsch and Friesen 2002; Friesen et al. 2006; Li et al. 2010; Choi et al. 2012b). The distribution area of section Rhizirideum reaches from Europe to East Asia (Sinitsyna et al. 2016). There is a distinct narrowing of the distribution area east of the Ural Mountains approximately along 70° eastern longitude, and most species of section Rhizirideum are distributed in temperate Asia (Sinitsyna et al. 2016). The center of species diversity is situated in the mountain steppes of South Siberia and Mongolia (Sinitsyna et al. 2016). The species of section Rhizirideum share a basic chromosome number of \(x = 8\), and four ploidy levels were found: di-, tetra- penta-, and hexaploids (Sinitsyna et al. 2016).

The taxonomy of the section is complicated because of morphological diversity and hybridization involving polyploidy (Friesen 1988, 1992; Kamelin 2004). Additionally, the nomenclature is confusing, which may be explained by similar morphology of some species and disappearance of many morphological characters in the voucher specimens in herbaria (Sinitsyna et al. 2016; Sinitsyna and Friesen 2018). Recently, Sinitsyna et al. (2016) and Sinitsyna and Friesen (2018) investigated the phylogenetic relationships in the section Rhizirideum based on molecular markers, and organized nomenclature, distribution maps and identification key for all known species of the section. Although there is general agreement regarding the Allium species of section Rhizirideum in South Korea and its neighboring northeastern China (Choi and Oh 2011) studies on materials from these regions are still limited.

Here, we have combined morphological, cytological, and molecular characters to address the taxonomy of Allium section Rhizirideum, and organized nomenclature, distribution maps and identification key for species in South Korea and north-eastern China. The goals of this study are: 1) to review and expand the current knowledge on
general morphology (in addition to Choi and Oh 2011; Sinitsyna et al. 2016), somatic chromosome numbers (in addition to Choi and Oh 2011), DNA barcoding, and distribution (in addition to Choi and Oh 2011; Sinitsyna et al. 2016) especially with a focus on the materials from South Korea and north-eastern China, and 2) to describe a new species of section Rhizirideum from Ulleungdo Island, South Korea, *A. dumebuchum* H.J.Choi. This study together with that of Sinitsyna et al. (2016) and Sinitsyna and Friesen (2018) will provide a sound foundation for a global monograph and the systematic understanding of *Allium* section *Rhizirideum*.

**Materials and methods**

**Morphological characters**

This revision is based on the use of living and herbarium material, including photographs of type specimens, from the following herbaria: B, CBU, KB, KH, KWNNU, LE, LINN, PE (abbreviations are according to Thiers 2020+), and the herbarium of Changwon National University (CWNU). Field surveys were carried out mainly in South Korea and north-eastern China from July 2014 to October 2020. We also observed populations from Far Eastern Russia and Mongolia especially for *Allium spirale* Willd. and *A. senescens* L. Materials preserved in 70% ethanol were used especially for observation and measurement of floral parts, cross-sections of leaf and scape. Segments from the middle third of the leaf blade and scape were stained with 2% aceto carmin for observation of the cross-section. Measurements were based on at least 30 samples for quantitative characters.

**Principal component analysis**

To analyze floral morphology known as a key character to distinguish *Allium* species (Choi and Oh 2010; Choi and Oh 2011), principal components analysis (PCA) was performed based on 14 characters: flower number per inflorescence, inflorescence length, inflorescence width, pedicel length, inner tepal length, inner tepal width, outer tepal length, outer tepal width, inner filament length, inner filament width, outer filament length, anther length, anther width, and pistil length. The principal components analysis used the *ggfortify* and *ggplot2* packages of the R-project (Tang et al. 2016; Wickham 2016; R Core Team 2020). The specimens used for principal components analysis were indicated with an asterisk (*) in specimens examined for each species.

**Somatic chromosome numbers**

Root tips were pre-treated in distilled water on ice for 24 h in total darkness at 4 °C and then fixed in Carnoy’s fluid (3 parts absolute ethanol: 1 part glacial acetic acid, v/v) overnight at 4 °C. The root tips were macerated in 1M hydrochloric acid at 60 °C for 3–5 min. After washing 3–5 times to eliminate residual hydrochloric acid and staining
with feulgen for 5 min, the material was squashed for observation in 2% aceto carmin. Observations and photographing of chromosome micrographs were made using an Olympus BX43 (Tokyo, Japan).

DNA barcoding

In this study, we investigated the application of concatenated cpDNA regions of \textit{ndhJ-trnF}, \textit{trnH-psbA}, \textit{psbD-trnT}, and \textit{psbJ-petA} in barcoding analyses of \textit{Allium} section \textit{Rhizirideum} and related taxa (Table 1). In order to analyze the relationship among the species using these four cpDNA regions, we extracted each cpDNA region from complete chloroplast genome sequences stored in NCBI GenBank (https://www.ncbi.nlm.nih.gov/; Fig. 6). The species in subgen. \textit{Butomissa} were selected as outgroup referred from wide phylogenetic study of \textit{Allium} (Li et al. 2010). Detailed information on sample collection, voucher specimens and Genbank accession numbers of each sample is provided in Table 2.

Total genomic DNA was extracted from silica gel-dried leaf materials using the DNeasy Plant Mini Kit (Qiagen, Seoul, South Korea). We conducted PCR with a ProFlex 96-Well PCR System (Applied Biosystems, Foster City, CA, USA). Each reaction mixture contained AccuPower PCR PreMix (Bioneer, Daejeon, South Korea), ca. 10 ng (1μL) of genomic DNA, and 100 pM of primers in a total volume of 20 μL. Conditions included an initial denaturation at 94 °C for 5 min, followed by 30 amplification cycles comprising 94 °C for 1 min, 54 °C for 1 min, and 72 °C for 1 min, with a final extension at 72 °C for 7 min. After the PCR products were visualized on 2% agarose gels, they were treated with a MG PCR Purification kit (MGmed), and sequenced with the ABI 3730xl Analyzer, using the ABI BigDye Terminator v3.1 Cycle Sequencing Kits (Applied Biosystems, Foster City, CA, USA). The obtained sequences were manually determined and aligned by using MAFFT with Geneious Prime 2019.2.3 (Biomatters Ltd., Auckland, NZ). The DNA sequences generated in this study have been deposited in GenBank (Table 2).

The phylogenetic analyses were conducted using Maximum Likelihood (ML) by using W-IQ-TREE (Trifinopoulos et al. 2016), based on user-friendly web servers for IQ-TREE (Nguyen et al. 2015). The concatenated sequence dataset was tested to find the best-fit model by using W-IQ-TREE with the Akaike criterion and new model selection procedures. TIM+R3+F were confirmed as best-fit models for the sequences. Maximum likelihood analysis was performed with default settings in W-IQ-TREE (Fig. 6).

<table>
<thead>
<tr>
<th>Fragment</th>
<th>Marker</th>
<th>Sequence 5' → 3'</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndhJ-trnF</td>
<td>ndhJ</td>
<td>ATGCCYGAAGTTGGATAGG</td>
<td>Shaw et al. (2007)</td>
</tr>
<tr>
<td>TabE</td>
<td></td>
<td>GGTCAAGGGTCCCTATCCC</td>
<td>Taberlet et al. (1991)</td>
</tr>
<tr>
<td>trnH-psbA</td>
<td>trnH</td>
<td>CGGCCATGTGGGATCTCC</td>
<td>Tate and Simpson (2003)</td>
</tr>
<tr>
<td>psbA</td>
<td></td>
<td>GTTATGCATGGAGTATGCTC</td>
<td>Sang et al. (1997)</td>
</tr>
<tr>
<td>psbD-trnT</td>
<td>psbD</td>
<td>CTCCGCTCCGATGCTCCAT</td>
<td>Shaw et al. (2007)</td>
</tr>
<tr>
<td>trnH</td>
<td>CCCTTTAACTCCAGTGTCAGG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>psbJ-petA</td>
<td>psbJ</td>
<td>ATAGGCTACGCTACCC</td>
<td>Shaw et al. (2007)</td>
</tr>
<tr>
<td>petA</td>
<td></td>
<td>AACARTTGYGARAGTTTCAATT</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. List of the markers used for the DNA barcoding and phylogenetic analysis.
### Table 2. List of *Allium* species sequenced in this study.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Locality</th>
<th>Voucher information</th>
<th>GenBank number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>psbJ-petA</td>
</tr>
<tr>
<td><em>A. angulosum</em></td>
<td>Kazakhstan: Burlinsky, Zhatsuat</td>
<td>H.J.Choi 200923</td>
<td>MW478175</td>
</tr>
<tr>
<td></td>
<td>Mongolia: khovd, Khurek khesuu</td>
<td>H.J.Choi 160730-001</td>
<td>MW478174</td>
</tr>
<tr>
<td></td>
<td>Mongolia: khovd, Munkhhaarikhan</td>
<td>H.J.Choi 160730-002</td>
<td>MW478173</td>
</tr>
<tr>
<td><em>A. damaebuchum</em></td>
<td>South Korea: Gyeongbuk, Uleungdo, Nari</td>
<td>H.J.Choi 190917-01</td>
<td>MW478172</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gyeongbuk, Uleungdo, Nari</td>
<td>H.J.Choi 190917-02</td>
<td>MW478171</td>
</tr>
<tr>
<td><em>A. minus</em></td>
<td>South Korea: Gyeonggi, Yangju, Jangheung</td>
<td>H.J.Choi 151006-01</td>
<td>MW478170</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gyeonggi, Yangju, Jangheung</td>
<td>H.J.Choi 151006-02</td>
<td>MW478169</td>
</tr>
<tr>
<td><em>A. prostratum</em></td>
<td>Mongolia: Ulaanbaatar, Uvor Gunt davaa</td>
<td>H.J.Choi 140708</td>
<td>MW478168</td>
</tr>
<tr>
<td></td>
<td>Mongolia: Govi-Altai</td>
<td>H.J.Choi 160811</td>
<td>MW478167</td>
</tr>
<tr>
<td></td>
<td>Mongolia: Tuv, Mungunmorit</td>
<td>H.J.Choi 160706</td>
<td>MW478165</td>
</tr>
<tr>
<td><em>A. spirale</em></td>
<td>Russia: Primorskiy kray, Terneysky</td>
<td>H.J.Choi et al. 140826-01</td>
<td>MW478157</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Terneysky</td>
<td>H.J.Choi et al. 140826-02</td>
<td>MW478156</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Khasansky, Schultz</td>
<td>H.J.Choi et al. 150819-01</td>
<td>MW478153</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Khasansky, Schultz</td>
<td>H.J.Choi et al. 150819-02</td>
<td>MW478152</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Sukhanovka</td>
<td>H.J.Choi et al. 150817-01</td>
<td>MW478155</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Sukhanovka</td>
<td>H.J.Choi et al. 150817-02</td>
<td>MW478154</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Khasansky</td>
<td>2015RUSV017-01-01</td>
<td>MW478164</td>
</tr>
<tr>
<td></td>
<td>Russia: Primorskiy kray, Khasansky</td>
<td>2015RUSV017-02-01</td>
<td>MW478163</td>
</tr>
<tr>
<td><em>A. spuriom</em></td>
<td>South Korea: Gangwon, Goseong</td>
<td>H.J.Choi 191010-01</td>
<td>MW478159</td>
</tr>
<tr>
<td><em>A. thunbergii</em></td>
<td>South Korea: Gangwon, Goseong</td>
<td>H.J.Choi 191010-02</td>
<td>MW478158</td>
</tr>
<tr>
<td><em>A. tuberosum</em></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>H.J.Choi 190919-001-01</td>
<td>MW478162</td>
</tr>
<tr>
<td><em>A. tuberum</em></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>H.J.Choi 190919-001-02</td>
<td>MW478161</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>NAPI-10-139-01</td>
<td>MW478151</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>NAPI-10-139-02</td>
<td>MW478150</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>NAPI-10-139-03</td>
<td>MW478149</td>
</tr>
<tr>
<td></td>
<td>South Korea: Gangwon, Gangneung</td>
<td>H.J.Choi 190919-002</td>
<td>MW478160</td>
</tr>
<tr>
<td><em>A. spirale</em></td>
<td>South Korea: Gyeongbuk, Bonghwa, Cheongnyangsan</td>
<td>H.J.Choi 200831-01</td>
<td>MW478144</td>
</tr>
<tr>
<td><em>A. thunbergii</em></td>
<td>South Korea: Gyeongbuk, Bonghwa, Cheongnyangsan</td>
<td>H.J.Choi 200831-02</td>
<td>MW478143</td>
</tr>
<tr>
<td><em>A. tuberosum</em></td>
<td>China: Jilin, Erdaobaihe</td>
<td>H.J.Choi 190908-001-01</td>
<td>MW478146</td>
</tr>
<tr>
<td><em>A. tuberum</em></td>
<td>China: Jilin, Erdaobaihe</td>
<td>H.J.Choi 190908-001-02</td>
<td>MW478145</td>
</tr>
<tr>
<td><em>A. tuberum</em></td>
<td>China: Jilin, Linjiang</td>
<td>H.J.Choi 190908-002-01</td>
<td>MW478141</td>
</tr>
<tr>
<td><em>A. tuberum</em></td>
<td>China: Jilin, Erdaobaihe</td>
<td>H.J.Choi 190908-002-02</td>
<td>MW478140</td>
</tr>
</tbody>
</table>
Table 3. Comparison of major characters of *Allium* section *Rhizirideum* in South Korea and northeast China.

<table>
<thead>
<tr>
<th>Character</th>
<th>A. dumebuchum</th>
<th>A. spirale</th>
<th>A. spurium</th>
<th>A. minus</th>
<th>A. senescens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhizome</td>
<td>oblique to horizontal</td>
<td>horizontal</td>
<td>horizontal</td>
<td>oblique</td>
<td>horizontal</td>
</tr>
<tr>
<td>Leaf sheath</td>
<td>fleshy, glaucous</td>
<td>leathery, lustros</td>
<td>leathery, lustros</td>
<td>fleshy, glaucous</td>
<td>fleshy, glaucous</td>
</tr>
<tr>
<td>Leaf blade</td>
<td>19.5–38.0</td>
<td>20.0–45.0</td>
<td>15–30.0</td>
<td>11.4–24.5</td>
<td>23.0–45.0</td>
</tr>
<tr>
<td>width (mm)</td>
<td>3.8–13.0</td>
<td>4.0–10.0</td>
<td>1.5–4.0</td>
<td>2.8–4.5</td>
<td>5.0–15.0</td>
</tr>
<tr>
<td>Scape</td>
<td>rhomboid</td>
<td>rhomboid to subterete</td>
<td>rhomboid to subterete</td>
<td>subterete</td>
<td>subterete</td>
</tr>
<tr>
<td>length (cm)</td>
<td>23.4–49.0</td>
<td>33.0–65.0</td>
<td>10.0–40.0</td>
<td>11.7–20.5</td>
<td>25.8–70.0</td>
</tr>
<tr>
<td>diameter (mm)</td>
<td>2.5–5.6</td>
<td>4.0–5.1</td>
<td>1.5–2.5</td>
<td>1.5–1.6</td>
<td>3.0–5.5</td>
</tr>
<tr>
<td>Pedicel length</td>
<td>9.8–11.2</td>
<td>6.0–12.4</td>
<td>7.6–11.1</td>
<td>8.7–11.1</td>
<td>8.0–13.0</td>
</tr>
<tr>
<td>Perianth shape</td>
<td>semi-radially spreading</td>
<td>campanulate</td>
<td>campanulate</td>
<td>radially spreading</td>
<td>radially spreading</td>
</tr>
<tr>
<td>Perianth color</td>
<td>light purple</td>
<td>redish purple</td>
<td>strong purple or pale purple</td>
<td>pale purple</td>
<td></td>
</tr>
<tr>
<td>Inner tepal</td>
<td>elliptical to ovately-elliptical</td>
<td>ovately-elliptical</td>
<td>ovately-elliptical</td>
<td>elliptical</td>
<td>elliptical</td>
</tr>
<tr>
<td>length (mm)</td>
<td>5.2–7.2</td>
<td>4.0–6.8</td>
<td>3.9–6.3</td>
<td>4.0–4.8</td>
<td>4.3–6.4</td>
</tr>
<tr>
<td>width (mm)</td>
<td>3.4–4.5</td>
<td>2.0–4.2</td>
<td>2.2–3.4</td>
<td>1.2–1.9</td>
<td>1.8–2.9</td>
</tr>
<tr>
<td>Outer tepal</td>
<td>ovately-elliptical</td>
<td>ovately-elliptical</td>
<td>ovately-elliptical</td>
<td>ovate-oblong</td>
<td>ovate-elliptical</td>
</tr>
<tr>
<td>length (mm)</td>
<td>4.8–6.1</td>
<td>3.1–5.0</td>
<td>2.9–5.2</td>
<td>3.7–4.6</td>
<td>3.1–5.2</td>
</tr>
<tr>
<td>width (mm)</td>
<td>2.1–3.7</td>
<td>1.3–3.0</td>
<td>1.1–2.3</td>
<td>1.1–1.7</td>
<td>1.1–2.5</td>
</tr>
<tr>
<td>Filament exertion</td>
<td>exerted</td>
<td>exerted</td>
<td>exerted</td>
<td>non-exserted</td>
<td>exerted</td>
</tr>
<tr>
<td>length (mm)</td>
<td>6.2–8.4</td>
<td>5.3–8.8</td>
<td>5.0–7.0</td>
<td>3.2–4.4</td>
<td>4.6–6.9</td>
</tr>
<tr>
<td>Inner filament</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
<td>entire or 2-toothed</td>
</tr>
<tr>
<td>margin shape</td>
<td>narrowly triangular</td>
<td>entire subulate</td>
<td>entire subulate</td>
<td>broadened for ca. 1/2 in length</td>
<td></td>
</tr>
<tr>
<td>length (mm)</td>
<td>2.2–2.5</td>
<td>1.7–2.2</td>
<td>1.7–2.0</td>
<td>1.3–1.4</td>
<td>1.5–2.0</td>
</tr>
<tr>
<td>width (mm)</td>
<td>0.9–1.1</td>
<td>0.7–1.0</td>
<td>0.6–0.8</td>
<td>0.6–0.8</td>
<td>0.7–0.9</td>
</tr>
<tr>
<td>Ovary length</td>
<td>3.2–3.8</td>
<td>2.0–3.4</td>
<td>1.8–2.8</td>
<td>2.1–2.4</td>
<td>2.4–3.1</td>
</tr>
<tr>
<td>width (mm)</td>
<td>3.2–3.7</td>
<td>1.8–3.1</td>
<td>1.5–2.7</td>
<td>1.8–2.0</td>
<td>2.6–2.8</td>
</tr>
<tr>
<td>Capsule length</td>
<td>5.4–5.6</td>
<td>5.0–5.3</td>
<td>4.8–5.1</td>
<td>3.5–3.7</td>
<td>4.5–5.5</td>
</tr>
<tr>
<td>width (mm)</td>
<td>5.6–5.8</td>
<td>4.5–5.0</td>
<td>4.5–5.0</td>
<td>3.6–4.0</td>
<td>4.5–5.6</td>
</tr>
<tr>
<td>Seed length</td>
<td>3.7–3.8</td>
<td>3.0–3.3</td>
<td>2.8–3.2</td>
<td>2.0–2.2</td>
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<td>width (mm)</td>
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<td>Chromosome number (2n)</td>
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<td>2n = 16, 32</td>
<td>2n = 16, 32</td>
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</table>

Results

Morphological characters

Our data indicate that several morphological characters are of taxonomic utility in *Allium* section *Rhizirideum*. Among these, the shape and size of leaf, scape and various floral parts are useful diagnostic traits at the specific level (Table 3; Fig. 1; Choi and Oh 2010; Choi and Oh 2011). According to the PCA results, first combined five principal components accounted for 83.65% of the total variation among traits in the studied taxa. The PC1 accounted for 52.94% of variance, while PC2 accounted for 15.54% of total variability. The first two principal components were strongly associated with the inflorescence length, outer tepal length and inner filament width. The anther length and inner tepal width were mostly contributed to PC1, while the pedicel length and
flower number were contributed only to PC2. PC1 versus PC2 in scatter plot showed that *A. dumebuchum* and *A. minus* were distinctly separated from *A. senescens*, *A. spirale*, and *A. spurium* (Fig. 2).

**Somatic chromosome numbers**

The somatic chromosome numbers of *Allium* species investigated were counted as diploid (\(2n = 2x = 16\); Fig. 3C, D) or tetraploid (\(2n = 4x = 32\); Fig. 3A, B, E, F). Among studied species, *A. spirale* and *A. spurium* showed polyploidy (Table 3).

**Phylogenetic relationships**

Total combined dataset of four chloroplast regions was comprised of 93 samples, including 58 from chloroplast genome. The aligned dataset was 6,046 bp long (4,086 bp in newly sequenced samples) with 556 parsimony-informative site and 4,881 constant site. The dataset consists of *ndhJ-trnF*, *trnH-psbA*, *psbD-trnT*, and *psbJ-petA* with 923 bp, 609 bp, 1,121 bp, and 1,095 bp, respectively.

Our phylogenetic tree revealed a similar topology, not showing distinct monophyly, to the previous study (Li et al. 2010; Hauenschild et al. 2017). Nevertheless, subgen. *Rhizirideum* is monophyletic, despite subgen. *Cepa* and *Allium* being polyphyletic (Fig. 6). Section *Rhizirideum* especially constructed a clade supported high bootstrap value (Fig. 6). *Allium* species in section *Rhizirideum*, excluding *A. dumebuchum*, dispersed to several clades, showing a confusing phylogenetic relationship. Especially, *A. dumebuchum* revealed monophyly in the tree with high support value and specific morphological characters (Figs 1, 2 and 4), even though it does not show a distinct phylogenetic relationship among the species in section *Rhizirideum*.

**Taxonomic treatment**

**Key to the species of Allium section Rhizirideum in South Korea and northeastern China**

1a Leaf sheaths buried under ground; leaf blades leathery, lustrous; perianths campanulate; inner tepals ovate-elliptical; inner filaments entire at margin ..................2

1b Leaf sheaths exposed above ground; leaf blades fleshy, glaucous; perianths radially spreading; inner tepals elliptical; inner filaments entire or toothed at margin .... 3

2a Leaf blades 4–10 mm wide; scapes clearly flattened-winged in cross-section ....

.............................................................................................................2

2b Leaf blades 1.5–4 mm wide; scapes rhomboid in cross-section .........3

3a Leaf blades 2.8–4.5 mm wide; scapes subterete in cross-section, 11.7–20.5 mm long; inner tepals 4.0–4.8 mm long, 1.2–1.9 mm wide; outer tepals 3.7–4.6 mm long, 1.1–1.7 mm wide; filaments non-exserted, 3.2–4.4 mm long; capsules
3.5–3.7 mm long, 3.6–4 mm wide; seeds 2.0–2.2 mm long, 1.3–1.5 mm wide; flowering from May to July \((2n = 2x = 16)\)...\textit{A. minus}

3b Leaf blades 3.8–15 mm wide; scapes subterete to rhomboid in cross-section, 23.4–70 mm long; inner tepals 4.3–7.2 mm long, 1.8–4.5 mm wide; outer tepals 3.1–6.1 mm long, 1.1–3.7 mm wide; filaments exserted, 4.6–8.4 mm long; capsules 4.5–5.6 mm long, 4.5–5.8 mm wide; seeds 3.0–3.8 mm long, 2.2–2.6 mm wide; flowering from July to October \((2n = 4x = 32)\)...\textit{A. dumebuchum}

4a Scapes rhomboid in cross-section; perianths light purple; inner filaments narrowly triangular, entire at margin; inner tepals 3.4–4.5 mm wide; ovaries 3.2–3.7 mm wide; flowering from late September to October...\textit{A. senescens}

4b Scapes subterete in cross-section; perianths pale purple; inner filaments broadened for ca. 1/2 in length, entire or 2-toothed at margin; inner tepals 1.8–2.9 mm wide; ovaries 2.6–2.8 mm wide; flowering from July to August...\textit{A. senescens}

\textit{Allium dumebuchum} H.J.Choi, sp. nov.

urn:lsid:ipni.org:names:77216563-1

Figs 1A–E, 4

\textbf{Diagnosis.} This new species is morphologically similar to \textit{A. senescens} due to its habits. However, it is clearly distinguished from \textit{A. senescens}, particularly by its rhomboid scapes in cross-section (vs. subterete), light purple perianth color (vs. pale purple), entire and narrowly triangular inner filaments (vs. sometimes toothed and broadened for ca. 1/2 in length), and flowering season from late September (vs. from July).

\textbf{Type.} SOUTH KOREA. Gyeongbuk: Ulleung-gun, Namyang, 37.46702N 130.83665E, elev. 11m, 8 Oct 2020 [fl], H.J.Choi 201008-001* (Holotype: KH; Isotypes: CWNU, KB, KIOM).

\textbf{Description.} Herbs hermaphroditic. Rhizomes clearly elongated, thick and branched, oblique to horizontal, 14.8–55.4 mm long. Bulbs clustered, cylindrically conical, 9.6–15 mm in diam.; tunics membranous, smooth, white. Leaves 4–9; sheaths slightly exposed above ground, 4–7.8 cm long; blades ascending, slightly tortuous, linear, flat and solid in cross-section, flesh, 19.5–38 cm × 3.8–13 mm, apex obtuse to rounded. Scapes rhomboid and solid in cross-section, drooping before flowering, 23.4–49 cm × 2.5–5.6 mm. Inflorescences umbellate, subglobose, 23–41.5 × 37–53 mm, 48–113 flowered; pedicels terete, subequal in length, 9.8–11.2 mm long; bracts 3.2–5 mm long. Flowers bisexual; perianth semi-radially spreading, light purple; inner tepals longer than outer ones, elliptical, apex obtuse, 5.2–7.2 × 3.4–4.5 mm; outer tepals ovately elliptical, apex obtuse, 4.8–6.1 × 2.1–3.7 mm; filaments exserted, 6.2–8.4 mm long, margin entire; inner filaments narrowly triangular; anthers elliptical, reddish, 2.2–2.5 × 0.9–1.1 mm long; ovary obovoid, reddish, 3.2–3.8 × 3.2–3.7 mm, ovules 2 per locule; style terete, exserted; stigma smooth. Capsules cordiform, trigonous, 5.4–5.6 × 5.6–5.8 mm. Seeds oval, semi-circular in cross-section, 3.7–3.8 × 2.4–2.6 mm.

\textbf{Phenology.} Flowering from late September to October; fruiting from late October to November.
**Figure 1.** Comparative photographs of the inflorescence, cross-section of leaf and scape, flower, and tepal and filament arrangement of *Allium section Rhizirideum* in South Korea and northeastern China. 

- A–E *A. dumebuchum* (H.J.Choi 201008-001) 
- F–J *A. spirale* (H.J.Choi 191010-01) 
- K–O *A. spurium* (H.J.Choi 200831-01) 
- P–T *A. minus* (H.J.Choi 080063) 

**Distribution and habitat.** Endemic to South Korea (Ulleung-do Island; Fig. 5). Open slope of rocky area.

**Etymology.** The specific epithet, “*dumebuchum*” is based on the name of traditional vegetable for this species in South Korea.
**Vernacular name.** The Korean name of the new species is “Du-me-bu-chu (두메부추”).

**Conservation status.** The new species is endemic to Ulleungdo Island, and usually grows along the coast at altitudes of -23–171 m a.s.l. From the present study, the extent of occurrence (EOO) and the area of occupancy (AOO) of this species have been calculated to be 47,683 km² and 48 km², respectively. Currently, there is no information on population size and trend data. However, this new species is only known from a single location of Ulleungdo Island, and mainly occurs on the coast which is critically threatened by extensive construction and repair of coastal roads (Choi et al. 2012a). Therefore, decline in habitat area, habitat extent, and quality of habitat for this species have been continuously observed. Thus, *Allium dumebuchum* should be considered as Critically Endangered [CR B1ab(iii)] according to the IUCN Red List categories and criteria (IUCN 2021).

**Notes.** *Allium dumebuchum*, occurring in Ulleungdo Island of South Korea, has usually been misidentified as *A. senescens* (Choi and Oh 2010; Choi and Oh 2011). However, this new species remarkably distinguished itself from its related species of section *Rhizirideum* (e.g., *A. spirale*, *A. spurium*, *A. minus*, and *A. senescens*) in having clearly bigger floral parts that bloom from late September (Table 3; Fig. 1). The PCA results based on quantitative floral characters of five related species in section *Rhizirideum* clearly identified *A. dumebuchum* from others (Fig. 2). This new species is a tetraploid (2n = 4x = 32) taxon along with *A. senescens*, and *A. minus* is a diploid (2n = 2x = 16), whereas *A. spirale* and *A. spurium* showed polyploidy (Table 3; Fig. 3). Moreover, molecular phylogenetic analyses using chloroplast markers (*ndhJ-trnF, trnH-psbA, psbD-trnT*, and *psbJ-petA*) also clearly indicate that *A. dumebuchum* is genetically distinct from other species of section *Rhizirideum* (Fig. 6).

Allium section Rhizirideum in South Korea and northeastern China

Figure 2. Principal components analysis plot of five Allium species of section Rhizirideum in South Korea and northeastern China. dum = A. dumebuchum; min = A. minus; sen = A. senescens; spi = A. spirale; spu = A. spurium.

Allium spirale Willd., Enum. Pl. Suppl. 17 (1814)
Fig. 1F–J

Type. Russia (Far East), specimen without collection date and number (Holotype: B photo!).

Notes. Allium spirale is occasionally confused with A. senescens because of its more or less similar growth habit (Choi and Oh 2011), but the most distinctive characters include clearly flattened-winged scapes (Fig. 1H), campanulate perianth (Fig. 1I) and ovate tepals (Fig. 1J).

Figure 3. Mitotic metaphase chromosomes and their voucher plants of *Allium* species A *A. dumebuchum* (H.J.Choi 190917-01) B *A. spirale* (H.J.Choi 191010-01) C *A. spirale* (H.J.Choi 190910) D *A. spurium* (H.J.Choi 080390) E *A. spurium* (H.J.Choi s.n.) F *A. senescens* (H.J.Choi 080119, voucher plant: Fig. 2 of Choi and Oh 2010).


Type. Russia (Siberia, location in doubt). Type specimen not designated (protologue).

Notes. Allium spurium is occasionally confused with Allium spirale because of its more or less similar growth habit, but the most distinctive characters include narrower leaf blades and scapes and smaller floral parts (Table 3; Fig. 1L–N). This species is newly recorded for South Korea, and the new vernacular name ‘Gak-si-du-me-bu-chu’ is given. Besides, Cheongnyangsansan of South Korea is the disjunct southernmost limit for geographical distribution of Allium spurium (Fig. 5).


Fig. 1P–T


Type. South Korea. Gangwon: Inje, Wolhaksam-ri, 26 May 1979, B.S.Gil s.n. (Neotype: KH); Oh et al. 2018.

Notes. This species was originally published as a variety of Allium senescens, A. senescens var. minus ‘minor’. However, this Korean endemic taxon has been revealed as
a biologically distinct species. It is remarkably well distinguished from its relatives of the section *Rhiziridum* by having much narrower and shorter leaf blades and scapes, smaller floral organs, non-exerted filaments and earlier flowering season from May to late July (Table 3; Fig. 1; Choi and Oh 2010; Choi and Oh 2011). Considering these
major differences, Choi and Oh (2010) proposed the rank of species for this taxon as more appropriate than that of variety. Although it is cultivated as a vegetable in South Korea, its natural populations are only known from the type locality so far (Fig. 5). However, this species proved to have been extinct in the natural habitat in this study.

Fig. 1U–Y


**Type.** Russia. From Siberia (foreshaical region), *LINN 419.25* (Lectotype: LINN photo!).

**Notes.** *Allium sensescens*, originally described from the Baikal area of Russia, is certainly one of the most popular ornamental *Allium* species of the world, and is naturally distributed in southern Russia, Mongolia and north-eastern China (Sinitsyna et al. 2016; Sinitsyna and Friesen 2018). The existing records of this species in South Korea (Choi and Oh 2010; Choi and Oh 2011) are all the result of misidentification of herbarium materials, the identity of which we have verified to be *A. dumebuchum*. *Allium pseudosenescens* is newly proposed as an additional synonym of *A. sensescens* in this study.


**Acknowledgements**

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**References**


Allium section Rhizirideum in South Korea and northeastern China


Chrysosplenium sangzhiense (Saxifragaceae), a new species from Hunan, China

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Abstract

Chrysosplenium sangzhiense Hong Liu, a new species from Hunan, China, is described and illustrated. The phylogenetic analysis revealed that the new species belongs to subgen. Chrysosplenium and is closely related to C. grayanum, C. nepalense and C. sinicum. The chromosome number of the new species is 2n = 46, indicating a novel basic number x = 23 in Chrysosplenium that is different from other species. This also suggests that C. sangzhiense is probably an allopolyploid derivative of a species with x = 11 and one with x = 12. Morphologically, C. sangzhiense can be easily distinguished from C. grayanum, C. nepalense, C. sinicum and C. cavaleriei, a species not included in our phylogenetic analysis by a suite of characters relating to the sterile shoots, basal leaves, cauline leaves, flowering stem, sepals, disc, capsule and seed. A global conservation assessment is performed, and classifies C. sangzhiense as Least Concern (LC).

Keywords

Chrysosplenium, cytology, phylogeny, Saxifragaceae, subgen, taxonomy

Introduction

Chrysosplenium L. (1753) is a perennial herbaceous genus in Saxifragaceae and comprises more than 70 species (Kim et al. 2019; Fu et al. 2020). Chrysosplenium is distributed in Asia, America and Europe (Pan and Ohba 2001; Soltis 2007).

* These authors contributed equally to this work as first authors.

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The latest revision of Chinese *Chrysosplenium* included 35 species (Pan and Ohba 2001). Although no particular infra-generic classification was adopted in this revision, use of leaf arrangement as the primary character in the key to species reflected the recognition of two subgenera in previous taxonomic revisions (Pan 1986a, b). In addition, seed surface has been used as an important character to delimit sections (Pan 1986a, b). Soltis et al. (2001) showed that the two subgenera are both monophyletic and sister to each other using matK sequence data, thereby confirming that leaf arrangement is a phylogenetically informative morphological character. Subsequent taxonomic research on Chinese *Chrysosplenium* has been undertaken by Liu et al. (2016), Kim et al. (2019) and Fu et al. (2020), bringing the total diversity of the Chinese flora to 38 species, of which 23 (60%) are endemic.

Previous studies have demonstrated that *Chrysosplenium* has a diverse basic chromosome number with x = 7, 8, 9, 10, 11, 12 and 13 at species level indicating cytological data provides important evidence for the delimitation and evolution of *Chrysosplenium* (Hara and Kurosawa 1963; Funamoto and Tanaka 1988a, b, 1989; Funamoto et al. 1997, 1999, 2000, 2004; Funamoto and Zhou 2010).

As part of ongoing research into the diversity of Chinese *Chrysosplenium*, the authors undertook an extensive fieldtrip in Hunan, China. During the trip an unknown species of *Chrysosplenium* was collected. Following a thorough literature survey (Hara 1957; Pan 1992; Pan and Ohba 2001; Liu et al. 2016; Kim et al. 2019; Fu et al. 2020) along with the molecular and cytological evidence, we confirmed that it is a distinct and undescribed species.

**Materials and methods**

**Morphology observations and conservation assessments**

All morphological characters were studied based on the material from field and herbarium specimens using a dissecting microscope (SMZ171, Motic, China). For seed morphology, we also undertook scanning electron micrograph (SEM) observation; seeds were collected from the field and dried by silica gel. The pre-treatment including impurities removing, air-drying and gold-coating was performed, following Fu et al. (2020). Observations and photographs were taken under a Hitachi SU8010 scanning electron microscope. At least 15 seeds were used to determine the size and surface. Conservation assessment was undertaken following IUCN (2019).

**Genomic DNA extraction, PCR amplification, and Sequencing**

To confirm the systematic position of this unknown species, we conducted phylogenetic studies using matK sequence data. We chose this DNA region due to its highest species coverage within the genus (Soltis et al. 2001; De Vere 2012;
Saarela et al. 2013; Ebersbach et al. 2017; Kim et al. 2018) so that we could trace
the most closely related species. Forty-eight species of *Chrysosplenium* as in-group
and three species of *Saxifraga* and *Itea* as out-group were sampled. Of these, 15
sequences were obtained from the Genbank (https://www.ncbi.nlm.nih.gov/), while
36 sequences were newly generated. Their species names and GenBank accession
numbers are listed in Table 1. DNA extraction, PCR amplification, and sequencing
were performed following Soltis et al. (2001).

**Phylogenetic analysis**

We performed phylogenetic analyses of *Chrysosplenium* based on *matK* sequence data-
set using Bayesian inference (BI) and maximum likelihood (ML). For BI analysis, we
employed MrBayes v.3.2.6 (Ronquist et al. 2012) to obtain a maximum clade cred-
ibility (MCC) tree. The matrix of *matK* sequence was aligned by MAFFT. Bayesian
inference was performed using one million generations, four runs, four chains, a tem-
perature of 0.001, 25% trees discarded as burn-in, and trees sampled every 1,000
generations (1,000 trees sampled in total) with GTR+F+G4 model.

We conducted the ML analysis using IQ-TREE v 2.0.6 (Nguyen et al. 2015) with
1,000 bootstrap replicates, and default ModelFinder (Kalyaanamoorthy et al. 2017) to
find TVM+F+R3 as the best-fit substitution model. Tree visualization was achieved in
FigTree v1.4.3 (http://tree.bio.ed.ac.uk/software/figtree/).

**Chromosome preparations**

Living plants of the new species were cultivated in the greenhouse of South-Central
University for Nationalities. Actively growing root tips were harvested after 1–2 weeks.
Cytological examination was performed following Funamoto and Zhou (2010). The
best metaphase plates were photographed using an imager microscope with a camera
attachment. At least 3–5 cells from 3–5 root tips of five individuals of the new species
at somatic metaphase were counted to determine the chromosome numbers.

**Results**

**Molecular phylogenetic studies**

The aligned matrix of *matK* sequence was 1,644 characters. Of the 154 variable
characters, 90 (58.44%) were parsimony-informative, including indels. BI and ML
analyses resulted in the same tree topology which showed the undescribed species as
belonging to a strongly supported clade (BP = 89%, PP = 1) that included *Chrys-
osplenium grayanum* Maxim. (1877), *C. nepalense* D.Don (1825) and *C. sinicum*
Maxim. (1877) (Fig. 1).
Table 1. Species names and GenBank accession numbers of *matK* DNA sequences used in this study (*newly generated sequences*).

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<td>Chrysosplenium uniflorum Maxim.</td>
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<td>HSN7380</td>
<td>HSN</td>
<td>MW403029*</td>
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<tr>
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<td>HSN13356</td>
<td>HSN</td>
<td>MW403030*</td>
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<td>Chrysosplenium sangzhiense Hong Liu sp. nov.</td>
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<td>HSN</td>
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<tr>
<td>Chrysosplenium maximowiczii Franch. et Sav.</td>
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<td>–</td>
<td>–</td>
<td>AB003053</td>
</tr>
<tr>
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<td>–</td>
<td>AB003054</td>
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<tr>
<td>Chrysosplenium rosendahlii Packer</td>
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<td>Brysting_01-065_CAN</td>
<td>CAN</td>
<td>KC474470</td>
</tr>
<tr>
<td>Chrysosplenium tetrandrum (N. Lund) Th. Fries</td>
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<td>Bennett_O8-125_CAN</td>
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<tr>
<td>Chrysosplenium americanum Schwein. ex Hook.</td>
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<td>Chrysosplenium maximowiczii Franch. et Sav.</td>
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<td>Chrysosplenium rosendahlii Packer</td>
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<td>Chrysosplenium rosendahlii Packer</td>
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<td>–</td>
<td>–</td>
<td>KC474470</td>
</tr>
</tbody>
</table>
A new species of *Chrysosplenium* from Hunan

**Chromosome characteristics**

The chromosome number of *Chrysosplenium sangzhiense* was observed to be $2n = 46$ (Fig. 2). The chromosome size fell into the range $0.93–2.43 \mu m$, suggesting slight size variation. A detailed karyotype analysis was not possible because the chromosomes are small, and the position of centromere could not be determined.

*Figure 1.* Phylogenetic tree of *Chrysosplenium* generated from maximum likelihood (ML) of matK dataset. Numbers on the branches indicate bootstrap values ($\geq 50\%$) of the ML and the posterior probability ($\geq 0.5$) of Bayesian inference analyses.
Taxonomic treatment

*Chrysosplenium sangzhiense* Hong Liu, sp. nov.
urn:lsid:ipni.org:names:77216564-1
Figs 3–5

**Remarks.** Similar to *Chrysosplenium grayanum*, *C. nepalense*, *C. sinicum* and *C. cavaleriei* (Table 2). *C. sangzhiense* differs from *C. grayanum* in its usually fewer cauline leaves, a square flowering stem and red-brown seeds; from *C. nepalense* it differs in its usually fewer cauline leaves, a square flowering stem and conspicuously unequal capsule lobes; from *C. sinicum* it differs in producing sterile shoots from all leaf axils, an absence of basal leaves, larger cauline leaves, and red-brown seeds; and from *C. cavaleriei* it differs in its erect sepals and absent disc.

**Type.** China. Hunan: Badagongshan National Nature Reserve, Sangzhi County, 29°47’10”N, 110°5’33”E, under broadleaved forests and near the stream in a mountain area at ca 1,220 m altitude, 22 April 2017, *Hong Liu* HSN07449 (holotype HSN; isotypes HSN, IBK).

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>C. sangzhiense</em></th>
<th><em>C. cavaleriei</em></th>
<th><em>C. grayanum</em></th>
<th><em>C. nepalense</em></th>
<th><em>C. sinicum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile branch</td>
<td>from all leaf axils</td>
<td>from near stem base</td>
<td>from all leaf axils</td>
<td>from all leaf axils</td>
<td>only from basal leaf axils</td>
</tr>
<tr>
<td>Basal leaves</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>present</td>
</tr>
<tr>
<td>Cauline leaves</td>
<td>2–3 pairs, 10–30 × 10–25 mm</td>
<td>1–3 pairs, 9–13 × 10–14 mm</td>
<td>2–7 pairs, 4–17 × 4–17 mm</td>
<td>3–5 pairs, 3–18 × 5–18 mm</td>
<td>1–2 pairs, 6–10.5 × 7.5–11.5 mm</td>
</tr>
<tr>
<td>Flowering stem (upper part)</td>
<td>square</td>
<td>unknown</td>
<td>rounded</td>
<td>rounded</td>
<td>square</td>
</tr>
<tr>
<td>Sepals</td>
<td>erect</td>
<td>spreading</td>
<td>erect</td>
<td>erect</td>
<td>erect</td>
</tr>
<tr>
<td>Disc</td>
<td>absent</td>
<td>distinct</td>
<td>somewhat inconspicuous</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>Capsule lobe</td>
<td>lobes conspicuous unequal</td>
<td>lobes conspicuous unequal</td>
<td>lobes conspicuous unequal</td>
<td>lobes subequal</td>
<td>lobes conspicuous unequal</td>
</tr>
<tr>
<td>Seed</td>
<td>red brown, papillose</td>
<td>dark brown, papillose</td>
<td>dark brown, papillose</td>
<td>red brown, smooth</td>
<td>dark brown, papillose</td>
</tr>
</tbody>
</table>

Figure 2. Somatic chromosomes at metaphase of *C. sangzhiense* Hong Liu, sp. nov. from three different individuals. Scale bar: 10 μm.
A new species of *Chrysosplenium* from Hunan

**Description.** Perennial herbs, 10–25 cm tall. *Root* fibrous and robust. *Rhizome* long creeping without stolons or bulbs. *Basal leaves* absent. *Sterile shoots* well developed, arising from all leaf axils, round in cross-section, 5–15 cm long at anthesis, later elongate and decumbent, up to 50 cm long, rooting at nodes, without forming

---

**Figure 3.** Illustration of *Chrysosplenium sangezhiense* Hong Liu, sp. nov. **A** habit in flowering phase **B** non-flowering stem **C** inflorescence with flowers **D** flower **E** capsule **F** seeds.
a rosette. Leaves of sterile shoots opposite, isophyllous, always ca 8 at anthesis, dark purple, petiole 6–10 mm long, blade 10–30 × 10–25 mm, rounded, glabrous, apex obtuse, margin obtusely dentate (10–16 teeth), base broadly cuneate; post-anthesis 10–30 or more, green, petiole 6–10 mm long, blade 20–35 × 15–20 mm, rounded or ovate, glabrous, apex obtuse, margin obtusely dentate (12–20 teeth), base broadly cuneate. Cauline leaves 4–6 (2–3 pairs), opposite, petiole 6–10 mm long; blade 6–13 × 5–12 mm, rounded or broadly ovate, glabrous, apex obtuse, margin obtusely dentate (10–14 teeth), base broadly cuneate. Flowering stem(s) erect, branched, 10–23 cm tall, glabrous, purple, square in cross-section. Inflorescence 8–25-flowered cyme, dense, 1.4–9 cm long, 5–10 cm in diam.; bracteal leaves yellow-green, triangular arrangement and unequal, the middle one larger, petiole 2–8 mm long, blade 4–15 × 7–10 mm, subrounded, glabrous, apex obtuse, margin obtusely dentate (6–12 teeth), base broadly cuneate; Flowers tetramerous, actinomorphic; sepals 4 (2 pairs), erect, yellow in flowering phase but turn green in fruiting time, 2–3 × 2–3 mm, broadly ovate, apex obtuse; disk absent; stamens 8, homostyllic, 1–2 mm long, shorter than
A new species of *Chrysosplenium* from Hunan

**sepals; filaments slender, ca 1 mm long; anther yellow, 2-locular, longitudinally dehiscent; ovary 2-locular, semi-inferior; stigma 2; styles erect, ca 1–2 mm long.** Fruit a capsule, 5–7 mm long, green, smooth, 2-lobed (horn-shaped), conspicuous unequal, dehiscent along the adaxial suture; seeds numerous, reddish brown, sub-ovoid, a raphe on one side, 650–800 × 600–750 μm, papilllose.

**Etymology.** *Chrysosplenium sangzhiense* is named after the type locality, Sangzhi County, Hunan Province, China.

**Vernacular name.** sāng zhí jīn yāo (Chinese pronunciation); 桑植金腰 (Chinese name).

**Conservation status.** At present, *Chrysosplenium sangzhiense* is only known from a single locality (IUCN criterion D2). At this locality, the population is ca 500 mature individuals (IUCN criterion D1) growing in at least ten patches within a nature reserve. Using the IUCN methodology, *C. sangzhiense* would be classed as Vulnerable (VU), however no plausible threat could be found to confirm its status as the population is located within a protected area and not under threat in the near future. In addition, considering that the surrounding area has not been completely explored, there may be hitherto undocumented additional populations. For these reasons the Global Species Conservation Assessment for *C. sangzhiense* is Least Concern (LC).
Discussion

Our phylogenetic analysis is consistent with previous studies (Soltis et al. 2001) that *Chrysosplenium* is monophyletic and comprises two strongly supported clades namely subgen. *Gamosplenium* (with alternate leaves) and subgen. *Chrysosplenium* (with opposite leaves). *C. sangzhiense* is recovered as a member of subgen. *Chrysosplenium* and falls into a strongly supported clade that includes *C. grayanum*, *C. nepalense* and *C. sinicum*. In addition, *C. cavaleriei* H.Lév. & Vaniot (1911) is also a morphologically similar species despite that it is not included in our phylogenetic analysis. All five species are close morphologically (Table 2), but nevertheless distinguishable. *C. grayanum* is likely the most closely related species despite the fact that it is endemic to Japan, while *C. nepalense*, *C. sinicum* and *C. cavaleriei* are widespread in China.

The basic chromosome number of Japanese *Chrysosplenium* species is $x = 11$ or $x = 12$, but in China there is more diversity with $x = 7, 8, 9, 10, 12$ and $13$ (Hara and Kurosawa 1963; Funamoto and Tanaka 1988a, b, 1989; Funamoto et al. 1997, 1999, 2000, 2004; Funamoto and Zhou 2010). Our cytological studies support this. The chromosome number of *C. sangzhiense* is $2n = 46$ indicating its basic number to be $x = 23$. Given the relationship of reported basic chromosome number of *Chrysosplenium*, it suggests that the new species is probably an allopolyploid derivative of a species with $x = 11$ and one with $x = 12$. Furthermore, this is a novel basic number for the genus, and different from the closely related species such as *C. grayanum* ($x = 11$), *C. sinicum* ($x = 12$) and *C. nepalense* ($x = 12$) (Hara and Kurosawa 1963; Funamoto and Tanaka 1989; Funamoto et al. 1999; Funamoto and Zhou 2010).

Conclusion

In this study, we confirm and describe a new species of *Chrysosplenium* based on morphological, molecular and cytological evidence. The newly generated molecular data contributes to reconstruct a robust phylogenetic framework for further studies on the aspects of biogeography and character evolution of *Chrysosplenium*. In addition, a novel basic chromosome number for *Chrysosplenium* reported here will be useful data to evaluate the evolutionary pattern of chromosome number change and to estimate the basic chromosome number of clades of the genus.

Acknowledgements

This work was supported by the construction plan of Hubei province science and technology basic conditions platform (No.2017BEC014), Fund for key laboratory construction of Hubei province (No.2018BFC360) and the major projects of technological innovation in Hubei province (2019ABA101).
A new species of *Chrysosplenium* from Hunan

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Tigridiopalma exalata, a new and endangered species of Melastomataceae from China

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2 Key Laboratory of Plant Resources Conservation and Sustainable Utilization, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, Guangdong, China
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4 University of Chinese Academy of Sciences, Beijing 100049, China
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Abstract

A new species of the genus Tigridiopalma, formerly considered monotypic, is here described as T. exalata and illustrated based on molecular and morphological evidence. It is morphologically similar to T. magnifica in having a short stem, huge basal leaves, scorpoid cymes, and 5-merous flowers, but differs in having ribbed and pale yellow puberulent petioles, purple petals with a small white apical patch, connectives of longer stamens with a distinct dorsal short spur at their base, and wingless capsules. Due to the restricted distribution, small populations and horticultural potential of this new species, it should be categorized as an Endangered species (EN).

Keywords

Chinese melastomes, Guangdong, monospecific genus, new species, Sonerileae
Introduction

The genus *Tigridiopalma* C.Chen, with its sole species, *Tigridiopalma magnifica* C.Chen, is endemic to China (Chen 1984; Chen and Renner 2007; Lin and Xiong 2007). It is characterized by having a short and stoloniferous stem, huge leaves (up to 70 cm), scorioid cymes, 5-merous flowers, 10 dimorphic and unequal stamens, and an ovary with a 5-lobed membranous crown at apex. The stamen connectives are d-current, slightly spurred or forming a short spur, of which the bases are 2-tuberculate (Chen 1979, 1984; Chen and Renner 2007). *Tigridiopalma* was first placed in the tribe Sonerileae Triana by Chen (1984), and this placement was accepted by subsequent researchers (Renner 1993; Cellinese 1997; Cellinese 1999). Recent phylogenetic studies showed that *Tigridiopalma* belongs to Sonerileae, a major clade in the family although there is still uncertainty regarding the relationships of genera, where it is closely related to *Driessenia* Korth., *Heteroblemma* (Blume) Cámara-Leret, Ridd.-Num. & Veldkamp, *Medinilla* Gaudich., *Phyllagathis* Blume, *Scorpiothyrsus* H.L.Li and *Tashiroea* Matsum. ex T.Itô & Matsum. (Zeng et al. 2016; Zhou et al. 2019a, b).

*Tigridiopalma magnifica* is only found in the Western Guangdong presently (Gaozhou, Xinyi and Yangchun, Fig. 1) (Chen and Renner 2007; Li et al. 2009; Ren et al. 2012). Due to its restricted distribution and small populations, it was categorized as an Endangered species (EN) in the latest version (2013) of the IUCN Red List of China and the Threatened Species List of China’s Higher Plants (Qin et al. 2017).

Here we describe a new species of *Tigridiopalma*, *T. exalata* S.Jin Zeng, Y.C.Xu & D.F.Cui, from Eastern Guangdong, China. It can be easily distinguished from
T. magnifica by having ribbed and pale yellow puberulent petioles (vs. not ribbed and reddish hispid), purple petals with a small white apical patch (vs. dark red petals with a large white apical patch), connectives of longer stamens with a distinct dorsal short spur at the base (vs. indistinct) and wingless (vs. narrowly winged) capsules. We also provide a phylogenetic analysis confirming that the new species belongs to *Tigridiopalma*.

**Materials and methods**

The morphological data collected for the species described here are based on living plants and specimens collected in the field. Voucher specimens were deposited at the herbaria CANT, IBSC, KUN and PE (acronyms according to Index Herbariorum in Thiers 2021).

We collected and sequenced the specimen (S.Jin Zeng 397) and then built a phylogenetic hypothesis with other sequences gathered from Genbank. Total genomic DNA was extracted from fresh material using a modified CTAB procedure (Smith et al. 1991). One nuclear DNA region (internal transcribed spacer, nrITS) and two plastid DNA markers (*ndhF* and *rpl16*) were used in this study following by Zeng et al. (2016).

Amplification and sequencing were performed according to Zeng et al. (2016). The primers used for Polymerase Chain Reactions (PCRs) are listed in Suppl. material 1: Table S1. PCRs were performed in a reaction mix (30 μL) containing total DNA (1 μL), primers (2 μL each), 2× MightyAmp Buffer (Ver.2) (15 μL), MightyAmp DNA polymerase (Takara Bio) (0.5 μL) and H2O (9.5 μL). The PCR program consisted of an initial 3 min pre-melt stage at 98 °C, followed by 38–42 cycles of 20–30 s at 98 °C (denaturation), 30 s at 45–58 °C, and 60–120 s at 68 °C, followed by a final 7 min extension at 68 °C. The PCR products were run on 1.5% agarose gels to check the quality of amplified DNA. Target products were excised from these gels, purified and sequenced by Invitrogen (Shanghai). Both forward and reverse sequences were edited and assembled with DNASTAR (http://www.dnastar.com/). DNA sequences were aligned in MEGA 7 (Kumar et al. 2016) using MUSCLE (Edgar 2004) and manually adjusted to account for obvious errors.

To determine the phylogenetic position of the new species in the Sonerileae clade, 45 species from 22 genera (including 2 species of *Tigridiopalma*) were used for molecular analyses (Suppl. material 1: Table S2). *Dissochaeta vacillans* Blume and *Pseudodissochaeta lanceata* Nayar were selected as outgroup taxa based on Zhou et al. (2019b). Maximum likelihood (ML) analysis was performed by RAxML-HPC2 on XSEDE (Stamatakis 2014) through the CIPRES portal (Miller et al. 2010) using GTRCAT model and 1000 bootstraps.

**Results**

The aligned sequence matrix contained 2694 characters. Summary features of sampled sequences are summarised in Suppl. material 1: Table S3. The phylogenetic analysis indicated that the genus *Tigridiopalma* is recovered sister to *Scorpiothyrsus* plus *Tashiroea*.
clade (BSML 26), and the new species is sister to *Tigridiopalma magnifica* with strong support (BSML 100) (Fig. 2).

A detailed comparison of this new species and *T. magnifica* is shown in Table 1.

![Figure 2. Phylogenetic relationships of Sonerileae based on combined nuclear ITS and two plastid makers (*ndhF*+*rpl16*). The maximum likelihood bootstrap values above 70 are shown at the nodes.](image)

**Table 1.** Morphological comparisons of *Tigridiopalma exalata* and *T. magnifica*.

<table>
<thead>
<tr>
<th>Items/species</th>
<th><em>T. exalata</em></th>
<th><em>T. magnifica</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Petioles</td>
<td>abaxially ribbed, densely pale yellow puberulent trichomes</td>
<td>abaxially not ribbed, densely reddish hispid trichomes</td>
</tr>
<tr>
<td>Leaf blades</td>
<td>abaxially densely pale yellow puberulent trichomes on veins</td>
<td>abaxially densely reddish villous and puberulent trichomes on veins</td>
</tr>
<tr>
<td>Petals</td>
<td>purple with a small white apical patch</td>
<td>dark red with a large white apical patch</td>
</tr>
<tr>
<td>Connectives of longer stamens</td>
<td>basally with a distinct dorsal short spur</td>
<td>basally without a distinct dorsal spur</td>
</tr>
<tr>
<td>Capsules</td>
<td>wingless</td>
<td>narrowly winged</td>
</tr>
</tbody>
</table>

...
Discussion

Zeng et al. (2016) first investigated the phylogenetic position of *Tigridiopalma* by using four makers (nrITS, *ndhF*, *rbcL* and *rpl16*) and found that it was close to *Sonerila* Roxb. and *Tashiroea* with moderate support (BS ML 73). Subsequently, more taxa were added to reconstruct the phylogeny of Sonerileae with two markers (nrITS and *trnV-trnM* spacer), which indicated that *Tigridiopalma* was sister to *Medinilla* with weak support (BS ML 49) (Zhou et al. 2019a). Subsequent phylogenomic analyses of Sonerileae using 171 plastid genomes showed that *Tigridiopalma* is sister to the clade consisting of *Driessenia*, *Heteroblemma*, *Medinilla* and some species of *Phyllagathis* with moderate support (BS ML 71) (Zhou et al. 2019b). Due to the highly structurally conserved plastomes of Melastomataceae (Reginato et al. 2016; Zhou et al. 2019b), more nuclear DNA makers or SNPs are required to resolve the generic relationships of Sonerileae, including the closest relatives of *Tigridiopalma*.

Taxonomic treatment

*Tigridiopalma exalata* S.Jin Zeng, Y.C.Xu & D.F .Cui, sp. nov.
urn:lsid:ipni.org:names:77216565-1
Figs 3, 4

**Type.** CHINA. Guangdong: Huizhou, Longmen, on damp slopes of ravines in broad-leaved forests, 115 m, 13 October 2019, S.Jin Zeng 982 (*holotype*: IBSC!; *isotypes*: CANT!, KUN!, PE!).

**Diagnosis.** The new species *Tigridiopalma exalata* resembles *T. magnifica* in having a short stem, huge basal leaves, scorpioid cymes, and 5-merous flowers, but differs in its ribbed and densely pale yellow puberulent petioles, connectives of longer stamens with a distinct dorsal short spur at their base, and wingless capsules.

**Description.** Perennial herbs, succulent, with raphides in both vegetative and reproductive parts. Stems stoloniferous, 3–5 cm long, internodes indistinct. Leaves in a basal or sub-basal rosette, decussate; petiole somewhat square in cross-section, 6–21 cm long, abaxially ribbed, densely pale yellow puberulent; leaf blade cordate, 16–30(–58) × 16–34(–54) cm, slightly fleshy, base cordate, apex subrounded, margin ciliate and irregular abruptly denticulate, adaxial surface green, glabrous, abaxial surface usually purple, densely pale yellow puberulent on veins; secondary veins 3–4 on each side of the midvein, conspicuous; tertiary veins numerous, parallel, and connecting with secondary veins. Inflorescences terminal, scorpioid cymes, 12–50 flowers; peduncle nearly rounded in cross-section, 13–27 cm long, densely pale yellow puberulent; bracts linear, ca. 0.1 cm, puberulent, caducous. Pedicel nearly rounded in cross-section, 1.2–2.0 cm long, puberulent. Hypanthium funnelform to cup-shaped, 5-sided, wingless, ca. 0.6 × 0.6 cm, puberulent, apex truncate. Calyx lobes triangular-semiorbicular, less than 0.1 cm, puberulent, apex apiculate. Petals purple, broadly obovate, ca. 1.0–1.5
**Figure 3.** *Tigridiopalma exalata* S.Jin Zeng, Y.C.Xu & D.F.Cui: **A** plant **B** leaf base, abaxial view **C** opening flower, front view **D** petal, front view **E** longer stamens, side view **F** longer stamen, front view **G** short stamens, side view **H** short stamen, front view **I** opening flower, longitudinal section **J** hypanthium, with attached style, longitudinal section. Scale bars: 5 mm. Drawn by Ding-Han Cui.
Figure 4. Comparison of *Tigridiopalma exalata* and *T. magnifica*: A–E *Tigridiopalma exalata* a–e *T. magnifica* A, a flowering plants B, b leaf bases, abaxial view C, c flowers, front view D, d stamens, side view E, e infructescences, side view. Photographed by Si-Jin Zeng.
× 0.7–1.0 cm, oblique, almost rhomboid, apex white, truncate and oblique. Stamens 10, 5 long antisepalous and 5 short antipetalous, arranged in 2 whorls. Antisepalous (longer) stamens 1.7–2.2 cm long; anthers 0.7–1.0 cm long; connective decurrent, basally with 2 ventral tubercles and a dorsal short spur. Antipetalous (shorter) stamens 1.2–1.5 cm long; anthers 0.6–0.8 cm long; connective slightly decurrent, basally with 2 ventral tubercles and a dorsal short spur. Ovary half-inferior, ovoid, apex with membranous crown; crown 5-lobed, lobe margins ciliate; placentas short stalked. Capsule funnelform cup-shaped, apex truncate, dehiscence poricidal; crown woody, 5-lobed, exserted ca. 0.2 cm beyond calyx, margin irregularly denticulate. Seeds more than 100, light brown, ca. 0.1 cm long.

**Phenology.** Flowering in October–November, fruiting in January–March.

**Etymology.** The specific epithet combined from ex- (lacking) and alatus (winged) which refers to the wingless capsules.

**Vernacular name.** Hui Zhou Hu Yan Hua (Chinese pronunciation); 惠州虎颜花 (Chinese name).

**Distribution.** Tigridiopalma exalata grows in damp, shaded but well-drained places in broad-leaved forests, in elevations between 100 m and 350 m in Huizhou, Guangdong Province, China (Fig. 4).

**Preliminary conservation assessment.** About 1000 mature Tigridiopalma exalata individuals from one locality have been found in less than 60 km² up to now. This area can be classified as the extent of occurrence. The plants are not well protected in a Forest Park and the populations are severely fragmented. This species has horticultural potential as an ornamental plant. According to the IUCN Standards and Petitions Committee (2019), a category of Endangered (EN) is recommended for Tigridiopalma exalata for the present.

**Paratype.** China. Guangdong: Huizhou, Longmen, on damp slopes of ravines in broad-leaved forests, 121 m, 25 November 2017, S.Jin Zeng 397 (CANT!, IBSC!).

**Acknowledgements**

We thank Dr Yi-Hua Tong for his valuable comments on the manuscript, Mr Ding-Han Cui for preparing the line drawing and Mr Jing-Bo Ni for his kind assistance with our field survey.

**References**


Tigridiopalma exalata, a new and endangered species of Melastomataceae from China


Supplementary material 1

Tables S1–S3
Authors: Si-Jin Zeng, Ye-Chun Xu, Gang-Tao Wang, Peng Jia, Da-Fang Cui
Data type: tables
Explanation note: Table S1. Primers used in this study. Table S2. Vouchers and accession numbers of the specimens used in this study. Newly generated sequences are indicated in bold, other sequences of two makers (*ndhF* + *rpl16*) were extracted from published complete chloroplast genomes. Table S3. Summary features of sequences used for phylogenetic analysis. PIS, parsimony-informative sites.

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Link: https://doi.org/10.3897/phytokeys.176.63619.suppl1
Impatiens wutaishanensis (Balsaminaceae), a new species from Southeast Yunnan, China

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Abstract

Impatiens wutaishanensis R.L. Liao & Lei Cai, a new species from Southeast Yunnan, China, is here described and illustrated. This new species is most similar to Impatiens parvisepala S.X. Yu & Y.T. Hou in its racemose inflorescences, its four lateral sepals, the leaf arrangement, and in having yellow flowers. However, it differs in the height of the plants, the length of the petiole, the size and shape of the leaf blade, the shape of the spur, and the number of flowers in each inflorescence. A detailed description, color photographs, and a provisional IUCN red list assessment are provided, and its geographical distribution, ecology, and morphological relationship with relevant similar species are discussed.

Keywords

China, Flora of Yunnan, Impatiens parvisepala, Impatiens wutaishanensis, morphology

Introduction

The genus Impatiens Linnaeus (1753: 937) belongs to the family Balsaminaceae, and has a mainly Old World tropical and subtropical distribution, although a few species are found in the northern temperate regions of Europe, Russia and China

* This author contributed equally as the first author.
as well as North America. There are over 1000 species known to the genus to date (Grey-Wilson 1980; Fischer 2004). Major biodiversity hotspots for *Impatiens* species include tropical Africa, Madagascar, southern India and Sri Lanka, eastern Himalayas, and Southeast Asia (Song et al. 2003; Yuan et al. 2004). In China, more than 270 species of *Impatiens* are recorded, of which over 240 are endemic to the country. Southwest China is, in the broad sense, part of the Southeast Asian area, and belongs to one of the biodiversity hotspots of the genus *Impatiens* with more than 200 species (Yuan et al. 2004; Xia et al. 2019a; Peng et al. 2020). The Chinese *Impatiens* species are mainly found in Southwest China’s Yunnan, Sichuan, Tibet, Guangxi and Guizhou Provinces (Chen 2001; Chen et al. 2007; Yu 2012; Zhang et al. 2013). In recent years, about 30 new species of *Impatiens* have been described from China, and a large proportion of these are found in Southwest China (e.g. Hou et al. 2011; Cai et al. 2015; Tan et al. 2015; Guo et al. 2016; Ding et al. 2016; Xia et al. 2019a, b; Lu et al. 2020). In 2015, during a botanical investigation in Jinping County, Southwest Yunnan Province, China, we collected some specimens of an unknown *Impatiens* species. After careful examination of the relevant specimens and literature of the genus *Impatiens* within the adjacent regions (Chen 2001; Chen et al. 2007; Hou et al. 2011; Shui et al. 2011; Yu 2012; Cai et al. 2015; Tan et al. 2015; Chinh et al. 2015; Xia et al. 2019b), we concluded that the *Impatiens* species differed from previously reported or described taxa, and which we describe it here as a new species.

**Materials and methods**

The material for this study was mainly collected during field surveys assessing the conservation status of the plants of Yunnan Province, China. Herbarium specimens were made carefully and dissected flowers were dried separately to enable examination and illustration in the laboratory. Additionally, flowers were preserved in formalin-acetic acid-alcohol (FAA) solution, and field notes were taken. The morphological characteristics of the new species were measured using a ruler and vernier calipers from both dried herbarium specimens and mature individuals of living plants in the field. Morphological features of the flowers were described and measured using a dissecting microscope.

Fresh pollen grains and leaf blades were collected from the living plants introduced from the field and cultivated at Kunming Botanical Garden (KBG) and loaded on the cryo-specimen holder and cryo-fixed in slush nitrogen (-210 °C), then sublimed and sputter-coated with Pt in a vacuum scanning electron microscopy (SEM) chamber at -140 °C. Morphological characters were observed, examined, and photographed with a cryo-SEM. The morphology of 30 pollen grains was measured and described according to terminology of pollen grains (Lu 1991; Janssens et al. 2012).
**Impatiens wutaishanensis** (Balsaminaceae), a new species from China

**Taxonomic treatment**

*Impatiens wutaishanensis* R.L. Liao & Lei Cai, sp. nov.

urn:lsid:ipni.org:names:77216566-1

Figs 1, 2

**Type.** China, Yunnan Province, Jinping County, Maandi, alt. 1650 m a.s.l., 22°46′19.97″N, 103°28′29.78″E, 10 September 2016, Lei Cai & Z.Y. Yu CL16050 (holotype:1498854, KUN!; isotypes:1498855, KUN!).

**Diagnosis.** This species is similar to *Impatiens parvisepala* S.X. Yu & Y.T. Hou (2011: 57) (Hou et al. 2011) in its racemose inflorescences, its alternate and aggregated or subverticillate at stem apex arrangement leaf, and its yellow flowers, but it can be distinguished by its conspicuous 0.5–2.4 cm long petiole (vs. sub-sessile or sessile), its shorter 10–35 cm high plants (vs. 35–60 cm high), its 3.5–12 × 1.5–4 cm elliptic to lanceolate-oblong leaf blades with cuneate bases (vs. 12–20 × 3.5–6 cm obovate or obovate-lanceolate blade with attenuate bases), its slightly incurved or narrowing to incurved spur (vs. nearly straight spur), and its racemose inflorescences with up to 22 flowers (vs. 6–8 flowers per inflorescence).

**Description.** Perennial herb, 10–35 cm tall, glabrous. Root-system shallow, with runners and adventitious roots. Stem fleshy, erect, simple, lower nodes swollen. Leaves simple, alternate, aggregated or subverticillate at stem apex; petiole 0.5–2.4 cm long, leaf blade 3.5–12 × 1.5–4 cm, elliptic, lanceolate, or lanceolate-oblong, base cuneate, margin roughly crenate, mucronulate, apex acuminate, adaxial surface dark green, abaxial surface pale green, lateral veins 4–8 pairs. Racemes in the upper leaf axils, 1–4, 4.2–28 cm long, erect, each with up to 22 flowers. Pedicels 0.6–2.5 cm long, bracteate at base. Bracts ca. 8 mm long, lanceolate to subulate, apex acute, base obtuse, margin entire. Flowers yellow. Lateral sepals 4, light green, the outer pair ca. 5–8 × 3–4 mm, ovate or obovate; the inner pair ca. 8–13 × 1–3 mm, sickle-shaped, obliquely lanceolate, apex acuminate or ciliate. Lower sepals 1.5–2.2 × 1.2–2 cm excluding the spur, yellow to yellowish green with reddish patches, obliquely infundibuliform, base gradually constricted into a spur, spur 1.2–3 cm long, slightly incurved or narrowing to incurved, apex rostellate. Dorsal petal 1.3–2.3 × 0.7–1.6 cm, yellow with nearly transparent base, obovate to ovate, apex acuminate, with an inconspicuous dorsal crest, base truncate or cuneate. Lateral united petals ca. 1.6–3 cm long, yellow with nearly transparent base and reddish patches; the upper petals ca. 1.5–2.3 × 0.7–1 cm, oblong; the lower petal ca.1.2–1.8 × 0.6–0.8 cm, reniform. Stamens 5, filaments linear, ca. 3 mm long, anthers obtuse. Ovary fusiform, slightly curved. Placentation axile with four locules. Capsule (immature) clavate, 2–2.5 cm long.

**Pollen morphology.** Pollen grains triangular-round with three equal sides in polar view, and the equatorial view is elliptic, long-elliptic, P×E=16.56±1.78 (14.51–21.73)× 30.00±0.98 (28.35–32.11) μm. 3-colpate, linear, the entire surface is covered with reticulate ornamentation, granules in lumina (Fig. 3).
Leaf surface micromorphology. The anticlinal walls of the epidermal cells on the adaxial surfaces are straight, while those of the abaxial surface are sinuate. The stomata only appeared on the abaxial surface of the leaf, the shape was anomocytic and the outline of the guard cells was suborbiculate (Fig. 3).
**Figure 2. Impatiens wutaishanensis** R.L. Liao & Lei Cai (drawn by R.M. Zhang)  
A habit  
B root  
C inner lateral sepal  
D outer lateral sepal  
E dorsal petal  
F lateral united petals (F1: upper petal  
F2: lower petal)  
G lower sepal  
H ovary and stamens  
I flower in front view  
J flower in lateral view  
K partial view of leaf margin.
Phenology. This new species was observed flowering from August to November, and fruiting from September to December.

Distribution. This species is currently known from only two small subpopulations less than 10 km away (Shidong and Biaoshuiyan) in Jinping County of Southeast Yunnan, China (Fig. 4). The distribution area is very close to the border between China and Vietnam. We assume that this species should be distributed in Vietnam due to its similar habitat and proximity to the type locality, which will be verified by future investigation.

Ecology. This new species has a runner with adventitious root produced from the nodes and was collected growing in the understory of forest at an elevation of 1300–1650 m. In the subpopulation in Shidong, the plants found coexist with the cultivated *Amomum tsako* Crevost & Lemarie (Zingiberaceae). In the subpopulation in Biaoshuiyan, the plants were found beside the artificial trail in a scenic area. The main accompanying species were *Begonia* Linn. sp. (Begoniaceae), *Didymocarpus purpureoarctatus* W.W. Smith (Gesneriaceae), *Epigeneium amplum* (Lindl.) Summerh. (Orchidaceae), *Hedychium villosum* Wall. (Zingiberaceae), *Polygala fallax* Hemsl. (Polygalaceae) and *Vaccinium* Linn. sp. (Ericaceae).

Conservation status. This species is currently known only from Jinping County, Yunnan, China with one type locality and a subpopulation. The Extent of Occurrence (EOO) is less than 100 km² and the known Area of Occupancy (AOO) is less than 15 km². The conservation status can be evaluated as Vulnerable (VU) D2 based on IUCN
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Figure 4. Distribution of Impatiens wutaishanensis R.L. Liao & Lei Cai and I. parvisepala S.X. Yu & Y.T. Hou.

Red List Categories and Criteria (IUCN 2019). About 350 and 200 individuals were known in the two subpopulations of Biaoshuiyan and Shidong, respectively, and both are exposed to human disturbance. Therefore, we assess this species as a Plant Species with Extremely Small Populations (PSESP) (Yang et al. 2020).

Etymology. The specific epithet ‘wutaishanensis’ refers to the type locality where the new species was found, located in the Wutaishan area of Jinping Fenshuiling National Nature Reserve, Jinping County, Southeast Yunnan, China. The Chinese name is given as “五台山凤仙花”.

Additional specimens examined. Paratypes. CHINA. Yunnan Province: Jinping County, Maandi Town, Shidong. 22°46′19.97″N, 103°28′29.78″E, 1650 m a.s.l., 5 August 2015, Lei Cai et al., CL155 (KUN!); The same locality, 2 August 2020, R.L. Liao & X.Y. Li, LRL202008003 (KUN!); Yunnan Province: Jinping County, Maandi Town, Biaoshuiyan, 22°43′56.61″N, 103°30′36.58″E, 1311 m a.s.l., 2 August 2020, R.L. Liao & X.Y. Li, LRL202008001 (KUN!)

Discussion. The new species is most similar to Impatiens parvisepala in its racemose inflorescence, its yellow flowers with four lateral sepals. However, I. wutaishanensis is usually a shorter plant and its petiolate leaf blades are smaller and elliptic, lanceolate, or lanceolate-oblong. Its nectar spur is slightly incurved or narrowing to an incurved spur, and each inflorescence may have up to 22 flowers (Figs 1, 2). In contrast, the plants of I. parvisepala are taller, the sessile or subsessile leaf blades are larger and obovate or obovate-lanceolate, the spur is nearly straight and the number of flowers per

<table>
<thead>
<tr>
<th>Character</th>
<th><em>I. wutaishanensis</em></th>
<th><em>I. parvisepala</em></th>
<th><em>I. apalophylla</em></th>
<th><em>I. clavigera</em></th>
<th><em>I. tianlinensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>10–35 (16.71±5.30) cm</td>
<td>35–60 cm</td>
<td>30–60 cm</td>
<td>50–60 cm</td>
<td>50–80 cm</td>
</tr>
<tr>
<td>Length of petiole</td>
<td>0.5–2.4 (1.02±0.44) cm</td>
<td>sub-sessile or sessile</td>
<td>2–4 cm</td>
<td>(0.5–) 1–2 cm</td>
<td>1–2 cm</td>
</tr>
<tr>
<td>Shape of leaf blade</td>
<td>elliptic, lanceolate, or lanceolate-oblong</td>
<td>obovate or obovate-lanceolate</td>
<td>oblong-ovate or oblong-oblanceolate</td>
<td>obovate or oblanceolate</td>
<td>obovate to oblanceolate</td>
</tr>
<tr>
<td>Size of leaf</td>
<td>3.5–12 (7.53±1.86) × 1.5–4 (2.90±0.79) cm</td>
<td>12–20 × 3.5–6 cm</td>
<td>10–22 × 4–8 cm</td>
<td>8–15 (–18) × 3.5–5 cm</td>
<td>10–15 (–18) × 5–8 cm</td>
</tr>
<tr>
<td>Length of peduncle</td>
<td>4–28 (13.00±6.71) cm</td>
<td>15–17 cm</td>
<td>7–15 cm</td>
<td>8–10 cm</td>
<td>10–15 cm,</td>
</tr>
<tr>
<td>No. of flowers in an inflorescence</td>
<td>up to 22 flowers</td>
<td>6–8 flowers</td>
<td>4–10 flowers</td>
<td>5–9 flowers</td>
<td>3–5 (–7) flowers</td>
</tr>
<tr>
<td>Shape and length of spur</td>
<td>slightly incurved or incurved,</td>
<td>nearly straight, gradually</td>
<td>incurved, abruptly elongated,</td>
<td>incurved, abruptly narrowed,</td>
<td>involuted, abruptly constricted,</td>
</tr>
<tr>
<td></td>
<td>gradually constricted, 1.2–3 (2.06±0.45) cm long</td>
<td>gradually constricted, 2–2.5 cm long</td>
<td>2–2.5 cm long</td>
<td>5–6 mm long</td>
<td>1–1.5 cm long</td>
</tr>
<tr>
<td>Bracts</td>
<td>lanceolate to subulate, persistent</td>
<td>lanceolate or subulate, persistent</td>
<td>invisible</td>
<td>ovate, caducous</td>
<td>ovate, deciduous</td>
</tr>
<tr>
<td>Lower sepal</td>
<td>obliquely infundibuliform, with reddish</td>
<td>narrowly funnel-shaped, with</td>
<td>narrowly funnel-shaped, absent</td>
<td>slightly narrowly funnel-shaped,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>patches, 1.2–2.8 (1.94±0.38) × 0.8–2.2 (1.38±0.37) cm</td>
<td>reddish patches, 3 cm</td>
<td>patch, 2 × 3 cm</td>
<td>with reddish patches, 2.5–3.5 cm</td>
<td></td>
</tr>
<tr>
<td>Dorsal petal</td>
<td>ovate, 1.3–2.3 (1.80±0.28) × 0.7–1.6 (1.15±0.26) cm</td>
<td>obovate, 1.8–2.2 × 1.5–2 cm</td>
<td>ellipticum, 1–4 cm</td>
<td>obovate, ca. 2 cm</td>
<td>ovate, 10–12 × 7–9 mm</td>
</tr>
<tr>
<td>Lateral united petals</td>
<td>1.6–3 cm long, with reddish patches</td>
<td>2.8–3 cm long, with reddish patches</td>
<td>2–3 cm long, with apparent</td>
<td>2–6 cm long, absent patch</td>
<td>2–2.5 cm long, with reddish</td>
</tr>
<tr>
<td>Pollen grains</td>
<td>30.00±0.98 (28.35–32.11) × 16.56±1.78 (14.51–21.73) μm</td>
<td>28.84 (27.98–30.17) × 20.57</td>
<td>31.85 (30.96–32.73) × 5.57 (5.13–6.75) μm</td>
<td>Missing data</td>
<td>30.13 (29.62–30.47) × 12.95 (12.68–13.54) μm</td>
</tr>
</tbody>
</table>

Rong-Li Liao et al. / PhytoKeys 176: 43–53 (2021)
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The inflorescence is 6–8 (Hou et al. 2011; Son et al. 2015). The distribution of these two species is geographically isolated from each other: Impatiens wutaishanensis, is confined to Southeast Yunnan Province with two subpopulations, where the I. parvisepala is recorded in western Guangxi and northern Vietnam (Fig. 4).

In order to illustrate the morphological circumscription of the new species, we compare the new species with four species with similar morphological characters in Table 1: Impatiens apalophylla Hook. f. (1908:243), I. clavigera Hook. f. (1908:2863), I. parvisepala and I. tianlinensis S.X. Yu & L.J. Zhang (2015: 253) (Zeng et al. 2015).

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References


Impatiens wutaishanensis (Balsaminaceae), a new species from China


Saussurea talungensis (Asteraceae), a new species from Humla, Nepal Himalayas

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Abstract

A new species Saussurea talungensis S.K. Ghimire & H.K. Rana, sp. nov. (sect. Strictae), from Talung valley of Humla district, Nepal, is described and illustrated. Morphologically, this species resembles Saussurea roylei and Saussurea lanata in habit, though it can be distinguished in having longer leaf petioles, purplish leaf margin, 1 or 3 capitula, shorter phyllaries, shorter receptacle bristles and the same anthers, comparatively shorter corolla with shorter lobes. Phylogenomic analysis also supports S. talungensis as a distinct species of Saussurea. Here, we provide taxonomic note, distribution map and phylogenomic inference to distinguish the new species and its allied members.

Keywords

Nepal, new species, phylogenomics, Saussurea, Talung valley, taxonomy

Introduction

Genus Saussurea DC. is one of the largest and species-rich taxa in the Asteraceae (Shi and von Raab-Straube 2011). Geographically, it is confined to the high mountains of Central and East Asia, including the Himalaya but also occurs in arid highlands and
open vegetation types elsewhere in the Northern Hemisphere (Wang et al. 2009). Chen (2015) reported ca. 458 species and von Raab-Straube (2017) approximated the species number to be 493. Among them, Nepal represents 44 species including 8 endemics (Rana et al. 2018; Tiwari et al. 2019). Recently, a number of new species were discovered from the Himalaya and Central/East Asia, including *S. ramchaudharyi* S.K.Ghimire & H.K.Rana, *S. bogedaensis* Y.J.Wang & J.Chen, *S. balangshanensis* Y.Z.Zhang & H.Sun, *S. yiwuensis* L.Q.Zhao & X.Ri, *S. yilingii* Y.S.Chen, *S. sagittifolia* L.S.Xu, S.Y.Yi & Y.S.Chen and *S. xinjiangensis* Y.S.Chen & L.S.Xu. However, explorations are insufficient in many remote regions of Nepal compared to the neighboring region e.g., China.

A distinct population of _Saussurea_ (Fig. 1) was recognized in 2012, during a botanical expedition to the alpine region of Humla district (NW Nepal). Based on habit, this population of _Saussurea_ was initially considered as _S. roylei_ (DC.) Sch.Bip. with some extent of resemblance with _Saussurea lanata_ Y.L.Chen & S.Y.Liang. However, the population from Talung valley could not be ascribed to any known species of the genus _Saussurea_ and may represent a new species. Therefore, in order to clarify this presumption, we characterized its morphology and clarify its genetic distinctness using chloroplast genome sequence. In particular, with the advent in the next-generation sequencing (NGS) technology, DNA-barcoding provides a rapid and precise solution for honing plant taxonomies when combined with more traditional, morphology-based approaches (Kress et al. 2005; Hajibabaei et al. 2007; Hollingsworth 2011; Ji et al. 2020). Integratively, morphological observations and molecular analysis led us to conclude that this population belongs to a new previously undescribed species of _Saussurea_ (see below). We thus formally presented the description of the new species, _Saussurea talungensis_ S.K.Ghimire & H.K.Rana.

**Methods**

Three _Saussurea_ specimen were collected in September 2012 from the type locality, Talung valley, Humla district in NW Nepal (Fig. 1A–D). The specimens were used for morphological and phylogenomic inference. A distribution map was produced using the type locality coordinates (Fig. 1A, B).

**Morphological observations**

Morphological characteristics were described based on both observation and measurement collected with a ruler, calipers and electronic digital compound microscope. For the comparative morphological characteristics of allied taxa (_S. roylei_ and _S. lanata_), related literatures (Chen et al. 1981; Shi and von Raab-Straube 2011; Chen 2014, 2015), live plant images and herbarium, and digitized specimen images from E, GH, K, KATH, PE, BM (acronyms following Thiers 2020, continuously updated) and CVH (www.cvh.ac.cn) were consulted.
Plastome sequencing, assembly, annotation and phylogenomic analyses

Total genomic DNA was extracted from ~20 mg herbarium leaf tissue using a modified cetyltrimethylammonium bromide (CTAB) method (Doyle and Doyle 1987). A 500 bp DNA TrueSeq Illumina (Illumina Inc., San Diego, CA, USA) sequencing pair-end libraries were constructed using 3–5 μg sonicated DNA, according to the manufacturer’s instructions. The libraries were pair-end sequenced on the Illumina HiSeq 2000 platform. Raw reads were subsequently filtered to remove the low-quality reads and adaptors using the NGS QC Toolkit (Patel and Jain 2012), setting the cut off value for percentage read length to 80 and Phred quality score to 30. Remaining high-quality reads were assembled de novo to generate complete plastome with GetOrganelle pipeline developed by Jin et al. (2020). All the reads were then reference-assembled against the plastome of *S. hookeri* C.B.Clarke (MK952740) to check if the genomes were correctly assembled. The consensus sequence was annotated using *S. hookeri* as a reference in GENEIOUS v.7.0.2 (Kearse et al. 2012) and then corrected manually for the start/stop codons and intron/exon boundaries. Finally, the annotated plastid genome was submitted to GenBank (MW524864) and a physical map of the circular plastome was visualized with OrgannellarGenomeDRAW (OGDRAW: Lohse et al. 2013). To determine the phylogenetic position of the new species within the genus *Saussurea*, 64 plastome and a rbcL sequence (of *S. roylei*) of the genus *Saussurea*, plus one each for *Hemisteptia lyrata* (Bunge) Fisch. & C.A.Mey. and *Aucklandia costus* Falc. were accessed from GenBank (Table 1) and aligned with the newly generated sequence of *S. talungensis* in MAFT-WIN v.7.221 (Katoh and Standley 2013; Yamada et al. 2016). From the initial alignment, we selected conserved blocks with GBLOCK.

**Table 1.** Accession numbers of the allied taxa of *Saussurea* and outgroups for the phylogenomic analysis (https://www.ncbi.nlm.nih.gov/).

<table>
<thead>
<tr>
<th>Species name</th>
<th>Accession numbers</th>
<th>Species name</th>
<th>Accession numbers</th>
<th>Species name</th>
<th>Accession numbers</th>
<th>Species name</th>
<th>Accession numbers</th>
<th>Species name</th>
<th>Accession numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aucklandia costus</em></td>
<td>MH926063</td>
<td><em>S. gusipophora</em></td>
<td>MH926100</td>
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v.0.91b (Castresana 2000). We used GTR+I+G as the best fitting substitution model based on the Akaike information criterion (AIC) using JMODELTEST v.2.1.6 (Posada and Crandall 1998). We performed Bayesian phylogenetic inference (BI) analysis in MRBAYES v.3.2.6 (Ronquist and Huelsenbeck 2003) on online CIPRES Science Gateway v.3.3 (Miller et al. 2010; https://www.phylo.org). For BI, two independent analyses of four Markov Chain Monte Carlo (MCMC) chains were run for $5 \times 10^7$ generations each with sampling every 1,000 generations. We assessed the stationarity of the runs using TRACER v.1.7 (Rambaut et al. 2018) and generated a majority rule consensus after removing a 20% burn-in. Maximum Likelihood (ML) analysis was performed using the graphical front-end RAXML GUI v.1.5b2 (Silvestro and Michalak 2012) in RAXML v.8.2.x (Stamatakis 2014) with 1,000 rapid bootstraps with 10,000 maximum number of trees. The Bayesian posterior probability (PP) from BI and Likelihood bootstrap support (BS) from ML of each branch was obtained. Nodes with PP $\geq 0.95$ (Ronquist and Huelsenbeck 2003) and BS $\geq 75\%$ (Hillis and Bull 1993) were considered well-supported.

Results and discussions

Taxonomic treatment

*Saussurea talungensis* S.K.Ghimire & H.K.Rana, sp. nov.
urn:lsid:ipni.org:names:77216567-1
Figs 1–3

**Type.** Talung valley, between Nyalu Pass and Ning Tsho, open gravelly or stony slopes, 30.234°N, 81.692°E, 4300 m a.s.l., 13 September 2012, S.K. Ghimire, A. Poudel, L.R. Joshi, S. Lo, P. Subedi, & C. Thapa CHH-1352 (holotype: KATH!; isotypes: TUCH!, KUN!).

**Description.** Perennial herb, caespitose, 22–50 cm tall. Caudex branched, stout, apex covered with petioles’ residues. Stem well-developed leafy, erect, simple, stiff, $> 1.3$ cm in diameter, purplish-brown at maturity, covered with brownish-white tomentose hairs. Basal leaves petiolate; petioles 9.0–10.5 cm; leaf blades lanceolate, chartaceous, 10–15 × 2.5–4.0 cm, adaxially green, with brownish-white tomentose hairs, abaxially greenish-white, with dense white tomentose hairs, base attenuate, margin purplish, sinuate-dentate to shallowly pinnately lobed, lobe margins entire, apex acute to acuminate, midvein distinct, purplish-green. Cauline leaves 5–7, gradually decreasing in size upwards, margin purplish; lower cauline leaves petiolate, petiole to 4 cm, leaf blades lanceolate, 8.0–11.5 × 1.5–2.5 cm, apex acute or acuminate; middle and upper cauline leaves subsessile to sessile, narrowly lanceolate to linear, 4.0–7.5 × 0.6–1.2 cm, undivided, margin dentate, purplish-green uppermost leaves subtending the capitula or synflorescence. Capitula 1 or 3 (2 not seen), shortly pedunculate to subsessile, tomentose. Involucres campanulate, 1.2–2.0 cm in diameter. Phyllaries in 4 to 5 series, imbricate,
Saussurea talungensis sp. nov. from Nepal

Figure 1. Distribution of *Saussurea talungensis* S.K.Ghimire & H.K.Rana A, B distribution map showing type locality in Nepal and Humla district respectively C, D type locality habitat between Nyalu Pass and Ning Tsho, Talung valley, Humla district E quadripartite plastome map of *S. talungensis* (Photographs C, D and plant picture in E by S.K. Ghimire).
densely tomentose, apically purplish, acuminate, spreading to reflexed; outer phyllaries ovate-elliptic, 7–10 × 3.0–3.5 mm, middle phyllaries elliptic, 11–13 × 2.5–3.0 mm, inner phyllaries narrowly elliptic to linear, 13–15 × ca. 2 mm, only tips densely tomentose. Receptacles with bristles, ca. 4 mm long. Florets > 20; corolla purplish, 10.0–12.5 mm long; limb 4–6 mm including 1.5–2.2 mm lobes; tube 5–7 mm long. Anthers ca. 5 mm long, tails lanate, ca. 1.2 mm long. Style branches ca. 1.2 mm long, reflexed, short, papillate. Achenes cylindrical, 3.5–4.5 × 1.5–2.0 mm, ribbed, glabrous, apex shortly crowned. Pappus in two rows, pale brown; outer bristles 3.0–4.5 mm, scabrid, deciduous; inner bristles 10–12 mm long, plumose, persistent, sub-equaling floret.

**Phenology.** Flowering and fruiting from July to September.

**Etymology.** The specific epithet is derived with reference to the type locality of *Saussurea talungensis*, Talung valley, Humla district, NW Nepal.
**Distribution and habitat.** *Saussurea talungensis* is currently recorded only from the type locality in Talung valley (between Nyalu Pass and Ning Tsho), Humla district, NW Nepal (Fig. 1A–D). It grows on the alpine open gravelly or stony slopes at an elevation ca. 4300 m a.s.l. (Fig. 1C, D).

**Conservation status.** *Saussurea talungensis* is restricted to a single mountain and is represented by ~50 mature individuals within an area of < 500 m² and appears to be local endemic. Moreover, its habitat and the population are subjected to high anthropogenic pressure, due to livestock grazing, and harvesting of caterpillar fungus and other aromatic plants used in medicine. Owing to population size, isolated distribution and observed constraints on the habitat due to anthropogenic pressure, *Saussurea talungensis* should be categorized as Critically Endangered [CR; B1ab (iii), B2ab (iii) and D] according to the IUCN Standards and Petitions Committee (2019).

**Morphological affinities.** Critical examination of collected specimens, comparison with type material of allied taxa and relevant taxonomic literature revealed that *S. talungensis* is a new member of *Saussurea* (sect. *Strictae*). Based on morphology, distribution and ecology, this population of *Saussurea* was initially considered as *S. roylei* from sect. *Strictae*. To a certain extent it also resembles *S. lanata* in being a perennial herb with well-developed leafy stem, leaf blade undivided but lanceolate, many series phyllaries, campanulate involucres with more than 1 cm diameter, lanate anther tails, ribbed and glabrous achenes, and two rows of pale brown pappus. However, it differs from its allied taxa in having a number of qualitative and quantitative characters (see Table 2; Figs 2, 3). Furthermore, in the western Himalayan alpine region, *S. roylei* is considered to have diverse morphological variations but this proposed new species owned peculiar affinities which undoubtedly differentiates it from the stated and other *Saussurea* species.

Table 2. Character comparison of *S. talungensis* S.K.Ghimire & H.K.Rana and its allied taxa.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Saussurea talungensis</th>
<th>Saussurea roylei</th>
<th>Saussurea lanata</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem diameter / forms</td>
<td>&gt; 1.3 cm / stiff</td>
<td>≤ 1 cm / less stiff or herbaceous</td>
<td>≤ 1.2 cm or more / stiff</td>
</tr>
<tr>
<td>Basal leaf size / petiole</td>
<td>10–15 × 2.5–4.0 cm / 9.0–10.5 cm</td>
<td>7.5–25.0 × 0.5–2.0 cm / to 5 cm rarely up to 8 cm</td>
<td>7–28(–30) × 1.5–4.7 cm / 4–9 cm</td>
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<tr>
<td>Leaf blade</td>
<td>lanceolate, comparatively broader, chartaceous, margin purplish, base attenuate</td>
<td>lanceolate, chartaceous, margin green, base attenuate</td>
<td>oblanceolate to narrowly elliptic, coriaceous, margin green, base decurrent</td>
</tr>
<tr>
<td>Capitula number</td>
<td>1 or 3 (2 not seen)</td>
<td>usually 1, rarely 2</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Phyllaries</td>
<td>4 to 5 rows, densely pubescent (outer exposed parts)</td>
<td>ca. 5 rows, densely pubescent</td>
<td>4 to 6 rows, sparsely pubescent</td>
</tr>
<tr>
<td>Outer phyllaries</td>
<td>ovate-elliptic, 7–10 × 3.0–3.5 mm</td>
<td>ovate-elliptic, 16–18 × 1.5 mm</td>
<td>narrowly triangular or ovate-triangular, 7–12 × 2–3 mm</td>
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<tr>
<td>Inner phyllaries</td>
<td>narrowly elliptic to linear, 13–15 × 2 mm</td>
<td>broadly linear, 20–22 × 2.3–2.5 mm</td>
<td>linear-narrowly lanceolate, 11–13 × 1–2 mm</td>
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<tr>
<td>Receptacle bristles</td>
<td>ca. 4 mm long</td>
<td>6–8 mm long</td>
<td>5–7 mm long</td>
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<tr>
<td>Corolla (tube / limb with lobes) size</td>
<td>1.0–1.25 cm (5–7 mm / 4–6 mm with 1.5–2.2 mm lobes)</td>
<td>1.2–2.5 cm (10–13 mm / 6–9 mm with 4–5 mm lobes)</td>
<td>1.2–1.6 cm (4–8 mm / 6–8 mm with ca. 3 mm long lobes)</td>
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<tr>
<td>Anther</td>
<td>ca. 5 mm with 1.2 mm tail</td>
<td>ca. 8 mm with ca. 1.5 mm tail</td>
<td>ca. 6.5 mm with ca. 1.8 mm tail</td>
</tr>
<tr>
<td>Achenie size</td>
<td>3.5–4.5 × 1.5–2.0 mm</td>
<td>5–6 mm</td>
<td>4–5 mm</td>
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Figure 3. Illustration of *Saussurea talungensis* S.K. Ghimire & H.K. Rana based on the holotype A habit B leaf showing adaxial and abaxial surface details C phyllaries (outer to inner from left to right) D floret E stamens F style branches G achene H pappus I bristle of inner pappus J bristle of outer pappus (Drawn by H.K. Rana and S.K. Rana).
Saussurea talungensis sp. nov. from Nepal

Choling, 28°35'22.92"N, 93°55'12.54"E, 3960 m a.s.l., 2013, FLPH Tibet Exped. 12-2144
93°41'38.35"E, 3350 m a.s.l., 2012, (PE); Lhunze, Sanga Choling, 28°35'22.92"N, 92°55'12.54"E, 3960 m a.s.l., 2013, FLPH Tibet Exped. 13-0860 (PE).

**Figure 4.** Complete chloroplast genome sequence-based phylogenomic tree inferred from Maximum Likelihood (ML) analyses. Numbers above branches are Bayesian posterior probability (PP)/Likelihood bootstrap support (BS) from BI and ML, respectively.

**Molecular affinities.** The typical quadripartite structure of the newly sequenced plastome has size of 152,355 bp (37.7% GC content) consisting of a large single copy (LSC: 83,371 bp, 35.8% GC content), a small single copy (SSC: 18,562 bp, 31.4% GC content), inverted repeats (IRs: 25,211 bp, 43.1% GC contents each of IRA and IRB) (Fig. 1E). The newly sequenced chloroplast genome was used to determine the phylogenomic relationship of *S. talungensis* with its allied species and infer its position within *Saussurea*. The molecular phylogeny through BI and ML tree revealed that *S. talungensis* is nested within a clade comprising *S. roylei*, *S. lanata*, *S. hookeri*, *S. eriostemon* Wall. ex C.B.Clarke, *S. leontodontoides* (DC.) Sch.Bip., *S. paleacea* Y.L.Chen & S.Y.Liang, *S. centiloba* Hand.-Mazz., *S. stella* Maxim. and *S. andryaloides* (an allied species), and is supported by Bayesian posterior probability (PP > 0.98, BS > 93%; Fig. 4). It is more evident that *S. talungensis* is a sister to *S. roylei* (an allied species), and is supported by Bayesian posterior probability (PP = 1) and Likelihood bootstrap support (BS = 98%) (Fig. 4). Also, complete chloroplast genome structure is conservative in overall size and the order and size of each gene and intergenic region (Fig. 1E). The identical BI and ML phylogenomic tree using plastome sequence revealed that *S. talungensis* is most closely related to *S. roylei* (Fig. 4), which is in congruence with the morphological observations.

**Additional herbarium specimens examined.** *Saussurea lanata*. Nepal. Jumla: 3050 m a.s.l., 1952, O. Polunin et al. 3101 (BM, E); Mustang: Tukucha, 3050 m a.s.l., 1954, J.D.A. Stainton et al. 7846 (BM). China. Xizang: Lhozhag, 4450 m a.s.l., 2013, FLPH Tibet Exped. 13-1617 (PE); Gyaca, 4800 m a.s.l., 1972, Tibet Chinese Herbal Medicine Census Team 4538 (PE); Gongbo'gyamda, Bahe, 98°59'41.15"N, 93°41'38.35"E, 3350 m a.s.l., 2012, FLPH Tibet Exped. 12-2144 (PE); Lhunze, Sanga Choling, 28°35'22.92"N, 92°55'12.54"E, 3960 m a.s.l., 2013, FLPH Tibet Exped. 13-0860 (PE).

**Key to the three closely related Saussurea species**

1. Leaf blades oblong to narrowly elliptic, coriaceous, base decurrent; phyllaries 4 to 6 rows, sparsely tomentose, outer phyllaries narrowly triangular or ovate-triangular .......................................................... *S. lanata*

– Leaf blades lanceolate, chartaceous, base attenuate; phyllaries in 4(5) rows, densely tomentose, outer phyllaries ovate-elliptic ..............................................

2. Stem diameter < 1 cm; leaf margin green; capitula usually 1 rarely 2; receptacle bristles 6–8 mm long; corolla tube 10–13 mm and limb 6–9 mm including 4–5 mm lobes; anthers ~8 mm with 1.5 mm tails .............. *S. roylei*

– Stem diameter > 1.3 cm; leaf margin purple; capitula 1 or 3; receptacle bristles ~4 mm long; corolla tube 5–7 mm and limb 4–6 mm including 1.5–2.2 mm lobes; anthers ~5 mm with 1.2 mm tails .................................. *S. talungensis*

**Acknowledgements**

We have conducted botanical expedition in Humla district in reference to the long-term biodiversity conservation and monitoring program of Kailash Sacred Landscape Conservation and Development Initiative, implemented by International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. Authors are thankful to Department of Plant Resources (DPR), Kathmandu, Nepal, Division Forest Office, Humla, Nepal and Department of Forest, Kathmandu, Nepal for research permission. The field expedition was financially supported by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Kathmandu, Nepal and ICIMOD. The laboratory and molecular works were financially supported by the Second Tibetan Plateau Scientific Expedition and Research (STEP) programme (2019QZKK0502). The authors acknowledge Alexander Robert O’Neill (USA) for valuable inputs and English language editing, and to Asha Poudel, Smriti Lo, Chhabi Thapa, Prem Subedi, Rabi Rokaya and Shyamjor Lama for the help during field expedition.
References


A new species of Viola (Violaceae) from Guangdong Province, China

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Abstract

Viola huizhouensis (Violaceae), a new species from Xiangtoushan National Nature Reserve of Guangdong Province in China, is described and illustrated. The new species is most similar to V. guangzhouensis, but it can be easily distinguished by its much stouter rhizome, lack of aerial stem, dense pubescence of the basal pedicel and the whole plant. Our phylogenetic analysis, based on ITS sequences, confirms that the new species belongs to V. sect. Diffusae.

Keywords

Morphology, new species, phylogeny, section Diffusae, Viola huizhouensis

Introduction

Mount Xiangtoushan in Guangdong Province, China, is located in a subtropical zone with abundant rainfall, mainly a low-lying hilly landform, but has an extremely high altitude compared with the surrounding environment. A large area of granite in this region is exposed on the surface due to intense erosion and denudation and there are climax lithophytic vegetation communities with a high level of biodiversity. During fieldwork in March 2018 for the investigation of the biodiversity patterns in this mountainous region, a distinct new species, Viola huizhouensis, was collected on Mount Xiangtoushan.
Viola L. is the largest genus of family Violaceae, with approximately 525–600 species around the world (Ballard et al. 1998; Clausen 1929). This genus has a high level of morphological differentiation and there are hybridisation and horizontal evolution amongst sections and species (Marcussen et al. 2015). There are about 93–108 native Viola species in China which belong to four subgenera according to Yuzepchuk and Klokov’s (1949) classification, i.e. Melanium, Chamaemelanium, Dischidium and Viola. Amongst them, Viola is the largest subgenus, which includes nine sections and 78–95 species in China (Wang 1991; Chen et al. 2007).

Material and methods

Leaf material of the putative new species and its related species V. guangzhouensis, was collected and stored with silica gel in zip-lock plastic bags until use for comparisons and taxonomical treatment. Specimens of V. huizhouensis and V. guangzhouensis were collected respectively from Darenryan, Xiangtoushan National Nature Reserve and Shaoashangling, LiuXi River State Forest Park in March 2018. Voucher specimens were deposited in the Herbarium of Sun Yat-sen University (SYS).

Total DNA was extracted with the modified CTAB method (Doyle and Doyle 1987). The regions of partial internal transcribed spacer 1, 5.8S ribosomal RNA gene and partial internal transcribed spacer 2 were amplified using previously-reported primers ITS1, ITS4 (White et al. 1990). PCR amplifications were performed following Fan et al. (2015). The sequences of the species and related ones, downloaded from NCBI, were aligned using MEGA 6.0 (Tamura et al. 2013) with ClusterW and subsequently manually adjusted. Phylogenetic constructions were carried out with Maximum Likelihood (ML). ML was run by Iqtree 2.0.3 (Minh 2020), selecting best-fit model TIM+F+G4 with 2000 bootstraps. Phylogenetic analyses, based on Bayesian Inference (BI) were carried out using MrBayes version 3.1.2 (Huelsenbeck and Ronquist 2001). Bayesian analysis was run with four chains for 200,000 generations with the first 25% of sampled trees discarded as burn-in. Main quantitative characteristics of the putative new species and V. guangzhouensis were statistically analysed using IBM SPSS version 22.0.

Result

The aligned length of ITS sequences was 638 bps in total. ML and BI analyses produced similar topology (Fig. 1 and Suppl. material 1: Fig. S1). The samples of the putative new species (Viola huizhouensis) and V. guangzhouensis A.Q. Dong, J.S. Zhou & F.W. Xing, clustered into their own species clade respectively, with strong support (BS = 100% for V. huizhouensis and BS = 98% for V. guangzhouensis). The V. huizhouensis clade clustered with the V. guangzhouensis clade, forming a sister relationship (BS = 100%). Then, the two species, together with V. yunnanensis W. Beck. & H. De Boiss., V. diffusa Ging., V. nanlingensis J.S. Zhou & F.W. Xing and V. lucens W. Beck., consti-
Figure 1. Maximum Likelihood tree of the new species and related species. Numbers beside branch nodes are bootstraps. Outgroups: Rinorea bengalensis. Viola huizhouensis clade is marked in green and V. guangzhouensis clade is marked in red.
tuted a monophyletic clade (BS = 99%). Quantitative characteristics and a statistical analysis showed that there was a significant difference between *V. huizhouensis* and *V. guangzhouensis* in the diameter of rhizome and the leaf shape (Table 2).

**Table 1.** Morphological differences between the species *V. huizhouensis* and *V. guangzhouensis*.

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>V. huizhouensis</em></th>
<th><em>V. guangzhouensis</em></th>
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<tbody>
<tr>
<td>Leaf shape</td>
<td>narrowly ovate to ovate, apex obtuse, never acute</td>
<td>ovate-triangular to narrowly triangular, apex acute obtusely dentate</td>
</tr>
<tr>
<td>Leaf margin</td>
<td>coarsely serrate</td>
<td></td>
</tr>
<tr>
<td>Rhizome</td>
<td>rhizome erect or obliquely erect, rather stout, 4–7 mm diam.</td>
<td>rhizome obliquely ascending, slender, 1–2 mm diam.</td>
</tr>
<tr>
<td>Aerial stem</td>
<td>lack of aerial stem</td>
<td>slender, 1–1.5 mm diam., 10–25 cm tall</td>
</tr>
<tr>
<td>Pedicel</td>
<td>pedicel basal, 6–10 cm long, densely pubescent</td>
<td>pedicel basal or axillary, 5–8 cm long, sparsely puberulous or subglabrous</td>
</tr>
</tbody>
</table>

**Table 2.** Quantitative characteristics and significant difference analysis of the species *V. huizhouensis* and *V. guangzhouensis*.

<table>
<thead>
<tr>
<th>Quantitative characteristics</th>
<th><em>V. huizhouensis</em></th>
<th><em>V. guangzhouensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>(l_p) (mm)</td>
<td>24.4 ± 9.9</td>
<td>53.4 ± 14.9</td>
</tr>
<tr>
<td>(l_m) (mm)</td>
<td>22.2 ± 5.0</td>
<td>31.4 ± 7.1</td>
</tr>
<tr>
<td>(L) (mm)</td>
<td>22.5 ± 5.2</td>
<td>34.8 ± 7.5</td>
</tr>
<tr>
<td>(L/l_m)</td>
<td>1.01 ± 0.02</td>
<td>1.11 ± 0.04</td>
</tr>
<tr>
<td>(N)</td>
<td>304.1 ± 73.9</td>
<td>92.3 ± 16.5</td>
</tr>
<tr>
<td>(D) (mm)</td>
<td>4.53 ± 1.47</td>
<td>1.61 ± 0.34</td>
</tr>
</tbody>
</table>

Note: \(l_p\) = length of petiole; \(l_m\) = distance from the proximal end of the mid-vein to the distal end; \(L\) = lamina length; \(N\) = number of the pubescence per 25 mm²; \(D\) = rhizome diameter. Independent-Sample Mann-Whitney Test was used and seven rhizomes and 30 basal leaves were measured for each species, all quantitative characteristics representing significant difference at the 0.5% nominal level.

**Viola huizhouensis** Y. S. Huang & Q. Fan, sp. nov.
urn:lsid:ipni.org:names:77216568-1
惠州堇菜

**Type.** China. Guangdong: Huizhou City, Xiangtoushan National Nature Reserve, Darenyan, 23°15.99′N, 114°22.27′E, 535 m a.s.l., 29 March 2018, Y. S. Huang and Q. Fan 1803 (holotype: SYS; isotypes: IBSC, SYS). (Figs 2, 3)

**Diagnosis.** *Viola huizhouensis* is most similar to *V. guangzhouensis*, but differs by its much stouter rhizome, lack of aerial stem, different leaf shape and dense pubescence of the basal pedicel and the whole plant.

**Description.** Herbs, perennial, basal leaves rosulate, 10–15 cm tall. Rhizome erect or obliquely erect, rather stout, 4–7 mm diam.; stolons with an apical rosette of leaves, usually producing adventitious roots. Leaves alternate; stipules leaf-like, base adnate to the petiole, densely pubescent, lanceolate, 6–8 × 1–1.5 mm, apex acuminate, margins sparsely fimbriate or fimbriate-laciniate; pedioles densely pubescent, 3–5 cm long, narrowly decurrent-alate; blades narrowly ovate to ovate, apex obtuse, 1.5–3 × 1–2 cm, thinly leathery or chartaceous, densely pubescent, abaxially dark purple, 5 to 7 veins on
A new violet species from the South China

Figure 2. *Viola huizhouensis* A habitat B habit C young capsule with sepals and bracteoles D stem with stipules E abaxial surface of leaf blade F bracteoles G flowers H petals I longitudinal section of stigma and ovary J comparison of leaf blades. Left, *V. guangzhouensis*. Right, *V. huizhouensis*. K. Specimen of *V. huizhouensis* (Y.S. Huang and Q. Fan 1803). L. Specimen of *V. guangzhouensis* (Y.S. Huang 1804).
Figure 3. *Viola huizhouensis* A habit and flowering branch B leaf and stipules C flower, front view and lateral view D young capsule with sepals and bracteoles and dehiscent capsule with seeds E stamens in adaxial view (below) and abaxial view (above) F stigma and pistil G bracteoles H petals.

each side of mid-rib, margin coarsely serrate, base cuneate. Flowers 15–18 mm diam.; pedicels slender, 6–10 cm long, pubescent, usually exceeding leaves, with two opposite bracteoles above middle; bracteoles lanceolate, pubescent, 4–8 mm long, margin entire, apex obtuse. Sepals green, pubescent, linear-lanceolate, 2.7–3.7 × 0.5–1 mm, margin entire, apex obtuse, base truncate or rounded. Petals whitish to light purple,
A new violet species from the South China

with apparent violet lines, anterior one with a yellow to green patch at base; upper petals, oblong to linear-lanceolate, 2.5–3 × 0.5–0.8 mm, glabrous, margin entire, apex obtuse or erose; lateral petals with glandular hairs at the base adaxially, oblong, 4.5–5 × ca. 1.5 mm, margin entire, apex obtuse or erose; anterior petal with a short saccate spur at base, broadly spatulate or flabellate, margin entire to slightly undulate, apex obtuse. Stamens 5, unequal, puberulent, the anther thecae ca. 1 mm long, terminal appendages ca. 0.7 mm long, the posterior appendages (nectar spurs) of two anterior stamens 0.7–1 mm long. Ovary ovoid to ellipsoid, ca. 0.7 mm diam., puberulent; style ca. 1.0 mm long, conspicuous geniculate at base; stigma thickly margined on lateral sides, slightly raised at central part, shortly beaked at the apex. Capsule with brownish lines at maturity, ovoid, 6–8 mm long. Seeds brown, ovoid, 1–1.5 mm long.

**Phenology.** Flowering from March to June, fruiting from April to July.

**Distribution, ecology and conservation status.** Populations of *Viola huizhouensis* were only discovered in Darenyan, Xiangtoushan National Nature Reserve, Guangdong Province. The species was observed to grow on damp cliffs and rocks in broad-leaved forests at altitudes between 400 and 800 m. Its known localities are well protected and more field investigations are needed to determine its distribution.

**Note.** Based on its slightly 2-lobed stigma and stolons topped by rosettes of leaves, *Viola huizhouensis* should be a member of section *Diffusae* (W. Beck.) C.J. Wang, which was formerly treated as subsection *Diffusae* under section *Viola* by Becker (1925). The closest relative of *V. huizhouensis* on morphological grounds could be *V. guangzhouensis*. They shared several characteristics, for example, the well-developed rhizome and the bearded lateral petals. The new species can be distinguished from *V. guangzhouensis*, however, by its much stouter rhizome; lack of aerial stem; different leaf shape (apex obtuse, never acute vs. apex acute); and dense pubescence of the basal pedicel and the whole plant (vs. the basal pedicel sparsely puberulous or subglabrous and the stem glabrous) (Tables 1, 2; Fig. 2).

The ITS tree shows that *V. huizhouensis* is sister to *V. guangzhouensis* (BS = 100%), then they form a well-supported clade with *V. yunnanensis*, *V. diffusa*, *V. nanlingensis* and *V. lucens* (BS = 99%) (Fig. 1). *Viola guangzhouensis* and the other four species in this clade all belong to section *Diffusae* (Dong et al. 2009). Thus, the phylogenetic analysis supports *V. huizhouensis* as being close to *V. guangzhouensis* and belongs to section *Diffusae*.

In conclusion, the morphological differences and the molecular phylogenetic results provide sufficient evidence for treating *V. huizhouensis* as a distinct new species and it is a member of section *Diffusae* (W. Beck.) C.J. Wang (Wang 1991).

**Acknowledgements**

We are deeply grateful to Mrs Yun-Xiao Liu for her excellent illustration in the manuscript. This study was supported by the project of the Research on Co-evolution of Vegetation and Geological Environment of Shenzhen Dapeng Peninsula Geopark (2020F36), the project of the Fourth Survey of Chinese Traditional Medicine Re-
sources (2019-302-001; 2019-303-001), the National Natural Science Foundation of China (31800175) and the Natural Science Foundation of Guangdong Province (2018A0303130109).

References


# Appendix I

GenBank accessions for phylogenetic analysis.

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<th>Taxon</th>
<th>GenBank accessions</th>
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<td><em>V. huizhouensis</em>5</td>
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<td><em>V. huizhouensis</em>6</td>
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<tr>
<td>Rinorea bengalensis</td>
<td>FJ002919</td>
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</table>
Supplementary material I

Figure S1
Authors: Yan-Shuang Huang, Ning Kang, Xiang-Jing Zhong, Wen-Bo Liao, Qiang Fan
Data type: molecular data
Explanation note: Strict consensus tree derived from ITS sequence with Bayesian posterior probabilities in the nodes.
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Link: https://doi.org/10.3897/phytokeys.176.65443.suppl1
Revision of Gymnomitriaceae (Marchantiophyta) in the Korean Peninsula

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Abstract
This paper provides a revision of Gymnomitrion and Marsupella in the Korean Peninsula based on a study of the collections housed in the herbaria of Jeonbuk National University (JNU) and the Botanical Garden-Institute in Vladivostok (VBGI). In total, 12 species were recorded (six in Gymnomitrion and seven in Marsupella), including four taxa whose identity was not confirmed with the available materials and suspected to be recorded wrongly. Each confirmed species is annotated by morphological descriptions based on available Korean material, data on ecology, distribution, specimens examined as well as illustrations.

Keywords
Gymnomitriaceae, Gymnomitrion, Hepaticae, Korean Peninsula, Marsupella, taxonomy

Introduction

Gymnomitriaceae in the recent World Liverwort Checklist (Söderström et al. 2016) include Nardia, which is clearly distinct from other genera in the family due to the presence of underleaves. In fact, as demonstrated by Shaw et al. (2015), who were the first to transfer Nardia to Gymnomitriaceae, Nardia formed a basal clade to all other genera traditionally included in the family (Gymnomitrion, Marsupella, Prasanthus, Poeltia). It is therefore questionable whether Nardia should be treated as a member of Gymnomitriaceae or as a representative of its own family which has not yet been described. Following the second possibility (although refraining from any taxonomical formalities), we treat

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Gymnomitriaceae in the Korean Peninsula as housing only *Gymnomitrion* and *Marsupella*, putting aside *Nardia*. This point of view corroborates with that accepted in the worldwide compendium of Gymnomitriaceae by Váňa et al. (2010). Gymnomitriaceae house 85 taxa that occur in all continents. This family is most common and diverse in hemiarctic and alpine areas of Holarctic, with other noticeable diversity centers in the Sino-Himalayas and East Asia (Váňa et al. 2010). The recent advances in the *Marsupella* taxonomy in East Asia revealed that some additional taxa need to be recognized, including one taxon described from the Korean Peninsula that at this stage of knowledge is endemic to the Korean liverwort flora (Bakalin et al. 2019). Temperate East Asia (including Northeast China, Japan, Korean Peninsula and South Kurils) is characterized by the occurrence of a number of remarkable *Marsupella* species with ‘scapanioid' appearance due to strong distichous leaf arrangement and conduplicate leaves with commonly unequal leaf lobes and distinct keel. These ‘scapanioid' *Marsupella* are absent outside East Asia. Three species of this group occur in the Korean Peninsula.

The main goal of the present paper was to revise Gymnomitriaceae for the Korean Peninsula as it was never substantially revised. Moreover, despite the peculiarity of Gymnomitriaceae flora in East Asia, the family was never revised in eastern China, adjacent to the Korean Peninsula, while the revision for Japan (Kitagawa 1963) is somewhat outdated. Recent advances in knowledge about Gymnomitriaceae have been summarized in the Liverwort and Hornwort Flora of Korea (Choi et al. 2017). However, the long history of the preparation of this flora has resulted in the fact that it is already out of date, despite being recently published. The flora was based on the data available until the spring of 2015 and does not include novelties published in 2016 and later. Due to these circumstances, it does not include the recently described *Marsupella koreana* Bakalin et Fedosov, which is mistakenly named as *M. pseudofunckii* S.Hatt. in the flora. It also does not include a record of *M. vermiformis* (R.M.Schust.) Bakalin et Fedosov identified by molecular methods (Bakalin et al. 2019). *Gymnomitrion faurianum* (Steph.) Horik. was completely confused with *G. concinnatum* (Lightf.) Corda, while *G. parvitextum* (Steph.) Mamontov, Konstant. et Potemkin was misidentified as *G. commutatum* (Limpr.) Schiffn. It is worth mentioning that *G. commutatum* was nevertheless found in South Korea in Jeju-do, from where it was first reported by Mamontov et al. (2018), whereas other reports of *G. commutatum* occurring in the literature are based entirely on *G. parvitextum*. Therefore, about half of the information provided by Choi et al. (2017) is incorrect. Moreover, the flora provides the only identification keys (unreliable due to the aforementioned omissions) and morphological descriptions but does not include illustrations and taxonomical comments describing differentiation features. These facts inspired us to compile a new version of the Gymnomitriaceae revision.

**Methods**

Owing to the data at hand, it is known that Gymnomitriaceae s. str. is represented in the Korean Peninsula by only two genera: *Marsupella* and *Gymnomitrion*. Therefore,
regarding the species concept in particular cases, we were guided by recent works in this field, including Bakalin (2016), Bakalin et al. (2019), and Mamontov et al. (2018, 2019). The foundation of the work was formed on the basis of a study of over 500 specimens. This exhausts approximately 90% of all existing specimens of Gymnomitriaceae collected in the Korean peninsula (the numerical data on the northern part of the peninsula are unavailable and not included in this account). The main collections of Korean liverworts are now in JNU and VBGI, although some historical collections are available from HIRO, NICH, and G. Types were studied for several taxa indicated in the text.

This paper provides the descriptions compiled based on the study of specimens collected in Korea and to a lesser extent, the types. The morphological descriptions are supplemented by figures, list of specimens examined, discussion on ecology, distribution, and, in some cases, the taxonomy and morphology. The distribution within the Korean Peninsula, described using official regionalization, extended throughout the Korean Peninsula despite covering different countries (Fig. 1). This regionalization was accepted by both North Korean bryologists (Kim and Hwang 1991) and South Korean and Japanese hepaticologists (Yamada and Choe 1997) and is the most appropriate for our tasks. The data on the species distribution in adjacent areas are mostly from Bakalin (2010: the Russian Far East), Yamada and Iwatsuki (2006: Japan), Piippo (1990: China), the recent updates were added from the literature cited in each case separately.

The morphological descriptions for family and genera use features known in the taxa recorded in the Korean Peninsula. The taxa reported in the literature, but not revealed in the present revision (and suspected to be erroneously reported) are keyed out, in square brackets and are not supplied with descriptions; rather they are briefly discussed in the section ‘Excluded taxa’. After the accepted name of the species, only a few common synonyms are provided, with an emphasis on names previously applied to plants from the Korean Peninsula.

**Taxonomic treatment**


**Description.** Plants rigid to soft, variously colored. Rhizoids sparse to dense, mostly colorless, rarely purple. Stem with differentiation into scleroderm, hyaloderm and inner tissue or without differentiation (then mostly pachydermous in structure). Leaves shallowly emarginate to bilobed (not more than 2/5 of leaf length) into equal to unequal lobes. Underleaves absent (present in *Nardia* not treated here). Androecia intercalary, stalk biseriate. Perianth well developed to reduced or totally absent. Perigynium well developed to absent (and then perianth wanting or strongly reduced). Elaters with 2–4 spirals.

**Comment.** The above description is applicable to the Gymnomitriaceae taxa occurring in the Korean Peninsula.
Key to genera recorded in Korea

1 Plants with well-developed perigynium and reduced, but always distinct perianth, loosely leaved, leaves mostly (excluding androecious branches) not imbricate, if imbricate (*M. vermiformis*), then leaves narrower than the stem; leaf margin plane or revolute, if revolute the cell size in the midleaf wider 10 μm wide and never with large subquadrate trigones roughly equal in size to the cell lumen, giving the cell network a chequered appearance ............ *Marsupella*  

Plants with strongly reduced to absent perigynium and virtually absent perianth, leaves wider than stem, with margin plane or revolute, commonly imbricate, if not (*G. parvitextum*) then leaf margin is narrowly revolute (at least evident in the leaf base), cells in the midleaf less 10 μm wide, with large subquadrate trigones roughly equal in size to the cell lumen, giving the cell network a chequered appearance ........................................... *Gymnomitrion*


**Description.** Plants forming loose patches, commonly ascending or rarely creeping in habitats with strong insolation and incrusted by soil particles, deeply (deep green, brown-green, brown purple, blackish brown) to pale (yellowish, brownish, greenish and their combinations) colored, merely rigid, varying in size from 0.5 to 2.0 mm wide and 5.0–50.0 mm long. Rhizoids sporadic to solitary, although invariably present in ventral geotropic leafless stolons, colorless to grayish and soft-textured, or rarely and solitary purple and rigid. Stem with common ventral branching and rare lateral branches, with characteristic geotropic stolons present in the majority of taxa; in cross section mostly differentiated into three strata: hyaloderm, scleroderm and inner tissue. Leaves transversely or nearly so inserted, obliquely to erect spreading from sheathing or not sheathing base, concave to canaliculate and strongly conduplicate, divided by evident but not deep sinus into two equal to strongly unequal lobes with rounded to acute apices. Underleaves absent. Cells in the leaf in the most taxa pachydermous with large convex trigones, unequally thickened along margin and having smooth cuticle; oil-bodies few in number, (1–)2–3(–4) per cell, finely granulate to papillose or almost smooth, rarely with central eye. Dioicous. Androecia intercalary, spicate, antheridium stalk biseriate (rarely uniseriate near the base). Perianth short, but always developed, onion-shaped or conical, wider than long, mostly hidden, but rarely emergent from bracts; perigynium well developed, commonly 2–3 times longer than the perianth, with (1–)2 pairs of bracts. Elaters 2–4-spiral, spores brownish, papillose.

**Comment.** *Marsupella* is easily recognized, even in the field, due to characteristic rigid texture, transversely inserted and sheathing stem leaves, absence of underleaves, and hidden perianth. Under the microscope, additional features such as pachydermous leaf cells, defined scleroderm in stem cross section, few oil bodies, and high perigynium are helpful to refer specimens to this genus.
This paper accepts recent emendations for the circumscription of *Marsupella*,
the most valuable being the removal of ‘perianth-less’ taxa (e.g., *M. commutata*) to
*Gymnomitrion*. Five species were confirmed for this genus in Korean flora and one
(*M. sphacelata*) regarded as likely reported erroneously.

In the specimens examined section, we cite only one specimen per locality (or 2
to 3, if they were collected at different elevations) with the intention of economizing
space. Only specimens from the Korean Peninsula are cited.

**Key to *Marsupella* species recorded in Korea**

1. Plants with strongly distichously arranged and keeled to narrowly canalicu-
late leaves, lobe apices acute to obtuse.................................................2
   – Plants not strongly distichous, concave to canaliculate (never conduplicate),
     lobe apices acute to rounded..........................................................4
2. Plants noticeable dilated to perianth, leaves conduplicate, lobes unequal, with
   margin plane, leaf keel distinct......................................................... *M. pseudofunckii*
   – Plants slightly or not dilated to the perianth, conduplicate to canaliculate,
     lobes unequal to subequal, with margin plane to recurved, leaf keel distinct
     or not ..................................................................................................3
3. Leaf lobes subequal, leaf margin commonly undulate and never narrowly re-
curved, leaf lobes commonly turned to dorsal side, midleaf cell with thick
walls and relatively small and concave trigones............................. *M. yakushimensis*
   – Leaf lobes unequal, leaf margin recurved, never undulate, leaf lobes never
     turned dorsally, midleaf cells with thin to slightly thickened walls and moder-
ate to large, convex trigones................................................................. *M. koreana*
4. Plants vermiform, with leaves narrower than the stem (except very apex) and
   very tightly appressed to the stem ..................................................... *M. vermiformis*
   – Plants with leaves spreading, distinctly wider than the stem...............5
5. Leaves lax, sometimes shallowly undulate at margin, divided by sinus de-
   scending at most for 2/5 of the leaf length, plants with green to brownish
   coloration (never red), hyaloderm in stem cross section with cells twice as
   large as inner cells, oil bodies not biconcentric [not confirmed for Korea]....
   ........................................................................................................... *[M. sphacelata]*
   – Leaves merely rigid, with recurved margins (sometimes obscurely so or only
     near the leaf base), distinctly concave, never undulate at margins, divided by
     sinus descending at most for 1/5(-1/4) of the leaf length, plants sometimes
     red, hyaloderm cells in the stem cross section less 1.5 times as inner cells, oil
     bodies biconcentric or not .................................................................6
6. Oil bodies without central eye or with very small eye, plants’ color varying in
   exposed places to brown and rusty, but never red and purple..... *M. apertifolia*
   – Oil bodies always or at least in 50% of oil bodies with central eye, plants com-
     monly purple in exposed places....................................................... *M. tubulosa*

Figure 2


**Type.** Japan, Miyokosan, U. Faurie 75 (*lectotype* (designated here): G [009469]).

**Description.** Plants in rather loose patches, rigid to more soft, erect or nearly so, mostly deep green to brownish green in color, but with many other variants intergrading to yellowish-brownish, yellowish, and pale greenish (later only in shaded wet places) or to deep brown and rusty pigmentation in insolated moist habitats; mostly 1.2–1.6 mm wide and 7.0–15.0 mm long, with small forms starting from 0.75–1.0 mm wide and robust varying to 1.5–2.2 mm wide. Branching lateral (rare) or ventral as subfloral innovations (more common), stem transversely elliptic in the cross section, 200.0–300.0 μm high (extreme variants not included) and 250.0–350.0 μm wide; outer cells (hyaloderm) nearly thin, with small trigones, 15.0–25.0 μm along margin, scleroderm in 3–4 layers, with cells slightly smaller, very thick-walled, with lumen just 8.0–11.0 μm, inner cells (10.0–12.0–20.0 μm, thin- to slightly thickened, with moderate in size, triangle to concave trigones. Rhizoids sparse to virtually absent, mostly colorless to brownish, in unclear obliquely to erect spreading fascicles, rarely (and very few in number) separated and deep purple. Leaves mostly contiguous and loosely enclosed one to another, to subimbricate or nearly distant in lax modifications, concave to canaliculate-concave, transversely inserted, evidently sheathing the stem in the base and obliquely to erect spreading above, transversely, subtransversely or (more rarely) obliquely oriented, with margin commonly narrowly recurved, at least in lower half of the leaf; transversely elliptic to orbicular and widely ovate in shape, mostly 500.0–750.0 μm long and 550.0–1050.0 μm wide, reaching in lax forms 1500.0–2250.0 × 1550.0–2750.0 μm, divided by sinus descending to 1/7–1/5(1/4) of leaf length into two nearly equal to subequal lobes; sinus varying from narrowly to widely γ-shaped; lobes rounded to (rarely) obtuse in apex. Cells in the midleaf subsisodiametric to shortly oblong, (12.0–20.0–25.0 × (12.0–13.0–25.0 μm, thin-walled to slightly thickened, trigones mostly large, rarer moderate in size, convex to bulging, cuticle smooth; cells along margin in upper part of leaf 5.0–8.0(–10.0) μm, mostly unequally thickened due to trigones confluence, trigones large, convex to concave, cuticle smooth; cells in the lobe middle similar to that in the midleaf or slightly smaller, 12.0–20.0 × 11.0–15.0 μm, thin-walled, trigones large, convex to bulging, cuticle smooth. Dioicous. Androecia intercalary, spicate, with 3–4 pairs of bracts, (1–)2–3-androus, antheridium body obovate, 130.0–150.0 μm wide, stalk biseriate, 100–150 μm long; bracts strongly inflate in lower half and obliquely to erect (especially lobes) spreading above,
trapezoidal-subtransversely elliptic. Perianth hidden within bracts or very shortly exerted, conical to onion-shaped, 400.0–750.0 × 750.0 μm; perigynium 750.0–1000.0 μm long, with two pairs of bracts; bracts sheathing perigynium in lower part and obliquely spreading above (lobes of lower pair commonly deflexed).

**Ecology.** Acidophilic hygro- to hydrophyte, occupying various habitats, from very wet (and even submerged) shaded cliffs near running water to moist mineral substrata in full sun. In moist and sunny habitats, robust phases are formed (then commonly acquiring deep rusty-brown pigmentation), where it is associated with *Anastrophyllum assimile*, *Trilophozia quinquedentata*, and *Diplophyllum taxifolium*. As an extreme variant, the species may be intermixed with *Gymnomitrion faurianum*. In wet and shady habitats, its common association is *Cephalozia otaruensis*.

**Distribution.** Montane temperate Kurils-Japanese-Korean endemic species is known in northern and middle Japan (until Shikoku), South Korea and South Kurils (Iturup Island), likely more widely distributed, at least to Kamchatka Peninsula in

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* The nomenclature of taxa mentioned in the ‘Ecology’ section follows Söderström et al. (2016).

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Figure 2. *Marsupella apertifolia* Steph. **A** male plant **B** female plants **C** stem cross section (fragment) **D** plant habit **E–H** leaves **I, K** cells along leaf margin **J** midleaf cells **L** gynoecium longitudinal section. Scale bars: a 1 mm (**A, B, D–H, L**); b 100 μm (**C, I–K**). All from Choi 7383 (JNU). Drawing by S.J. Park.

**Specimens examined.** **Chungcheongnam-do:** Mt. Daedun, 36°08'02.9"N, 127°18'29.1"E, 343 m, 31 Mar 2009, S.S. Choi 3405 (JNU); **Gangwon-do:** Mt. Seorak, 38°07'21.0"N, 128°27'27.7"E, 1649 m, 21 Sep 2009, S.S. Choi 5174 (JNU), Mt. Seorak, 38°07'42.2"N, 128°26'21.6"E, 1011 m, 14 Oct 2010, S.S. Choi 8607 (JNU), Mt. Seorak, 38°07'52.7"N, 128°26'11.2"E, 937 m, 14 Oct 2010, S.S. Choi 8632 (JNU); **Gyeongsangnam-do:** Mt. Jiri, 35°19'20.6"N, 127°44'59.4"E, 1134 m, 14 Jun 2009, S.S. Choi 3745 (JNU), Mt. Jiri, 35°20'01.7"N, 127°43'55.1"E, 1713 m, 3 Oct 2011, S.S. Choi 111079 (JNU), Mt. Namdeogyu, 30 Oct 2008, S.S. Choi 1119 (JNU); **Jeju-do:** Erimok valley, 33°21'59.6"N, 126°30'40.3"E, 1591 m, 6 Sep 2012, S.S. Choi 120765 (JNU), Erimok valley, 33°21'59.6"N, 126°30'40.27"E, 1615 m, 6 Sep 2012, S.S. Choi 120797 (JNU), Mt. Halla, 33°22'02.2"N, 126°33'05.9"E, 1563 m, 8 Aug 2010, S.S. Choi 7737 (JNU), Mt. Halla, 33°21'42.1"N, 126°32'02.8"E, 1861 m, 21 Sep 2012, S.S. Choi 120904 (JNU), Hyodon stream, 33°18'21.4"N, 126°33'38.5"E, 469 m, 7 Aug 2010, S.S. Choi 7638 (JNU), Witse Oreum, 33°21'33.4", 126°30'54.2"E, 1668 m, 7 Sep 2012, S.S. Choi 120847 (JNU); **Jeollabuk-do:** Mt. Deogyu, 22 Nov 2008, S.S. Choi site 2-35 (JNU), Mt. Jiri, 35°19'25.0"N, 127°41'36.8"E, 1300 m, 7 Oct 2009, S.S. Choi 6090 (JNU), Mt. Jiri, 35°19'50.1"N, 127°41'33.5"E, 1100 m, 21 May 2010, S.S. Choi 7383 (JNU); **Jeollanam-do:** Mt. Dureun, 5 Feb 2009, S.S. Choi 3064 (JNU), Mt. Jiri, 35°19'15.3"N, 127°31'50.0"E, 755 m, 19 Sep 2009, S.S. Choi 5043 (JNU).

**Comments.** This species was regarded as the variety within *M. emarginata* subsp. *tubulosa* by Kitagawa (1963); however, we agree with Stephani (1901) and treat it as a separate species because of the differences in DNA sequences between two taxa (Bakalin et al. 2019). *Marsupella apertifolia* differs from *M. tubulosa* in mostly rounded lobe apices (versus mostly acute), more or less equal lobes (versus distinctly unequal), non-biconcentric oil bodies (versus biconcentric), and constant absence of red or purple pigmentation.

*Marsupella koreana* Bakalin et Fedosov, Cryptogamie, Bryologie 40(7): 67, 2019

**Type.** South Korea, Gyeongsangnam-do, Jiri Mts., National Park, 7.V.2015, Bakalin V. A. Kor-28-4-15 (*holotype* VBGI!, *isotypes* MW!, JNU!).

**Description.** Plants in loose mats, more or less rigid, strongly distichous, brownish green to deep green, brownish greenish and yellowish brownish, also brown with rusty tint to brown purple, 500.0–1100.0 μm wide and 10.0–25.0 mm long. Rhizoids absent or very few, but common in geotropic stolons, colorless to grayish, obliquely to erect spreading. Stem rarely produces normal ventral branches, whereas commonly with ventral geotropic leafless stolons, almost always with 1–2 subfloral ventral or lateral innovations near gynoecia; stem cross section nearly rounded to slightly transversely...
elliptic, differentiated into strata, with outer layer cells 10.0–13.0 μm along margin, unequally thickened, but with thin and easily destroying external side, with moderate to small concave trigones; scleroderm well developed, in 2–3 layers, walls very thick, sometimes with visible median lamina, 7.0–10.0 μm in diameter, but with lumen only 3.0–6.0 μm in diameter, trigones moderate to large, concave; inner cells irregular in shape, 10.0–15.0 μm in diameter, walls thickened, trigones moderate, concave. Leaves distichously arranged, transversely to subtransversely inserted, obliquely spreading and subtransversely oriented, margins narrowly recurved in the both (dorsal and ventral) sides, narrowly canaliculate (looks conduplicate) with 'keel' slightly arched or nearly straight (in poorly developed phases), divided by gamma-shaped sinus into two strongly unequal gibbous lobes, lobe apices acute to obtuse. Cells in the midleaf mostly oblong, rarer subsodiometric, 7.0–20.0 × 7.0–13.0 μm, walls thickened, trigones large, triangle to convex, cuticle smooth, cells along lobe margin 5.0–10.0 μm, with unequally thickened walls, trigones small to moderate in size, concave, cuticle smooth; cells in the lobe middle 7.0–15.0 × 7.0–12.0 μm, with walls thickened to thin, trigones large and convex, sometimes confluent; oil-bodies (1–)2(–3) per midleaf cell, not bi-concentric, spherical to oblong, ca. 5.0–7.5 × 5.0 μm. Dioicus. Androecia intercalary, with 2–3 pairs of bracts (but adjacent 1–2 pairs of ‘sterile’ leaves are similar with bracts that gives the impression of long androecia), spicate, bracts cupped to spoon-shaped, with recurved margin, suborbicular and lacerate when flattened in the slide, divided by γ-shaped sinus into two almost equal gibbous lobes, 750.0–875.0 × 825.0–1050.0 μm, 2–3-androus, antheridium stalk biseriate, 100.0–200.0 μm long, body nearly spherical ca. 100.0–120.0 μm in diameter. Perianth hidden within bracts or shortly exerted, onion-shaped, ca. 250.0 × 600.0 μm; perigynium well developed, 600.0–800.0 μm long (when archegonia fertilized), with two pairs of bracts, bracts sheathing perianth, with lobes incurred to perianth or very narrowly spreading. Elaters entirely bispiral, ca.

Table 1. Distinction of Marsupella koreana from morphologically similar taxa.

<table>
<thead>
<tr>
<th>Features</th>
<th><em>M. pseudofunckii</em></th>
<th><em>M. apertifolia</em></th>
<th><em>M. yakushimensis</em></th>
<th><em>M. tubulosa</em></th>
<th><em>M. patens</em></th>
<th><em>M. koreana</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobes</td>
<td>unequal</td>
<td>more or less equal</td>
<td>unequal to slightly unequal</td>
<td>unequal</td>
<td>unequal</td>
<td>unequal</td>
</tr>
<tr>
<td>Leaf margin</td>
<td>Plane</td>
<td>recurved (at least in basal part)</td>
<td>plane to undulate</td>
<td>plane to indistinctly recurved near base</td>
<td>plane</td>
<td>recurved</td>
</tr>
<tr>
<td>Lobe apex</td>
<td>acute to obtuse</td>
<td>rounded</td>
<td>acute to obtuse</td>
<td>acute to obtuse</td>
<td>rounded</td>
<td>acute to obtuse</td>
</tr>
<tr>
<td>Cell wall in the midleaf</td>
<td>thin to slightly thickened</td>
<td>thin to slightly thickened</td>
<td>thick</td>
<td>thin to slightly thickened</td>
<td>thin to slightly thickened</td>
<td>thin to slightly thickened</td>
</tr>
<tr>
<td>Trigones in the midleaf</td>
<td>convex</td>
<td>convex</td>
<td>concave</td>
<td>convex to triangle</td>
<td>convex to triangle</td>
<td>convex</td>
</tr>
</tbody>
</table>
| Leaf basal part        | unistratose        | unistratose or bistratose in large phases | bistratose | unistratose | unistratose | unistratose  
| Leaf shape             | strongly conduplicate | concave-canaliculate to concave and nearly flattened | strongly conduplicate | canaliculate-concave to concave and canaliculate | canaliculate-concave | canaliculate  
| Purple shoot           | very rare          | sometimes present | common in Japan, but rare in Korea | very common   | common      | common      |
| Pigmentation           |                    |                  |                    |               |             |             |
200.0 \times 7.0–8.0 \, \mu m, with narrowed (sometimes even homogenous as in ‘Plectocolea-type’) ends. Spores brown, papillose, spherical, 10.0–11.0 \, \mu m in diameter.

**Ecology.** Acidophilic to neutro-tolerant meso- to hygrophyte. The ecology of this species is somewhat similar to that of *M. pseudofunkii*. It occupies mesic, rarely moist, or dry substrates in open to partly shaded areas. Among the common associates in drier habitats, *Sphenolobus minutus*, in open subalpine stations, it sometimes grows together with *Gymnomitrion parvitextum*. In wetter habitats *M. koreana* may grow with *Marsupella tubulosa* and *Cephalozia otaruensis*.

**Distribution.** Montane temperate species, known from only the southern part of the Korean Peninsula, but probably spreading northward. In Korea, Jeju-do, Chungchennie-do, Gyeongsangnam-do, Jeollabuk-do and Jeollanam-do (Bakalin et al. 2019).

**Specimens examined.** *Chungcheonnam-do:* Mt. Daedun, 36°08'02.9"N, 127°18’29.1"E, 343 m, 31 Mar 2009, S.S. Choi 3407 (JNU); *Gyeongsangnam-do:* Mt. Gaya, 35°49’14.8"N, 128°07’27.5"E, 1313 m, 8 Sep 2009, S.S. Choi (JNU), Mt. Gaya, 35°47’30.1"N, 128°05’46.3"E, 521 m, 28 Apr 2009, S.S. Choi 3511 (JNU), Mt. Gaya, 35°49’30.7"N, 128°07’07.9"E, 1350 m, 22 Jun 2010, S.S. Choi 7402 (JNU), Mt. Jiri, 35°18’51.9"N, 127°44’22.1"E, 848 m, 13 Jun 2009, S.S. Choi 3628 (JNU), Mt. Jiri.

Comments. This distinctive species is one of the most common Korean Marsupella members, completely misidentified with a couple of other taxa (most frequently with M. yakushimensis, M. apertifolia, M. pseudofunckii and M. tubulosa). It belongs to the peculiar group of East Asian Marsupella taxa with ‘scapanioid’ appearance. Tentatively, we suggest that M. koreana occurs in mainland China (we were unable to check whether specimens identified as M. pseudofunckii from China (Gao and Wu 2007) are in fact M. koreana), as well as in Japan. We were unable to find this taxon in areas adjacent to the Korean Peninsula northward, in the Primorsky Territory of Russia. The main distinctions between the mentioned morphologically related taxa are presented in Table 1.

Marsupella koreana is most morphologically similar to M. patens (N. Kitag.) Bakalin et Fedosov (the taxon not present in Korea proper and probably limited to the Japanese Archipelago) and M. pseudofunckii. The main distinctions of the former are in recurved leaf margins that are always flat or undulate in M. patens as well as in acute to obtuse (but in any way angular) lobe end, versus rounded in M. patens. The distinctions from M. pseudofunckii are the presence of narrowly recurved leaf margins in M. koreana, shoots not or slightly dilated to the perianth (versus distinctly dilated in M. pseudofunckii) and narrowly canaliculate, but not keeled-conduplicate (as in M. pseudofunckii) leaves.

Marsupella pseudofunckii S.Hatt., J. Hattori Bot. Lab. 4: 63, 1950

Figure 4

Type. Japan, Echime Prefectura, Omogo, 27 July 1940, S. Hattori 5540 (holotype TNS [174467!])

Description. Plants in loose mats, more or less rigid, erect to ascending, strongly distichous, brownish green to deep green, rarely brown with rusty, purplish or reddish tint near apices, strongly dilated to the perianth, 500.0–600.0 μm wide in normally developed part, with common depauperate plants (in shady and dry habitats) starting from 150.0 μm wide, near perianth much wider and reaching 1100.0 μm, 10.0–25.0 mm long. Rhizoids virtually absent with exception of leafless geotropic stolons, where common, obliquely spreading, separated or united into unclear fascicles. Stem branching ventral and (more commonly) lateral, as subfloral innovations and ventral leafless geotropic stolons that sometimes transform into normal branches; stem cross section transversely elliptic, differentiated into strata, outer layer with walls
unequally thickened (but external wall thin), 12.0–25.0 μm along margin, trigones moderate, concave, scleroderm cells 10.0–13.0 μm in diameter, with strongly thickened walls and moderate in size, concave trigones, gradually transformed to inner tissue, cells in inner part 10.0–18.0 μm in diameter, walls thickened to almost thin, trigones moderate, concave. Leaves transversely inserted, not or barely sheathing stem in base, obliquely spreading, transversely oriented, evidently keeled-conduplicate with plane margin, keel straight to slightly arched or suddenly turned downward near the

**Figure 4.** Marsupella pseudofunckii S.Hatt. A plant habit B, C leaves D female plant (fragment) E male plant (fragment) F cells along leaf margin G midleaf cells H stem cross section. Scale bars: a 1 mm (A); b 100 μm (F–H); c 1 mm (B–E). All from Choi 545 (JNU).
end, leaves contiguous to distant, rarely enclosed one to another, 220.0–430.0 μm long and 300.0–600.0 μm wide, obliquely transversely elliptic, divided by γ-shaped sinus descending to 1/4–1/3 of leaf length into two strongly unequal gibbous lobes with acute to obtuse or very rarely rounded apices. Cells in the midleaf 10.0–18.0 × 7.0–15.0 μm, walls thin, trigones moderate in size to large, triangle to convex, cuticle smooth; cells along margin 5.0–8.0(–10.0) μm, thin to (more commonly) thickened, trigones small to large, mostly concave, cuticle smooth; cells in lobe middle 7.0–15.0 × 6.0–12.0 μm, walls thin to thick, trigones moderate to large, triangle to convex. Dioicous. Androecia intercalary, spicate, with 2–3 pairs of bracts, sequential generations divided by 10 and more pairs of sterile leaves, 1–3-androus, stalk biseriate, 125.0–220.0 μm long, body nearly spherical, ca. 150.0 μm in diameter; bracts cupped to spoon-shaped, commonly with recurved margin. Perianth hidden within bracts or barely exerted, couple-shaped, ca. 150.0 μm long and 400.0 μm wide, perigynium well developed, 500.0–700.0 μm long, with two pairs of bracts; bracts sheathing perigynium and above incurved inward to the perianth if archegonia were fertilized, or obliquely spreading, if archegonia not fertilized.

**Ecology.** Acidophilic meso- to hygrophyte taxon. The species occupies dry to moist cliffs, rarely wet rocks as well as stones near streams, in open to (more commonly) partly shaded places. It grows together with various Scapania and Cephaloziella or Marsupella tubulosa in wetter habitats. In dry to mesic and shady conditions, it is associated with Tetralophozia filiformis, Bazzania ovifolia, Cylindrocolea recurvifolia, Diplophyllum taxifolium, D. albicans, and Syzygiella autumnalis.

**Distribution.** Temperate Montane East Asian species, aside from Korea known from China (Taiwan, Zhejiang (the report from the latter is based on Zhu et al. 1998)), Russian Far East (southern Sikhote-Alin only), and Japan. In Korea, Jeju-do, Chungchengnam-do, Gyeongbuk-do, Gyeongnam-do, Gangwon-do, and Jeollabuk-do (Kim and Hwang 1991; Yamada and Choe 1997). This species is here newly recorded from Gyeongsangbuk-do Province.

**Specimens examined.** **Chungchengnam-do:** Mt. Daedun, 36°08′02.9″N, 127°18′29.1″E, 343 m, 31 Mar 2009, S.S. Choi 3414 (JNU), Mt. Gyeryong, 36°21′06.9″N, 127°12′50.9″E, 290 m, 8 Jul 2009, S.S. Choi 4083 (JNU); **Gangwon-do:** Mt. Seorak, 38°06′02.8″N, 128°23′43.1″E, 840 m, 28 Aug 2009, S.S. Choi 4257 (JNU), Mt. Seorak, 38°06′35.7″N, 128°25′33.7″E, 1449 m, 21 Sep 2009, S.S. Choi 5146 (JNU), Mt. Seorak, 38°07′55.5″N, 128°25′42.3″E, 805 m, 14 Oct 2010, S.S. Choi 8655 (JNU); **Gyeongsangbuk-do:** Is. Ulleung, Mt. Mireuk, 26 Aug 2008, S.S. Choi site5-191 (JNU), Seonginbong, 22 Aug 2008, S.S. Choi site6-48 (JNU); **Gyeongsangnam-do:** Mt. Jiri, 35°20′02.4″N, 127°43′54.2″E, 1720 m, 15 Jun 2009, S.S. Choi 3772 (JNU); **Jeju-do:** Mt. Halla, 33°21′45.3″N, 126°32′08.9″E, 1916 m, 8 Aug 2010, S.S. Choi 7757 (JNU); **Jeollabuk-do:** Mt. Deogyu, 22 May 2008, S.S. Choi 545 (JNU), Mt. Jeoksang, 35°57′24.3″N, 127°41′86.3″E, 724 m, 18 Mar 2009, S.S. Choi 3416 (JNU), Mt. Naejang, 35°29′16.2″N, 126°53′46.3″E, 250 m, 16 Mar 2009, S.S. Choi 3482 (JNU); **Jeollanam-do:** Mt. Dureun, 5 Feb 2009, S.S. Choi 3057 (JNU), Mt. Jiri, 35°17′44.0″N, 127°31′59.0″E, 1421 m, 29 Apr 2009, S.S. Choi 3537 (JNU).
Comments. This is a distinctive species belonging to the group of *Marsupella* with conduplicate leaves. It may be mistaken for *M. koreana* (distinguishing characters given under that species) or (less probably) for *M. yakushimensis*. The latter and *M. pseudofunckii* share conduplicate leaves with not revolute margins, although being different in: 1) lobes are subequal in *M. yakushimensis*, but strongly unequal in *M. pseudofunckii*, 2) leaf margin of *M. yakushimensis* is commonly undulate and lobe ends turned away of the stem, whereas leaf margin in *M. pseudofunckii* is always plane and not reflexed away from the stem, 3) shoots of *M. pseudofunckii* are strongly dilated to the perianth, versus almost stable shoot width in *M. yakushimensis*, 4) the width of sterile shoots of *M. pseudofunckii* generally less than 0.6 mm, but in *M. yakushimensis* it commonly is more than 1.5 mm.

*Marsupella tubulosa* Steph., Bull. Herb. Boiss. 5: 99, 1897

*Fig. 5*


**Type.** Japan, Unzen, 5 Mar 1895, *Faurie* 15385 (*lectotype* (designated here) G [15042/00061032!])

**Description.** Plants merely rigid, forming loose patches, deep green-brown, purple-brown, purple-green, or rarely greenish (actually plants extracted from the patch yellowish brownish in general, but with purple-rusty coloration in apices and upper parts of insolated leaves that gives expression of purple-brown color of patch), or yellowish greenish, pale brownish with purple tint in apical parts, rarer brownish greenish without purple or rusty pigmentation; 0.6–1.2 mm wide (the largest lax plants up to 1.3–1.5 mm) and 5.0–15.0 mm long. Rhizoids nearly absent or few, colorless. Stem brownish, not branched or branched as ventral leafless stolons (rarely becoming to normal branch) or more commonly as subfloral ventral or lateral innovations; transversely elliptic in cross section, 160.0–180.0 μm high and 200.0–250.0 μm wide (depauperate shoots omitted), differentiated into strata; hyaloderm with external wall thin, radial walls thin to unequally thickened (becoming thicker inward), inner wall thick, 15.0–20.0 μm along margin; scleroderm in (1–)2 rows of cells, cells thick-walled, but not so strongly as in *M. apertifolia*; inner cells thin to slightly thickened, trigones moderate in size, concave, 12.0–18.0 μm in diameter. Leaves contiguous to distant, sometimes ‘enclosed’ one to another, concave to almost flattened in upper half, transversely inserted, evidently or very loosely sheathing stem in the base, obliquely (rarely erect) spreading, subtransversely to obliquely oriented, suborbicular to widely ovate, margin flat to loosely recurved near base (especially in the leaves sheathing the stem), divided into two unequal (rarely subequal) lobes by widely V- to γ-shaped sinus descending to 1/7–1/5(1/4) of leaf length, lobe apex couple-shaped, obtuse to acute. Cells in the midleaf shortly oblong, 10.0–20.0(–25.0) × 8.0–16.0(–18.0) μm, walls thin to slightly thickened,
trigon large to (rarer) moderate in size, convex to bulging, cuticle smooth; cells along leaf margin 6.0–12.0 μm, walls thin to slightly (to strongly and unequally) thickened in tangential walls, trigones moderate to large, concave to slightly convex, tangentially sometimes confluent; cells in lobe middle oblong, 15.0–22.0 × 8.0–13.0 μm, walls thin to slightly thickened, trigones moderate to large, convex to triangle. Oil-bodies in the midleaf cells 2(–3) per cell, biconcentric (at least (30–)70%), finely to normally papillose, spherical, ca. 5.0 μm in diameter to oblong, 7.5–12.5 × 5.0–7.5 μm. Dioicous. Androecia intercalary, with 1–3 or 3–5 pairs of bracts, different generations divided by

**Figure 5. Marsupella tubulosa** Steph. A gynoecium longitudinal section B stem cross section (fragment) C plant habit, dorsal view D leaf margin cells E, F leaves G elater, H midleaf cells. Scale bars: 1 mm (A, C, E, F); b 100 μm (B, D, G, H). All from Choi 3732 (JNU).
4–8 pairs of sterile leaves, spicate, 3–5-androus, stalk biseriate, 75.0–100.0 μm long, body ellipsoidal, ca. 140.0 × 115.0 μm; bracts spoon-shaped, nearly subquadrate when flattened, with deflexed to erect-spreading lobes. Perianth onion-shaped, hidden within bracts, ca. 300.0 × 500.0 μm; perigynium 500.0–700.0 μm long, with (1–)2 pairs of bracts; bracts sheathing perianth near base and erect spreading in upper 1/3–1/2. Capsule elliptic, outer layer cells rectangular, 27.0–50.0 × 20.0–25 μm, with 2(–4) nodular thickenings in vertical walls and 1(–3) thickenings in horizontal wall; inner cells elongate and flexuous, 45.0–63.0 × 7.0–10.0 μm, with 7–10 sometimes bifurcate semicircular bands. Elaters (2–)3-spiral, 150.0–180.0 × 7.0–8.0 μm. Spores brown, papilllose, spherical, 10.0–12.0 μm in diameter.

**Ecology.** Acidophilic meso- to hygrophyte. The species occupies sandy soils and mineral substrates, over wet to moist, and sometimes mesic cliffs, being most common along streams near running water. In drier habitats, it is commonly associated with *Odontoschisma pseudogrossiverrucosum*, *Cheirolejeunea obtusifolia*, and rarely with *Microlejeunea punctiformis*, *Cephalozia* spp., *Gymnomitrion faurianum*. In wetter habitats *M. tubulosa* sometimes grows intermixed with *Solenostoma minutissimum*, *Lophocolea horikowana*, *Marsupella pseudofunckii*, and *M. koreana*.

**Distribution.** The distribution of the species is confined to insular and peninsular areas in Amphi-Pacific Boreal and Temperate Eastern Asia, while the records provided by Bakalin, (2010), Cherdantseva and Gambaryan (1986), Gambaryan (1992, 2001), Konstantinova et al. (2002) for the Russian Far East continental mainland are likely incorrect. This species is strikingly characterized by biconcentric oil bodies – an uncommon feature in *Marsupella* that has never been reported from continental Asia or from North America. This suggests the reports of the species in Schuster (1974) for North America and Schljakov (1981) for Russian Asia are incorrect. We suggest the ‘true’ *M. tubulosa* (the type is from Honshu) occurs only in Japan, Kurils, Kamchatka and the Korean Peninsula, as well as probably in China (Anhui, Taiwan), from where, unfortunately, oil bodies were not studied. All specimens collected in the continental mainland of the Russian Far East and checked alive had non-biconcentric oil bodies, whereas specimens from peninsular and insular parts of the Far East possess biconcentric oil bodies. The species was recorded for nearly all provinces of the Korean Peninsula (Jeju-do, Gyeongsangnam-do, Gyeongsangbuk-do, Chungcheongnam-do, Chungcheongbuk-do, Gyeonggi-do, Gangwon-do, Yeonganbuk-do, Hamgyeongnam-do, Hamgyeongbuk-do: Yamada and Choe 1997; Kim and Hwang 1991) and was confirmed for most of the provinces in the southern part of the peninsula.

**Specimens examined.** Chungcheongnam-do: Mt. Daedun, 36°08’02.9”N, 127°18’29.1”E, 343 m, 31 Mar 2009, S.S. Choi 3399 (JNU), Mt. Gyeryong, 36°21’06.9”N, 127°12’50.9”E, 290 m, 8 Jul 2009, S.S. Choi 4098 (JNU); Gangwon-do: Mt. Seorak, 38°06’02.8”N, 128°23’43.1”E, 840 m, 28 Aug 2009, S.S. Choi 4258 (JNU), Mt. Seorak, 38°06’39.7”N, 128°24’56.2”E, 1347 m, 21 Sep 2009, S.S. Choi 5095 (JNU), Mt. Seorak, 38°07’21.0”N, 128°27’27.7”E, 1649 m, 21 Sep 2009, S.S. Choi 5175 (JNU); Gyeongsangbuk-do: Is. Ulleung, Seonginbong, 37°29’39.5”N,
130°52’35.4"E, 845 m, 20 Oct 2010, S.S. Choi 8712 (JNU), 37°29’53.9"N, 130°52’01.0"E, 977 m, 20 Oct 2010, S.S. Choi 8744 (JNU); **Gyeongsangnam-do:** Mt. Gaya, 35°48’53.9"N, 128°07’21.9"E, 1116 m, 8 Sep 2009, S.S. Choi 4361 (JNU), 35°49’14.8"N, 128°07’27.5"E, 1313 m, 8 Sep 2009, S.S. Choi 4376 (JNU), Mt. Jiri, 35°18’51.9"N, 127°44’22.1"E, 848 m, 13 Jun 2009, S.S. Choi 3741 (JNU), 35°19’50.7"N, 127°44’08.1"E, 1540 m, 14 Jun 2009, S.S. Choi 3732 (JNU); **Jeju-do:** Bolre Oreum, 33°21’20.8"N, 126°28’10.2"E, 1145 m, 5 Sep 2012, S.S. Choi 120721 (JNU), Erimok valley, 33°21’59.6"N, 126°30’40.25"E, 1613 m, 6 Sep 2012, S.S. Choi 20795 (JNU), Mt. Halla, 33°21’43.1"N, 126°32’21.9"E, 1835 m, 8 Aug 2010, S.S. Choi 7745 (JNU), Musu stream, 33°25’08.0"N, 126°26’56.4"E, 495 m, 28 Oct 2010, S.S. Choi 8827 (JNU), Suak valley, 33°20’14.0"N, 126°36’37.8"E, 523 m, 29 Oct 2010, S.S. Choi 8879 (JNU); **Jeollabuk-do:** Mt. Deogyu, 30 Jun 2008, S.S. Choi 887 (JNU), Mt. Jiri, 35°19’06.1"N, 127°31’47.5"E, 781 m, 20 Jun 2009, S.S. Choi 3993 (JNU); **Jeollanam-do:** Mt. Dureun, 5 Feb 2009, S.S. Choi 3061 (JNU), Mt. Jogyeo, 34°59’51.6"N, 127°16’51.7"E, 288 m, 7 Dec 2010, S.S. Choi 9094 (JNU).

**Comments.** This species may be confused with at least three other species: *Marsupella koreana*, *M. apertifolia*, and *M. emarginata*, though the last is not known from the Korean Peninsula. The distinctions between the former two are mentioned under those species. The species differs from *M. emarginata* (with which *M. tubulosa* was probably confused in parts outside of oceanic/suboceanic Eastern Asia) in biconcentric oil bodies (versus oil bodies without the central eye) and commonly obliquely oriented leaves that are not closely sheathing the stem in the base (versus transversely oriented leaves with leaves closely sheathing the stem near base). The latter feature is surely quantitative and variation in leaf orientation occurs within the two species.

*Marsupella vermiformis* (R.M.Schust.) Bakalin et Fedosov, Cryptogamie, Bryologie 40(7): 70, 2019

**Figures 6, 7I–K**


**Type.** Malaysia. North Borneo: Mt. Kinabalu National Park, S. slope, around Paca Cave, 2985 m, Mizutani, 2788 (not seen).

**Description.** Plants strongly vermicular, forming loose patches, brown to blackish brown, without red or purple pigmentation, orbicular in cross section, 100.0–140.0 μm in diameter, 3.0–6.0 mm long, freely ventrally branched, from leafless brownish to whitish in color densely ventrally branched rhizome. Rhizoids virtually absent, to solitary, colorless, obliquely spreading, short (less than 100.0 μm long). Stem 100.0–170.0 μm in diameter, orbicular in cross section, outer layer cells with external wall thin to obscurely thickened, tangential walls subequally thickened, trigones small, concave, walls brown in color, 6.0–10.0 μm in diameter, inner cells with
walls unequally thickened, walls colorless, trigones moderate in size, concave. Leaves appressed to the stem (commonly lacerate into two segments when try to detach), transversely inserted and oriented, not decurrent, widely triangular, 65.0–110.0 μm long and 90.0–175.0 μm wide, divided by V-shaped sinus descending to 2/5–1/2 of leaf length into two subequal triangle lobes with acute apices. Cells in the midleaf 5.0–10.0 × 5.0–8.0 μm, walls moderately thickened, trigones small, concave; cuticle smooth; oil-bodies 1–2 per cell, spherical, 2.0–3.0 μm in diameter. Dioicous. Pants suddenly dilated to the perianth, to form club-shaped structure, perianth completely hidden within bracts, nearly conical, 75.0–100.0 μm long and 200.0–230.0 μm wide, smooth, perigynium 120.0–150.0 μm long, with one pair of bracts; bracts nearly orbicular to orbicular-triangular in shape, ca. 250.0 × 250.0 μm, covering perianth and then occlude one with another.

Ecology. Acidophilic meso-xerophyte. In Korea, it occurs on dry well-exposed rocks in large block gravelly barrens in the crater rim of Halla Mt. *Marsupella vermiformis* formed pure patches or a slight admixture of *Gymnomitrion faurianum* or dwarf form of *Marsupella tubulosa*.

Distribution. Strongly disjunct rare taxon ranging the area from southernmost Korea (Jeju-do) across China, to Malaysia and Papuasia (Bakalin et al. 2019). The species belong to the oligotypic section *Stolonicaulon* (N.Kitag.) Vaňa, which it shares with rare South and South-East Asian *M. stoloniformis* N.Kitag.

Specimens examined. Jeju-do: Mt. Halla, 33°21’42.1”N, 126°32’02.8”E, 1861 m, 21 Sep 2012, S.S. Choi 120911, 120897 (JNU, VBGI).
Comment. The very distinctive species, superficially quite similar to Gymnomitrion pacificum Grolle due to vermicular shoots and never spreading, but closely appressed leaves, forming in female branches, a club-like structure. It is clearly different from G. pacificum in having much smaller leaves, with normally developed cells along the margin and presence of distinct perianth. The species may be mistaken for dwarf forms of arctic-alpine sub-circumpolar amphi-oceanic Marsupella boeckii (Austin) Lindb. ex Kaal. and, possible, European (amphi-Atlantic) – British Columbian (cf. Paton 1999) Marsupella stableri Spruce. However, besides distinct gaps in distribution this species differs: 1) the never spreading leaves in M. vermiformis versus at least slightly spreading in perianthous shoots in M. boeckii and obliquely spreading to squarrose in M. stableri, 2) shoot width not exceeding 140.0–170.0 μm, versus 200.0–500.0 μm in M. boeckii, and 100–400 μm in M. stableri, 3) small cells with brown colored, thickened tangential walls in stem cross

Figure 7. Gymnomitrion noguchianum S.Hatt. A, B, F leaves C plant habit (fragment) D plant habit E lacerate leaf apex G cells along leaf margin H stem cross section (fragment). All from Choi 120826 (JNU); Marsupella vermiformis (R.M.Schust.) Bakalin et Fedosov I, J leaves K plant habit (fragment). All from Choi 120911 (JNU). Scale bars: a 250 μm (A–C, F); a 500 μm (D); b 100 μm (E, G–J); c 100 μm (K).
Revision of Gymnomitriaceae (Marchantiophyta) in the Korean Peninsula

section in *M. vermiformis*, versus large and hyaline cells in *M. boeckii* and *M. stableri*), 4) small leaves that are wider than long, reaching at maximum 175.0 μm wide and 110 μm long, versus 200–300 μm wide in *M. boeckii* and distinctly longer than wide (up to 300 × 200 μm) in *M. stableri*, 5) very small leaf cells, 5.0–10.0 × 5.0–8.0 μm in *M. vermiformis*, versus 12.0–20.0 × 12.0–20.0 μm in *M. boeckii* and 10–16 μm in diameter in *M. stableri*. The distinction from *M. stoloniformis* (hardly possible in Korea) as well as the phylogenetic position of both is discussed by Bakalin et al. (2019).


Figure 8


**Type.** Japan. Kagoshima Pref., Yakushima Island, Horikawa, 11895 (not seen).

**Description.** Plants in loose patches, deep green-brown, yellow-brown, yellowish brownish, rarely with purple tint, (1.0)1.5–2.1 mm wide and 15.0–50.0 mm long, rigid. Rhizoids nearly absent to very sparse, colorless, obliquely spreading, however common in basal part of ventral branches and leafless stolons. Stem easily laterally and ventrally branched giving start to normal branches or geotropic leafless stolons; stem transversely elliptic in cross section 210.0–240.0 μm high and 250.0–320.0 μm wide, distinctly differentiated into strata, hyaloderm cell walls moderately thickened (but external wall thin), with small concave trigones, 17.0–25.0 μm along margin, scleroderm cells with very thick walls and visible median lamina, 12.0–17.0 μm in diameter, but with lumen disappearing or only 2.0–6.0 μm in diameter, inner cells with moderately thickened walls and moderate in size, concave trigones, 10.0–15.0 μm in diameter. Leaves strongly conduplicate and distichously arranged that gives ‘scapanioid’ appearance, contiguous to imbricate, as a rule enclosed one to another, obliquely spreading and transversely oriented, when flattened subquadrate, rectangular or obovate to suborbicular (mostly wider than long, but sometimes longer than wide), bistratose in lower 1/5–1/6 of the leaf length, 675.0–1250.0 μm long and 800.0–1500.0 μm wide, commonly dorsally secund, divided by ϒ-shaped sinus descending to 1/4–2/5 of leaf length into two equal to subequal lobes (either ventral or dorsal may be smaller), lobes gibbous, with obtuse to acute or rarely rounded apex. Cells in the midleaf subsisodiametric to (mostly) oblong, 12.0–25.0 × 7.0–20.0 μm, strongly thick-walled, with moderate to small, concave trigones, cuticle smooth; cells along leaf margin 7.0–10.0 μm, thick-walled (but with much thinner external wall), with moderate in size, concave trigones; cells in lobe middle 10.0–17.0 × 8.0–15.0 μm, thick-walled, with small to moderate in size, concave trigones, cuticle smooth. Dioicous. Androecia intercalary, with 2–3 pairs of bracts, spoon-shaped, with revolute margin and commonly deflexed lobe ends. Perianth (only unfertilized were found) hidden within bracts, onion-shaped, perigynium the same length with perianth or slightly longer, with 2 pairs of bracts and 1–3 lateral and ventral subfloral innovations.
Ecology. Acidophilic hygro- to hydrophyte. The species occurs on wet cliffs at a distance from watercourses or on stones washed with sluggishly running water in partly shaded habitats in the middle elevation of mountains covered with evergreen to deciduous broadleaved forests. Commonly, the species forms pure patches or rarer, associated with Scapania undulata.

Distribution. South temperate to subtropical Montane East Asian endemic species known in China (Anhui, Fujian, Guangdong, Jiangxi, Zhejiang), the southern part of the Korean peninsula (the report by Kim and Hwang (1991) for North Korea is doubtful) and the southern half of Japan. The species was reported from Gyeongsangnam-do, Gangwon-do, Gyeongbuk-do (Kim and Hwang 1991; Yamada and Choe 1997) and here added to Jeollabuk-do and Jeju-do. The specimen included in the phylogenetic tree in Bakalin et al. (2019) under the name Marsupella alata S.Hatt. et N.Kitag. (Republic of Korea, Seorak Mt., 11.V.2011, Bakalin, Kor-6-28a-11, VBGI) was re-studied and found as the dwarf modification of M. yakushimensis. Although the distinctive differences between cited specimen and another accession of M. yakushimensis may suspect more robust than infraspecific differences that should be considered in future studies of the genus in East Asia.

Specimens examined. Gangwon-do: Mt. Seorak, 38°09′34.3″N, 128°28′10.5″E, 631 m, 11 Oct 2010, S.S. Choi 8347 (JNU); Gyeongsangnam-do: Mt. Jiri,
Comments. This large and beautiful species is a rarity within the Korean flora and is known only from a few localities. Unlike Japanese populations, the Korean populations acquire purple to red pigmentation as an exception. The main characteristic of the species includes nearly equal lobes that do not have recurved margins, but commonly undulate and/or turned antically. Another characteristic feature is the absence of a distinctly sheathing leaf base. Dwarf plants of *M. yakushimensis* may be mistaken for *M. koreana*, and the distinctions are given under the latter. This species is regularly observed with androecia and rarely with archegonia. Androecious and gynoecious plants were intermixed within two specimens; however, we were unable to observe fertilized (in at least two descendant generations) and fully developed perianth. Whether this is the norm or not is not clear.

### Gymnomitrion Corda, Naturalientausch 12: 651, 1829.

**Description.** Plants worm-shaped to ribbon-like, with densely imbricate leaves or similar to *Marsupella* and with loosely spreading leaves, rigid to soft, whitish to brownish, brown, rusty, and blackish brown, without red or purple pigmentation. There are two kinds of phenotypes: *Gymnomitrion* in the old sense and the former genus *Apomarsupella* R.M. Schust. nested within Gymnomitrion (cf. Shaw et al. 2015). The first phenotype, with imbricate leaves and stems creeping to ascending, subclavate, from rhizomatous base, dorsiventrally compressed, commonly immersed to the substrate and incrusted by soil particles. The second phenotype comprises plants with spreading leaves with shoots dorsiventrally not compressed, as well as having a not evident rhizomatous base. In both ‘phenotypes’ rhizoids are common in the rhizomatous shoot base and geotropic stolons, but rare in leafy parts of the shoot, soft, colorless to grayish or rarely and solitarily deep purple. Stem not evidently different in strata, rather it is monomorphic (outer layer cells slightly larger), cells with unequally thickened walls, and well-developed trigones. Leaves lobed to unlobed or shallowly emarginate, with plane or narrowly recurved margin. Leaf cells pachydermous, commonly with the rim of discolored cells. Dioicous (taxa known in Korea). Androecia intercalary, (1–)2(–3)-androus, stalk biseriate. Perigynium and perianth virtually absent or strongly reduced. Elaters bispiral.

**Comment.** This treatment follows the recent emendations e.g. transfer to *Gymnomitrion* of the taxa *Marsupella commutata* (Limprr.) Bernet and *Apomarsupella revoluta* (cf. Shaw et al. 2015). These transfers made *Marsupella* more monomorphic in the series of features, but resulted in greater polymorphism in vegetative characters of *Gymnomitrion*, which now includes many taxa of ‘marsupelloid’ habit, although in reproductive characters is characterized by an absence, or strong reduction of, perianth and perigynium.
Key to Gymnomitrion taxa recorded in Korea

1 Leaves entire to emarginate, never distinctly bilobed .......... *G. noguchianum*
   – Leaves distinctly bilobed .............................................................. 2

2 Plants from huge rhizomatous base, leaved part clavate, leaves densely imbricate, leaf margin plane and discolored ................................................................. 3
   – Plants lacking huge rhizomatous base, not or scarcely clavate, leaves loosely spreading, margin not discolored, revolute (at least in base) ....................... 5

3 Branches vermicular, brownish to nearly brown (sometimes pure green in Europe, but such forms were never seen in Eastern Asia), cells along leaf margin nearly thick-walled, with large and convex trigones, never erose [not confirmed for Korea] ................................................................. [ *G. concinnatum* ]
   – Branches dorsiventrally compressed, whitish to grayish, rarely yellowish brownish, cells along leaf margin thin-walled .................................................. 4

4 Leaves with acute lobes, cells along lobe margin thin-walled, with trigones distinct, mostly with sharply verruculose cuticle (cf. Bakalin, 2016, Figure 3: Q-X), leaf margin persistent ............................................................ *G. faurianum*
   – Leaves with rounded lobe apices, cells along lobe margin thin-walled (easily destroyed in older parts), trigones virtually absent, cuticle smooth [not confirmed for Korea] ................................................................. [ *G. corallioides* ]

5 Black to black-brown plants, trigones in the midleaf concave, in apical part of the leaf triangle and never quadrate, leaf margin always strongly revolute, leaf cuticle coarsely verrucose [not confirmed for Korea] ......................... [ *G. revolutum* ]
   – Plants yellowish, yellow-brown, and yellowish green to somewhat whitish green, rarely blackish brown, trigones in the midleaf bulging, in lobe apex commonly quadrate and giving appearance of chessboard, margin recurved to somewhat plane in upper part of the leaf, leaf cuticle verrucose to smooth .... 6

6 Plants yellowish green to whitish green, somewhat dorsiventrally compressed, leaves distichously arranged, leaf margin crenulate due to projecting cell walls, commonly with hemispherical papillae ........................................... *G. parvitextum*
   – Plants blackish brown, not compressed dorsiventrally, leaves sheathing the stem, not distichous, leaf margin entire, cuticle smooth to finely verrucose, never with hemispherical papillae .................................................... *G. commutatum*


*Marsupella commutata* (Limpr.) Bernet, Cat. Hép. Suisse: 29, 1888

**Type.** Austria. Tirol, Montefuner Tal, 2300 m, 1868, leg. Jack, (lectotype BP (not seen)).
Description. Plants in loose patches, rigid, slightly glistening when dry, hardly soaking, blackish brown, without red or purple pigmentation, 450.0–700.0 μm wide and 5.0–15.0 mm long. Rhizoids nearly absent, with the exception of ventral stolons, where common (sometimes dense), colorless or with admixture of solitary deep purple. Stem brownish to whitish (commonly whitish in geotropic stolons), branching lateral or ventral, rather common as subfloral innovations, also as ventral stolons with scale-like leaves; transversely elliptic in cross section, 120.0–140.0 μm high and 130.0–150.0 μm wide, composed by rather uniform cells, outer layer cells 12.0–20.0 μm along margin, slightly larger than inner cells, with brownish and unequally thickened walls and large (sometimes confluent) concave trigones; inner cells 10.0–18.0 μm, walls unequally thickened, colorless, trigones large, triangular to convex. Leaves imbricate, enclosed one to another, concave-canaliculate to concave and spoon-shaped, transversely inserted, sheathing the stem, loosely obliquely spreading and transversely oriented, sometimes secund dorsally, elliptic to loosely widely ovate or obovate or nearly rectangular, 320.0–500.0 μm long and 300.0–450.0 μm wide, margin recurved to plane in upper part of the leaf, divided by V-shaped sinus, with commonly recurved basal part of the sinus, descending to 1/4–1/3 of leaf length, into two equal to subequal lobes, lobes triangular to gibbous with obtuse to acute, rectangular or even rounded apex. Cells in midleaf 8.0–20.0(–23.0) × 8.0–17.0 μm, walls thin, trigones large, bulging, cuticle smooth to finely verrucose; cells along margin 6.0–11.0 μm, with thin to thickened walls, trigones large, bulging or convex, sometimes confluent, in robust phases external wall protruding, the margin then crenulate, cuticle smooth to verrucose; cells in lobe middle 7.0–13.0 × 7.0–12.0 μm, thin-walled, with large bulging or quadrate and confluent trigones (gives expression of chessboard), cuticle smooth to verrucose.

Ecology. Acidophilic meso-xerophyte, the species occupies more or less dry substrata in exposed to (rarely) partly shaded areas. In the study area was intermixed with Gymnomitrion noguchianum. Distribution. Gymnomitrion commutatum was described based on plants from Austria. Váňa et al. (2010: 20) gave its distribution as “Northern Europe, Middle Europe, Southwestern Europe, Southeastern Europe, Siberia, Russian Far East, China, Eastern Asia, Indian Subcontinent, Malesia, Subarctic America, Western Canada, Northwestern USA”. Many of the Asian records may belong to other taxa, for instance, Gymnomitrion parvitextum, discussed below (Mamontov et al. 2018). In turn G. commutatum may possess disjunctive arctic-alpine distribution. Within Pacific Asia G. commutatum is known from the Russian Far East, Japan, and likely may be found in China. This species is only found in the Halla-san crater rim. It is noteworthy that this species is known from Jeju-do, whereas the morphologically similar G. parvitextum (see below) is not found there, but is quite common in other provinces of Korea.

Specimens examined. Jeju-do: Mt. Halla, 33°21’51.0”N, 126°31’42.9”E, 1814 m, 7 Sep 2012, S.S. Choi 120826 (JNU), 33°21’42.1”N, 126°32’02.8”E,
Comment. The species is very similar to *G. parvitextum*, and the distinctions between the two taxa are described below.

**Gymnomitrion faurianum** (Steph.) Horik., *Acta Phytotaxonomica et Geobotanica* 13: 212. 1943

Figure 9

Basionym. *Acolea fauriana* Steph. Species Hepaticarum 2: 8. 1901

**Type.** Japan. “Tidesan” 29 August, 1898, Faurie 212 (*lectotype* (designated here) G [00067200/15025!])

**Description.** Plants in loose mats, more or less soft, leaved part of shoot distinctly clavate, from rhizomatous base, dorsiventrally compressed, whitish to whitish green and pale brownish in general aspect, due to discolored leaf margins that gives expression of white pigmentation, although middle part of leaves maybe greenish to brownish green, 250.0–800.0 μm wide (large plants to 1000.0 μm wide) and 5.0–15.0 mm long. Rhizoids virtually absent to sparse in leaved shoots, but rather common in rhizomatous base and geotropic leafless stolons, soft, colorless, in indiscernible obliquely spreading fascicles, rarely with admixture of solitary purple in color and rigid rhizoids. Stem in leaved part branched as subfloral innovations, while in rhizomatous base freely and variously branched, leafless geotropic stolons infrequent, originated mostly near base of leaved part of shoot; cross section not differentiated into distinct layers, nearly orbicular to slightly transversely elliptic, 140.0–160.0 μm high and 170.0–190.0 μm long; outer cells slightly larger than inner, 20.0–30.0 μm along margin with walls thick (but external wall thinner), trigones moderate in size, concave; inner cells irregular in shape, with flexuous thickened walls, 15.0–23.0 μm in diameter, trigones moderate in size, concave. Leaves densely imbricate, enclosed one to another, obliquely spreading, transversely oriented, not sheathing in the base, ovate to obliquely ovate and widely triangular in shape, 350.0–700.0 μm long and 400.0–650.0 μm wide, divided by V-shaped sinus descending to 1/7 (smaller plants from drier habitats) – 1/6–1/5 of leaf length into two equal to subequal triangular to loosely gibbous lobes with acute to obtuse apes and distinctly crenulate margins. Cells in the midleaf subisodiametric to rectangular and irregularly oblong, 17.0–30.0 × 17.0–23.0 μm, thin-walled, with moderate to large, convex trigones, cuticle smooth; cells along margin 12.0–18.0 μm, thick- to merely thin-walled, with thinner external wall, discolored in 1–5 cells rows almost to the leaf base, with trigones moderate to small in size, concave, cuticle sharply verrucose; cells in lobe middle 15.0–30.0 × 12.0–(18.0)20.0 μm, walls thin to thickened, trigones varying from moderate to small and from concave to bulging (if trigones become bulging cell walls become thinner), cuticle verrucose to smooth. Dioicous. Androecia intercalary.
Perianth and perigynium absent, bracts similar to leaves, but larger, more deeply divided (up 15–1/4 of the length), with somewhat diverging and spreading, rarely erose-dentate lobes.

**Ecology.** Acidophilic mesophyte. The species occupies mesic to moist (rarely wet) cliffs in open places, and rarely occurs in partly shaded habitats, producing thinner forms with not densely appressed leaves. In drier habitats, it is commonly associated with *Gymnomitrion parvitextum*, dwarf forms of *Sphenolobus saxicola*, saxicolous

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**Figure 9.** *Gymnomitrion faurianum* (Steph.) Horik. A gynoeicum longitudinal section B plant habit C, D leaves E stem cross section (fragment) F midleaf cells G cells in leaf lobe apex. Scale bars: a 1 mm (A–D); b 100 μm (E–G).
modifications of *Anastrophyllum michauxii*, in more wet habitats it may be mixed with *Marsupella pseudojunckii* and *Protolophozia debiliformis*.

**Distribution.** East Asian oro-boreal species widely distributed in northern to middle Japan (although a rarity as far as Yakushima Island), abundant in southern Kurils. Within the Asian mainland, known from Sikhote-Alin mountain system, stretching to South Korea until Jeju-do. Likely to be found in North-East China (at least in Changbai Mountain). Previous reports of *Gymnomitron concinnatum* (Lightf.) Corda from Yanggang-do and Pyeongannam-do (Kim and Hwang 1991) likely belong to this taxon.

**Specimens examined.** **Gangwon-do:** Mt. Seorak, 38°06'35.7"N, 128°25'33.7"E, 1449 m, 21 Sep 2009, S.S. Choi 5148, 5148-2 (JNU), Mt. Seorak, 38°07'09.4"N, 128°27'54.8"E, 1710 m, 21 Sep 2009, S.S. Choi 5206 (JNU), Mt. Seorak, 38°08'02.8"N, 128°28'03.6"E, 908 m, 12 Oct 2010, S.S. Choi 8378, 8381, 8384 (JNU), Mt. Seorak, 38°06'36.3"N, 128°25'33.6"E, 1452 m, 13 Oct 2010, S.S. Choi 8502 (JNU), Mt. Seorak, 38°07'08.9"N, 128°27'55.4"E, 1718 m, 13 Oct 2010, S.S. Choi 8557 (JNU); **Jeju-do:** Mt. Halla, 33°21'45.3"N, 126°32'08.9"E, 1916 m, 8 Aug 2010, S.S. Choi 7759 (JNU), Mt. Halla, 33°21'45.3"N, 126°32'08.9"E, 1916 m, 8 Aug 2010, S.S. Choi 7765a (JNU), Mt. Halla, S.S. Choi 120372 (JNU), Mt. Halla, 33°21'51.0"N, 126°31'42.9"E, 1814 m, 7 Sep 2012, S.S. Choi 120827 (JNU), Mt. Halla, 33°21'42.1"N, 126°32'02.8"E, 1861 m, 21 Sep 2012, S.S. Choi 120890, 120894, 120907, 120909, 120924, 120925, 120936, 120937, 120938 (JNU).

**Comment.** The whitish plant coloration, distichous leaf arrangement, and distinctly bilobed leaves easily help in recognizing *G. faurianum*. The difference from *G. corallioides* is the presence of persistent cells along the leaf margin and verrucose cuticle in the leaf lobes, as was noted in the key. Moreover, we consider the occurrence of *G. corallioides* in Korea unlikely. Another problem is the differentiation of *G. faurianum* from *G. concinnatum*, which shares the papillose cuticle in the leaf apex and stout cell walls in the leaf margins. However, *G. faurianum* differs from *G. concinnatum* in strongly distichous leaf arrangement, dorsiventrally compressed shoots and whitish coloration (although in Europe *G. concinnatum* may be sometimes whitish green and pure green, such modifications were never observed in East Asia) – the features rather resembling *G. corallioides*, which were the reasons for the misidentifications of *G. faurianum* for both *G. concinnatum* and *G. corallioides*, as discussed by Bakalin (2016).


Figure 7A–H

**Type.** Japan. Tottori Prefecture, Daisen Mt., 1400 m, on volcanic rocks, 8 August 1947, A. Noguchi s.n. (*holotype*: NICH [13067!]).

**Description.** Plants in loose mats, more or less soft, leaved part of shoots distinctly clavate from rhizomatous base, dorsiventrally compressed, whitish to whitish green or almost completely white, immersed to soil and incrusted by soil particles, 250–350 μm wide and 500–700 μm long in leaved part, rhizomatous part ca. 3–5 mm long. Rhizoids common to (in rhizomatous base) dense, erect to obliquely spreading, separated or in
unclear fascicles. Stem freely ventrally branched in the base of leaved part and variously and feely branched in rhizome; slightly transversely elliptic in cross section, ca. 100 μm high and 120 μm wide, without evident differentiation into layers, outer cells 12–15 μm along margin, with thick walls (become noticeable thinner to thin in ventral epidermis), with moderate in size, concave trigones, inner cells 7–13 μm in diameter, irregular in shape, with thickened walls and moderate to small in size concave trigones. Leaves densely imbricate, transversely inserted, not sheathing at base, transversely oriented, widely ovate-lingulate to widely triangular, cupped to spoon shaped, lacerate when flattened, 220–330 μm long and 270–500 μm wide, with rounded to emarginate apex and entire to crenulate margin. Cells in the midleaf subsisodiametric (mostly quadrate) to oblong (mostly rectangular), 12–25 × 12–20(23) μm, walls thickened, trigones small to moderate in size, concave, cuticle smooth; cells along leaf margin 5–15 μm, mostly elongate perpendicularly to the margin, walls unequally thickened, trigones small to moderate, concave. Dioicous. Androecia intercalary, with cupped and loosely imbricate bracts. Perianth and perigynium absent, perichaetial area of the shoot distinctly wider than below.

Ecology. Acidophilic meso-xerophyte. The species occupies dry to mesic fine soils in well-exposed places at higher altitudes. It is commonly associated with dwarf xeric forms of Marsupella tubulosa, Gymnomitrion parvitextum, and Cephaloziella divaricata.

Distribution. Temperate Montane Eastern Asian endemic species with distribution confined to Japanese Honshu and Kushu as well as the southern tip of Korea (Jeju Island).

Specimens examined. Jeju-do: Mt. Halla, 33°21'51.0"N, 126°31'42.9"E, 1814 m, 7 Sep 2012, S.S. Choi 120809, 120812, 120826 (JNU).

Comment. Due to the presence of entire to emarginate leaves, Gymnomitrion noguchianum is unlikely to be mistaken for other members of this genus. However, it may be mistaken for Cryptocoleopsis imbricata, but that species is not yet known from the Korean Peninsula, though it should be expected to occur there. Both taxa are similar in prostrate growth, occurring in well-exposed places, and entire imbricate leaves. However, two taxa may be easily separated by 1) leaf cell walls are thickened and smaller in G. noguchianum, versus larger (more than 20 μm wide) and thin-walled in Cryptocoleopsis imbricata, 2) total absence of brown pigmentation in G. noguchianum versus almost constant presence in Cryptocoleopsis; and 3) presence of calyptral perigynium in Cryptocoleopsis – the structure does not occur in Gymnomitrion.

Gymnomitrion parvitextum (Steph.) Mamontov, Konstant. et Potemkin, Nova Hedwigia 106(1–2): 88, 2018

Figure 10


Type. Japan, Tosa, Mt. Tsutsujo, August 1898, Inoue n. 22 (lectotype (designated here): G [9470/00067518]).
Description. Plants in loose patches, rigid, slightly glistening when dry, hardly soaking, yellowish, yellow-brown and yellowish greenish, without red or purple pigmentation, 450.0–1000.0 μm wide and 3.0–20.0 mm long. Rhizoids nearly absent, with the exception of ventral stolons, where common (sometimes dense), colorless or with admixture of solitary deep purple. Stem brownish to whitish (commonly whitish in geotropic stolons), branching lateral or ventral, rather common as subfloral innovations, also as ventral stolons with scale-like leaves; transversely elliptic in cross section, 125.0–175.0 μm high and 150.0–190.0 μm wide, composed by rather uniform cells, outer layer cells 12.0–20.0 μm along margin, slightly larger than inner cells, with brownish and unequally thickened walls and large (sometimes confluent) concave trigones; inner cells 10.0–18.0 μm, walls unequally thickened, colorless, trigones large, triangle to convex. Leaves distichously spreading, enclosed one to another, concave-canaliculate to concave and spoon-shaped, transversely inserted, barely or not sheathing the stem in the base, transversely oriented, sometimes secund dorsally, elliptic to loosely widely ovate or obovate or nearly rectangular, 360.0–670.0 μm long and 500.0–625.0 μm wide, margin recurved to plane in upper part of the leaf, divided by V-shaped sinus, with commonly recurved basal part of the sinus, descending to 1/4–1/3 of leaf length, into two equal to subequal lobes, lobes triangular to gibbous with obtuse to acute, rectangular or even rounded apex. Cells in the midleaf 8.0–20.0(–23.0) × 8.0–17.0 μm, walls thin, trigones large, bulging, cuticle smooth; cells along margin 6.0–11.0 μm, with thin to thickened walls, trigones large, bulging or convex, sometimes confluent, in robust phases protrudent in external wall that gives expression of crenulate margin, cuticle smooth to verrucose; cells in lobe middle 7.0–13.0 × 7.0–12.0 μm, thin-walled, with large bulging or quadrate and confluent trigones (gives expression of chessboard), cuticle smooth to with hemispherical papillae. Dioicous. Androecia intercalary, with 2–4 pairs of bracts (adjacent pairs of leaves somewhat similar in shape with bracts that may be misinterpreted as bracts), spicate, 1(–2)-androus, stalk biseriate, ca. 100.0 μm long, body nearly spherical ca. 130.0–140.0 μm in diameter; bracts spoon-shaped, with more widely than in leaves recurved margin, widely ovate-trapezoidal when flattened. Perianth entirely absent; perigynium absent or very low (up 100.0 μm long); bracts similar to leaves, but longer; commonly with 1–2 subfloral innovations becoming into normal branch and fertilized soon again or forming flagelliform brown colored branch (in drier habitats).

Ecology. Acidophilic meso-xerophyte. The species occupies more or less dry substrata in exposed to (rarely) partly shaded habitats. It is commonly intermixed with Marsupella tubulosa, M. koreana, M. pseudofunckii, Gymnomiotrion faurianum, Herbertus dicranus, Anastrophyllum assimile, or (as exotic variant) with Scapania ampliata.

Distribution. East Asian oro-boreal taxon, known in areas adjacent to the Korea from the Russian Far East, Japan, and likely should be found in China. It was recorded in Korea from Gyeonggi-do, Gyeongsangnam-do, Hamgyeongnam-do (Kim and Hwang 1991; Yamada and Choe 1997) under the name Marsupella commutata. It is also reported from Gangwon-do.

Specimens examined. Gangwon-do: Mt. Seorak, 38°08′02.8″N, 128°28′03.6″E, 908 m, 12 Oct 2010, S.S. Choi 8383 (JNU), Mt. Seorak, 38°07′34.9″N,
128°27’16.0”E, 1487 m, 12 Oct 2010, S.S. Choi 8475 (JNU); Gyeongsangnam-do: Mt. Jiri, 35°19’20.6”N, 127°44’59.4”E, 1134 m, 14 Jun 2009, S.S. Choi 3703 (JNU), 35°20’10.6”N, 127°43’42.0”E, 1820 m, 15 Jun 2009, S.S. Choi 3816 (JNU), Mt. Namdeogyu, 35°45’53.5”N, 127°40’55.5”E, 1422 m, 11 Nov 2010, S.S. Choi 8954 (JNU).

Comment. Easily recognizable species in most cases, although confused several times with dwarf plants of Marsupella tubulosa from which it differs in commonly present subquadrate to quadrate trigones in leaf lobe cells, almost constantly recurved leaf margin, and in the absence of perianth. Gymnomitron parvitextum is morphologically

**Figure 10.** Gymnomitron parvitextum (Steph.) Mamontov, Konstant. et Potemkin A female plant (fragment) B male plant (fragment) C leaf lobe apex D–G leaves H midleaf cells I gynoeodium longitudinal section J stem cross section (fragment). Scale bars: a 1 mm (A, B, D–G); a 500 μm (I); b 100 μm (C, H, J). All from Choi 8475 (JNU).
similar to *G. alpinum*. The two taxa are distinct in the presence of subquadrate trigones in leaf lobe cells in *G. parvitextum* (absent in *G. alpinum*), recurved margin (versus margin plane), shortly or barely decurrent leaf base (versus long decurrent leaf base on both sides in *G. alpinum*) and inability to develop red or purple pigmentation (versus such coloration common in *G. alpinum*).

The bigger problem is the delimitation of *Gymnomitrion parvitextum* from morphologically similar and ‘semicryptic’ (Mamontov et al. 2018) *G. commutatum* (Limpr.) Schiffn., disjunct, mostly northern hemiarctic species. *Gymnomitrion parvitextum* differs from *G. commutatum* in the following features: 1) pale yellowish to brownish and even yellowish-greenish coloration, but never blackish brown and rusty-brown coloration so common in *G. commutatum*, 2) leaves semi-distichously arranged versus leaves subimbricate, 3) leaves in the vast majority of cases with widely recurved margins, versus margin recurved narrowly and commonly near the leaf base only.

**Excluded or doubtful taxa**


**Remarks.** The taxon was recorded for North Korea (Gangwon-do, Hamgyeongnam-do, cf. Kim and Hwang 1991), but was not found in specimens examined. We suggest that all reports regarding the occurrence of this species in Korea and adjacent regions are erroneous and probably belong to *M. apertifolia* to which the species are similar in coloration and rounded leaf lobes, but differ in leaf margin characteristics, leaf sinus deepness, and stem cross section features, all of which are included in the identification key. In general, *M. sphacelata* is a rarity in East Asia and probably absent southward of 53°N (southern part of Kamchatka Peninsula). The records for Honshu Island in Japan are doubtful due to reported red pigmentation (Kitagawa 1963) which is not known for this species from other parts of its range (cf. Schuster 1974).

*Gymnomitrion concinnatum* (Lightf.) Corda, *Gen. Hepat.*: 651, 1829

**Remarks.** All reports of this taxon belong to *G. faurianum*, as discussed under the latter.


**Remarks.** This taxon was recorded for Jeju-do (Yamada and Choe 1997) and identified many times in unpublished collections; however, all so-named specimens checked by us are characterized by acute lobes with persistent cells with moderate size trigones along the leaf margin. These features are characteristics of *Gymnomitrion faurianum*. Everywhere southward of 48°N. in East Asia *G. faurianum* was commonly misidentified as *G. corallioides* (Bakalin 2016).
**Gymnomitrion revolutum** (Nees) H.Philib., Rev. Bryol. 17: 34, 1890.


**Remarks.** This species was recorded on the Korean Peninsula from North Korea (Yang-gang-do, cf. Kim and Hwang 1991) but the vouchers were unavailable for the present study. The species resembles *G. parvitextum*, and the main differences are included in the key. The occurrence of *G. revolutum* in the Korean Peninsula is somewhat probable. In adjacent countries, it was recorded in China, in areas remotely located from the Korean Peninsula (Xizang, Taiwan) and in Japan.

**Acknowledgements**

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**References**


**Anthyllis apennina** (Fabaceae), a new species from central Apennine (Italy)

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**Abstract**

A new species of *Anthyllis* endemic to central Apennine growing in dry pastures on limestone in the montane belt, within Abruzzo and Lazio administrative regions (central Italy), is here described and illustrated and the IUCN assessment is proposed. This new species belongs to the morphologically very variable *Anthyllis vulneraria* species complex and it is close to *A. pulchella* (south-eastern Europe and Caucasus), but it can be clearly distinguished by its smaller flowers, mainly light yellow-coloured, bracts longer than flowers, calyx pink-coloured (usually only at apex) and size of cauline leaves and leaflets. Furthermore, the name *A. pulchella* is here lectotypified, by a second-step typification, on a specimen preserved at PAD.

**Keywords**

Abruzzo, *Anthyllis vulneraria* species complex, Italian endemics, Lazio, Loteae, Papilionoideae, taxonomy

**Introduction**

The genus *Anthyllis* L. belongs to subfamily Papilionoideae, tribe Loteae (Polhill 1981; Allan and Porter 2000; Degtjareva et al. 2012). The *A. vulneraria* species complex, distributed in Europe, Mediterranean Basin, Turkey, Caucasus, Iran, Eritrea and Ethiopia, is morphologically very variable and several infraspecific taxa, many of them frequently regarded as independent species, have been recognised (e.g. Cullen 1968, 1976; Akeroyd 1988; Roskov et al. 2006; Rola 2012; POWO 2019). Roskov et al. (2006) re-
ported from Europe and Mediterranean countries 29 infraspecific taxa. Further taxa are quoted by Lampinen (1990), Benedí (2000), Greuter and Raus (2005), Puidet et al. (2005), Tison and Foucault (2014) and Conti et al. (2016). With regards to Italy, the A. vulneraria complex is represented by 15 subspecies, of which two are endemic and one is alien (Bartolucci et al. 2018; Galasso et al. 2018). On the other hand, Pignatti et al. (2017, 2019) recognise the taxa belonging to this group as species and quoted for Italy 13 species (two alien), one subspecies and five hybrids. In Italy, according to our field observations, many taxa are clearly sympatric, growing in the same localities and habitat. These taxa are usually clearly distinct and, probably, to be considered as separate and independent species. The lack of nomenclatural, taxonomic and molecular studies regarding this species complex has led to unclear descriptions of taxa and to unworkable analytical keys. We believe that some taxa should be recognised at species rank as proposed by Pignatti et al. (2019), but further studies are still needed. During the fieldwork concerning the “Flora of Abruzzo” project, one of us (FC) came across a population of Anthyllis on Mt. Ocre showing peculiar morphological features. Later, we found other populations with plants characterized by the same features on Mt. Borage and Selva Rotonda (Lazio, Reatini Mountains) during the annual field trip of the working group for Floristics, Systematics and Evolution of the Italian Botanical Society held in 2016 (Bartolucci et al. 2019). Additional populations were discovered on the southern slopes of Pizzo Camarda and between S. Stefano di Sessanio and S. Colombo (Gran Sasso massif), Vallone di Sevice and Piani di Pezza (Mt. Velino), Mt. Sirente, Mt. Calvo and in some localities of the National Park of Abruzzo, Lazio and Molise (Mt. Tricella, Colle Biferno, La Brecciosa). Plants of these populations are morphologically different from other known taxa within the A. vulneraria species complex, showing a peculiar combination of characters as very small flowers, mainly light yellow-coloured, and bracts longer than flowers. They are confused in the past with the close A. pulchella (Vis.) Beck (= A. vulneraria L. subsp. pulchella (Vis.) Bornm.), a species distributed in south-eastern Europe, Crimea and Caucasus (Cullen 1976; Akeroyd 1986; Dimopoulos et al. 2013; Barina et al. 2018; Bartolucci et al. 2018; Pignatti et al. 2019). Two other similar taxa, but clearly distinguished, are the endemic to central Apennine A. vulneraria subsp. nana (Ten.) Tammaro (Conti et al. 2016) and the western European A. vulneraria subsp. vulnerarioides (All.) Arcang. (Benedí 2000; Tison and Foucault 2014; Conti et al. 2016). Field investigations and an extensive morphological study on herbarium material, providing evidence about the species differentiation between A. pulchella and the Apennine populations, have been carried out. The results allowed us to describe the Apennine populations as a new species with the name A. apennina.

Material and methods

This study is based mainly on field surveys, on an extensive analysis of relevant literature and on examination of herbarium specimens (including nomenclatural types) preserved at APP, B, BM, GAP, P, PAD, TO (codes following Thiers 2020). A total of 125
specimens from these herbaria were studied. Ad hoc sampling campaigns in the central Apennines to better understand the distribution of the new species were carried out. The herbarium specimens of *A. vulneraria* subsp. *vulnerarioides* and *A. vulneraria* subsp. *nana* were studied for a preliminary morphological circumscription of the species, and not used for morphological analyses. A more detailed morphological comparison involved *A. apennina* and the closest species *A. pulchella*. Morphological observations and measurements of qualitative and quantitative characters, considered as diagnostic in *Anthyllis* (e.g., Cullen 1968, 1976; Akeroyd 1988; Rola 2012), were analysed on dried specimens. The analyses were performed on 58 variables, including 40 quantitative continuous characters, 6 quantitative discrete characters, 2 ratios and 10 qualitative characters (Table 1). The morphometric analyses were carried out on 37 selected specimens including *A. apennina* (21 specimens) and *A. pulchella* (16 specimens). Each flower was soaked in water for a few seconds before taking the measurements, using the maximum parameters. Calyx length include hairs protruding upper teeth. The calyx was sectioned longitudinally and then the width of its entire development was measured. Flower colour is based on living specimens because it was not possible to evaluate this character reliably from herbarium specimens. All morphological characters were observed with a Leica MZ16 stereomicroscope. The herbarium specimens used for the morphometric analyses are shown in Fig. 1 (produced using QGIS 3.16.4).

For each quantitative character, Shapiro-Wilks normality test was first used to determine their distribution, then an independent sample T-test, after logarithmic transformation, was carried out with SPSS version 25 (IBM 2017). Principal coordinate analysis (PCoA) and cluster analysis (UPGMA) were performed in PAST package version 4.03 (Hammer et al. 2001; Hammer 2020). Furthermore, the variability of the analysed morphological characters was described by standard statistical parameters (mean, standard deviation, minimum, maximum, 10th and 90th percentiles). Boxplots were built by means of SPSS version 25 (IBM 2017).

![Figure 1](image-url). Distribution map of *Anthyllis apennina* and *A. pulchella* according to the analyzed material.
### Table 1. Morphological characters employed in the morphometric analyses.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 HB</td>
<td>Habit (erect=1; straggling=2)</td>
</tr>
<tr>
<td>2 SH</td>
<td>Stem height (mm)</td>
</tr>
<tr>
<td>3 SHAB</td>
<td>Stem hairiness below (appressed=1; patent=2)</td>
</tr>
<tr>
<td>4 SHAa</td>
<td>Stem hairiness above (appressed=1; patent=2)</td>
</tr>
<tr>
<td>5 SLL</td>
<td>Shape of lower leaves (equal leaflets=1; subequal=2; unequal =3)</td>
</tr>
<tr>
<td>6 LAFS</td>
<td>Leaves arrangement along the flowering stem (equal=1; mainly at base=2)</td>
</tr>
<tr>
<td>7 NSL</td>
<td>N. of stem leaves</td>
</tr>
<tr>
<td>8 HALB</td>
<td>Hairiness of the upper leaf blade (glabrous=1; hairy=2)</td>
</tr>
<tr>
<td>9 HAP</td>
<td>Hairiness of petiole (appressed=1; patent=2)</td>
</tr>
<tr>
<td>10 BLL</td>
<td>Basal leaf length (mm)</td>
</tr>
<tr>
<td>11 NBLL</td>
<td>N. leaflets in basal leaf</td>
</tr>
<tr>
<td>12 TBLLL</td>
<td>Terminal leaflet length in basal leaf (mm)</td>
</tr>
<tr>
<td>13 TBLW</td>
<td>Terminal leaflet width in basal leaf (mm)</td>
</tr>
<tr>
<td>14 LBLLL</td>
<td>Lateral leaflet length in basal leaf (mm)</td>
</tr>
<tr>
<td>15 LBLW</td>
<td>Lateral leaflet width in basal leaf (mm)</td>
</tr>
<tr>
<td>16 LCLL</td>
<td>Lower cauline leaf length (mm)</td>
</tr>
<tr>
<td>17 NLCLL</td>
<td>N. of leaflets in lower cauline leaves</td>
</tr>
<tr>
<td>18 TLCLL</td>
<td>Terminal leaflet length in lower cauline leaf (mm)</td>
</tr>
<tr>
<td>19 TLCLW</td>
<td>Terminal leaflet width in lower cauline leaf (mm)</td>
</tr>
<tr>
<td>20 LLCW</td>
<td>Lateral leaflet length in lower cauline leaf (mm)</td>
</tr>
<tr>
<td>21 LLCLW</td>
<td>Lateral leaflet width in lower cauline leaf (mm)</td>
</tr>
<tr>
<td>22 UCLL</td>
<td>Upper cauline leaf length (mm)</td>
</tr>
<tr>
<td>23 NUCLL</td>
<td>N. of leaflets in upper cauline leaf</td>
</tr>
<tr>
<td>24 TUCLLL</td>
<td>Terminal leaflet length in upper cauline leaf (mm)</td>
</tr>
<tr>
<td>25 TUCLLW</td>
<td>Terminal leaflet width in upper cauline leaf (mm)</td>
</tr>
<tr>
<td>26 LUCLLL</td>
<td>Lateral leaflet length in upper cauline leaf (mm)</td>
</tr>
<tr>
<td>27 LUCLLW</td>
<td>Lateral leaflet width in upper cauline leaf (mm)</td>
</tr>
<tr>
<td>28 NINFLL</td>
<td>N. of inflorescences for each stem</td>
</tr>
<tr>
<td>29 BL</td>
<td>Bract length (mm)</td>
</tr>
<tr>
<td>30 BLLL</td>
<td>Bract lobe length (mm)</td>
</tr>
<tr>
<td>31 NB</td>
<td>N. of bract lobes</td>
</tr>
<tr>
<td>32 BA</td>
<td>Bract apex (acute-apiculate=1; obtuse=2)</td>
</tr>
<tr>
<td>33 CI</td>
<td>Calyx indumentum (appressed=1; semipatent-patent=2)</td>
</tr>
<tr>
<td>34 CC</td>
<td>Calyx colour (apex concolour=1; pink-purple=2; purple=3)</td>
</tr>
<tr>
<td>35 CL</td>
<td>Calyx length (hairs included) (mm)</td>
</tr>
<tr>
<td>36 CW</td>
<td>Calyx width (mm)</td>
</tr>
<tr>
<td>37 BLC/LCL</td>
<td>Ratio bract/calyx length</td>
</tr>
<tr>
<td>38 UCTL</td>
<td>Upper calyx teeth length (mm)</td>
</tr>
<tr>
<td>39 UCTW</td>
<td>Upper calyx teeth width (mm)</td>
</tr>
<tr>
<td>40 LCRL</td>
<td>Lateral calyx teeth length (mm)</td>
</tr>
<tr>
<td>41 LCTW</td>
<td>Lateral calyx teeth width (mm)</td>
</tr>
<tr>
<td>42 LOCTL</td>
<td>Lower calyx teeth length (mm)</td>
</tr>
<tr>
<td>43 LOCTW</td>
<td>Lower calyx teeth width (mm)</td>
</tr>
<tr>
<td>44 UCTHAL</td>
<td>Hairs length on upper calyx teeth (mm)</td>
</tr>
<tr>
<td>45 LCTHAL</td>
<td>Hairs length on lower calyx teeth (mm)</td>
</tr>
<tr>
<td>46 MCHAL</td>
<td>Hairs length in the middle of calyx (mm)</td>
</tr>
<tr>
<td>47 SL</td>
<td>Standard length (mm)</td>
</tr>
<tr>
<td>48 SW</td>
<td>Standard width (mm)</td>
</tr>
<tr>
<td>49 SCL</td>
<td>Standard claw length (mm)</td>
</tr>
<tr>
<td>50 BL/SL</td>
<td>Ratio bract/standard length</td>
</tr>
<tr>
<td>51 WL</td>
<td>Wing length (mm)</td>
</tr>
<tr>
<td>52 WW</td>
<td>Wing width (mm)</td>
</tr>
<tr>
<td>53 WCL</td>
<td>Wing claw length (mm)</td>
</tr>
<tr>
<td>54 KL</td>
<td>Keel length (mm)</td>
</tr>
<tr>
<td>55 KW</td>
<td>Keel width (mm)</td>
</tr>
<tr>
<td>56 KCL</td>
<td>Keel claw length (mm)</td>
</tr>
<tr>
<td>57 STL</td>
<td>Staminal tube length (without free filaments and anthers) (mm)</td>
</tr>
<tr>
<td>58 SPL</td>
<td>Stipe of pod length (mm)</td>
</tr>
</tbody>
</table>
For the lectotype selection of the name *A. pulchella*, the protologue has been compared with original material and the most complete and informative specimen was selected (Art. 9.4, Turland et al. 2018).

The conservation assessment according to the IUCN Criteria is proposed and briefly discussed (IUCN 2019).

### Taxonomy

*Anthyllis apennina* F.Conti & Bartolucci, sp. nov.
urn:lsid:ipni.org:names:77216597-1
Figs 2, 3

**Diagnosis.** *Anthyllis apennina* differs from *A. pulchella* by the bigger cauline leaves and leaflets, leaves evenly distributed along the flowering stem vs. concentrated in lower half, higher number of inflorescences 2–5(–10) vs. 1–2, smaller flowers with standard (7.9–)8.5–9.9(–10.3) vs. (10–)10.4–13.6(–13.8) mm long, longer bracts (12–)14–23(–26) vs. (5.8–)6.5–11(–12) mm long, longer than flowers, with longer lobes (10–)11–21.5(–24) vs. (3.2–)3.9–7.5(–9) mm long, narrowly triangular and acute to apiculate vs. more or less parallel-sided and obtuse and by the colour of flowers which are mainly light yellow or flushed with pink vs. purplish-pink or cream flushed with pink and the calyx which is mainly pink only in the upper part.

**Type.** Italy. Abruzzo, M. Tricella (Ortona dei Marsi), pascoli aridi, 1300 m a.s.l., 29/05/2017, F. Bartolucci, F. Conti & L. Di Martino s.n. (holotype APP No. 59652; isotypes APP Nos. 59645, 59648, 59650, 59651, 59653, 59666) (Fig. 3).

**Description.** Annual, erect branched to straggling. Stem height (110–)160–330(–450) mm. Stem appressed sericeous over its whole length. Leaves alternate, pinnate, densely appressed hairy on the lower side, glabrous on the upper side (basal and lower cauline leaves) or sparsely hairy with long hairs (middle and upper cauline leaves), the basal ones usually withered at anthesis, (16–)17.6–35(–55) mm, reduced to a terminal leaflet or imparipennate with 2–5 leaflets with a much larger terminal leaflet elliptic, ovate or obovate, obtuse, (7–)8.9–19.1(–24) × (4–)5–13.1(14) mm, lateral leaflets 0–5.7(–9) × 0–2.9(–4.9) mm. Stem with 3–4(–6) leaves at subequal distances along the flowering stem. Lower cauline leaf (32–)42.8–69.4(–74) mm, imparipinnate with 3–7 leaflets with a much larger terminal leaflet ovate or obovate, obtuse to acute, (15–)19.6–33.8(–40) × (8–)9.6–17.4(–22) mm, lateral leaflets (4–)4.6–15.6(–21) × (1.2–)2.1–5.4(–6) mm. Upper cauline leaves (24–)26–40(–44) mm, imparipinnate with 7–13 leaflets subequal (equifoliolate), terminal leaflet narrowly elliptic to narrowly obovate, acute to apiculate, (13–)15–27(–29) × (2.5–)2.8–6(–8) mm, lateral leaflets (12.5–)14–25(–27) × (2–)2.2–4(–7) mm. Every stem with 2–5(–10) heads, many flowered subtended by 2 palmatisect bracts borne close beneath the flowers. Flowers light yellow or flushed with pink. Bracts (12–)14–23(–26) mm, lobes of bracts 3–7, (10–)11–21.5(24) mm, narrowly triangular, tapering, appressed hairy, acute to apiculate. Calyx (8.3–)8.5–10.4(–10.9) × (5.9–)6.2–7.8(–8.3) mm, whitish to yellowish, pink to pink-purple at apex, in dry spec-
Figure 2. *Anthyllis apennina* F. Conti & Bartolucci, sp. nov. **A** inflorescence (Mt. Tricella, photo F. Conti) **B** bracts of inflorescences (Mt. Tricella, photo F. Conti) **C** geminate inflorescences (Prati del Sirente, photo F. Conti) **D** drawing from herbarium specimen APP No. 59887 collected on Colle Biferno **a** calyx and pod with stylus and stigma **b** standard **c** wing **d** keel.
New species of *Anthyllis*

**Figure 3.** Holotype of *Anthyllis apennina* F.Conti & Bartolucci (APP No. 59652, reproduced with permission of the Herbarium, Centro Ricerche Floristiche dell’Appennino, Italy).
imens weakly pink, hairy subpatent, upper teeth triangular (0.3–)0.4–0.6(–0.9) mm at base, large (0.3–)0.4–0.9(–1) mm. Lateral teeth triangular (0.3–)0.4–0.7 mm, at base large (0.3–)0.4–0.7 mm. Lower tooth narrowly triangular to linear (0.5–)0.6–0.9(–1) × 0.3–0.6 mm. Standard (7.9–)8.5–9.9(–10.3) × (2.3–)2.6–3.3(–3.8) mm, standard claw (4.6–)5.4–6.1(–6.4) mm. Wing (8.1–)8.8–10.1(–10.5) × (1–)1.2–1.6(–1.7) mm, wing claw (5.3–)5.8–6.8(–7) mm long. Keel (8–)9–10.5(–10.8) × 1.1–1.4(–1.6) mm, keel claw 5.6–6.1(–7.4) mm long. Ratio bract length/standard length (1.5–)1.6–2.3(–2.5) and ratio bract length/calyx length (1.4–)1.6–2.3(–3.0). Staminal tube length (without free filaments and anthers) (6.6–)7.3–8.7(–8.8) mm. Stylus (3.8–)3.9–4.3(–4.4) mm. Stigma 1.9–2.1(–2.1) mm. Stipe of pod (0.9–)1–1.5(–1.8) mm. Legume 1-seeded 3.5–4 × 2.8–3 mm, seeds ca. 2 mm.

**Etymology.** *Anthyllis apennina* is named after the Apennine to which the species is endemic.

**Habitat.** Pastures in montane belt from 1200 to 1800 m a.s.l.

**Phenology.** Flowering from the second half of April to the end of July, fruiting in June-July.

**Distribution.** Central Apennine in Lazio and Abruzzo (Fig. 1).

**Conservation status.** Some of the populations of *A. apennina* occurred in a NATURA 2000 network within the Sites of Community Interest “IT7110208 Monte Calvo e Colle di Macchialunga”, “IT7110206 Monte Sirente e Monte Velino”, “IT710202 Gran Sasso” and within the Abruzzo, Lazio and Molise National Park, Gran Sasso and Laga Mountains National Park and Sirente-Velino Regional Park. The extent of occurrence (EOO) is 1788 km² calculated with the minimum convex hull polygon in QGIS and area of occupancy (AOO) is 52 km² calculated with a 2×2 km cell fixed grid. No pressures or threats are evidenced. According to IUCN Criteria (IUCN 2019), we propose to include *A. apennina* in the following category: Least Concern (LC).

**Morphometric analysis.** The principal coordinate analysis (PCoA, Fig. 4) shows on the first two axes (explained variance: 57.1% and 11.1%) a clear separation between *A. apennina* and *A. pulchella*. Concerning the intraspecific variation within *A. pulchella*, one separated specimen (“37” from Turkey; see Fig. 1 and specimens examined) can be recognized in the PCoA diagram. Cluster analysis (UPGMA, Fig. 5), shows two well-delimited clusters supporting a clear separation between the studied species. Also in the UPGMA the specimen “37” from Turkey is separated. Most of the quantitative morphometric characters evaluated showed significant differences between the two *Anthyllis* species (Table 2). The most relevant morphological characters differentiating the two species are summarized in Table 3 and shown in Fig. 6.

**Typification of the name *Anthyllis pulchella*.** Visiani (1872: 141) described *A. vulneraria* var. *pulchella* providing a short description, and reporting the following type localities: “in monte Orien, et Montenegro in monte Lovćen ad alt. ped. 6000: Legit rev. Huter”. Referring to the “type”, Cullen (1970) cited several syntypes of the gathering by Huter on Mt. Lovćen kept in BM, K, P, and W. The Cullen’s typification (1970) satisfies the Arts. 7.10 and 7.11 of the ICN (Turland et al. 2018), but he
did not cite a single specimen as type. However, it is possible to consider the Cullen typification as a “first-step lectotypification”, that may be further narrowed to a single specimen by a “second-step lectotypification” according to Art. 9.17 of the ICN. We performed a survey for original material at PAD, where the De Visiani’s main collection is housed (Stafleu and Cowan 1986) and in the above mentioned herbaria. We were able to trace some duplicate specimens of the gathering on Mt. Lovćen in PAD (barcode HD08734), B (barcode B 10 111324) and BM (barcodes BM000751284
**Table 2.** T score and P value of quantitative characters evaluated (significant P values at P < 0.05 in boldface).

<table>
<thead>
<tr>
<th>Characters</th>
<th>T score</th>
<th>P value</th>
<th>Characters</th>
<th>T score</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>7.176</td>
<td>0.000</td>
<td>CW</td>
<td>1.271</td>
<td>0.216</td>
</tr>
<tr>
<td>BLL</td>
<td>3.554</td>
<td>0.001</td>
<td>UCTL</td>
<td>0.476</td>
<td>0.638</td>
</tr>
<tr>
<td>TBLLL</td>
<td>3.118</td>
<td>0.004</td>
<td>UCTW</td>
<td>-2.007</td>
<td>0.054</td>
</tr>
<tr>
<td>TBLW</td>
<td>3.815</td>
<td>0.001</td>
<td>LCTL</td>
<td>-2.563</td>
<td>0.016</td>
</tr>
<tr>
<td>LBLL</td>
<td>0.979</td>
<td>0.343</td>
<td>LCTW</td>
<td>0.132</td>
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</tr>
<tr>
<td>LBLW</td>
<td>0.526</td>
<td>0.609</td>
<td>LOCTL</td>
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<td>0.000</td>
</tr>
<tr>
<td>LCLL</td>
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<td>LOCTW</td>
<td>-1.011</td>
<td>0.323</td>
</tr>
<tr>
<td>TLCLL</td>
<td>8.724</td>
<td>0.000</td>
<td>UCTHAL</td>
<td>0.839</td>
<td>0.411</td>
</tr>
<tr>
<td>TLCLW</td>
<td>6.716</td>
<td>0.000</td>
<td>LCTHAL</td>
<td>1.03</td>
<td>0.314</td>
</tr>
<tr>
<td>LLCLL</td>
<td>2.999</td>
<td>0.006</td>
<td>MCHAL</td>
<td>-1.802</td>
<td>0.085</td>
</tr>
<tr>
<td>LLCLW</td>
<td>1.747</td>
<td>0.091</td>
<td>SL</td>
<td>-8.533</td>
<td>0.000</td>
</tr>
<tr>
<td>UCLL</td>
<td>9.658</td>
<td>0.000</td>
<td>SW</td>
<td>-5.469</td>
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</tr>
<tr>
<td>TUCLLL</td>
<td>11.663</td>
<td>0.000</td>
<td>SCL</td>
<td>-5.273</td>
<td>0.000</td>
</tr>
<tr>
<td>TUCLLW</td>
<td>3.721</td>
<td>0.001</td>
<td>WL</td>
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<td>0.000</td>
</tr>
<tr>
<td>LUCLLL</td>
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<td>0.000</td>
<td>WW</td>
<td>-6.268</td>
<td>0.000</td>
</tr>
<tr>
<td>LUCLLW</td>
<td>5.909</td>
<td>0.000</td>
<td>WCL</td>
<td>-4.355</td>
<td>0.000</td>
</tr>
<tr>
<td>BL/CL</td>
<td>15.452</td>
<td>0.000</td>
<td>KL</td>
<td>-5.96</td>
<td>0.000</td>
</tr>
<tr>
<td>BL/SL</td>
<td>17.547</td>
<td>0.000</td>
<td>KW</td>
<td>-3.732</td>
<td>0.001</td>
</tr>
<tr>
<td>BL</td>
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<td>KCL</td>
<td>-3.79</td>
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</tr>
<tr>
<td>BLL</td>
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<td>STL</td>
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<td>0.000</td>
</tr>
<tr>
<td>CL</td>
<td>-4.774</td>
<td>0.000</td>
<td>SPL</td>
<td>-2.447</td>
<td>0.024</td>
</tr>
</tbody>
</table>

**Figure 6.** Boxplots expressing morphological variation between *Anthyllis apennina* (APE) and *A. pulchella* (PUL): stem height (mm), lower cauline leaf length (mm), terminal leaflet length in lower cauline leaf (mm), upper cauline leaf length (mm), terminal leaflet length in upper cauline leaf (mm), bract length (mm), bract lobe length (mm), standard length (mm), ratio bract length/standard length. Outlined central box depicts middle 50% of data, extending from 25th and 75th percentiles, and horizontal bar is the median. Ends of vertical lines (or “whiskers”) indicate minimum and maximum data values, unless outliers are present, in which case whiskers extend to a maximum of 1.5 times inter-quartile range. Circles indicate outliers.
**Table 3.** Main diacritic features of *Anthyllis apennina* and *A. pulchella*. Quantitative continuous characters are expressed in mm and are reported as mean ± standard deviation and 10–90 percentiles (extreme values in brackets). For quantitative discrete cardinal characters, 10–90 percentiles are given (extreme values in brackets).

<table>
<thead>
<tr>
<th>Character</th>
<th><em>Anthyllis apennina</em></th>
<th><em>Anthyllis pulchella</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem height</td>
<td>(110–)160–330(–450)</td>
<td>(45–)60–160(–200)</td>
</tr>
<tr>
<td></td>
<td>237.4±88.2</td>
<td>95.6±44.6</td>
</tr>
<tr>
<td>Leaves arrangement along the flowering stem</td>
<td>evenly distributed</td>
<td>concentrated in lower half</td>
</tr>
<tr>
<td>Lower cauline leaf length</td>
<td>53.2±10.8</td>
<td>28.5±7.8</td>
</tr>
<tr>
<td></td>
<td>(32–)42.8–69.4(–74)</td>
<td>(17–)18–39(–45)</td>
</tr>
<tr>
<td>Terminal leaflet length in lower cauline leaf</td>
<td>26.3±6.2</td>
<td>10.4±2.9</td>
</tr>
<tr>
<td></td>
<td>(15–)19.6–33.8(–40)</td>
<td>(3–)8–13.5(–15)</td>
</tr>
<tr>
<td>Terminal leaflet width in lower cauline leaf</td>
<td>13.4±3.6</td>
<td>5.5±1.8</td>
</tr>
<tr>
<td></td>
<td>(8–)9.7–17.4(–22)</td>
<td>(1–)3.7–7.2(–8)</td>
</tr>
<tr>
<td>Upper cauline leaf length</td>
<td>33.6±5.6</td>
<td>17.3±3.8</td>
</tr>
<tr>
<td></td>
<td>(24–)26–40(–44)</td>
<td>(11–)12–22.2(–23)</td>
</tr>
<tr>
<td>Terminal leaflet length in upper cauline leaf</td>
<td>21.1±4.5</td>
<td>9.6±1.6</td>
</tr>
<tr>
<td></td>
<td>(13–)15–27(–29)</td>
<td>(6.1–)8–11(–13)</td>
</tr>
<tr>
<td>Lateral leaflet length in upper cauline leaf</td>
<td>18.6±4.1</td>
<td>7.1±2.3</td>
</tr>
<tr>
<td></td>
<td>(12.5–)14–25(–27)</td>
<td>(2.5–)5–10.2(–11)</td>
</tr>
<tr>
<td>Lateral leaflet width in upper cauline leaf</td>
<td>3.2±1.1</td>
<td>1.7±0.6</td>
</tr>
<tr>
<td></td>
<td>(2–)2.2–4(–7)</td>
<td>(0.9–)1.1–2.5(–2.8)</td>
</tr>
<tr>
<td>Number of inflorescences for each stem</td>
<td>2–5(–10)</td>
<td>1–2</td>
</tr>
<tr>
<td>Bract shape and apex</td>
<td>narrowly triangular and acute to apiculate</td>
<td>more or less parallel-sided and obtuse</td>
</tr>
<tr>
<td>Bract length</td>
<td>18.4±3.9</td>
<td>8.8±1.8</td>
</tr>
<tr>
<td></td>
<td>(12–)14–23(–26)</td>
<td>(5.8–)6.5–11(–12)</td>
</tr>
<tr>
<td>Bract lobe length</td>
<td>15.4±4.4</td>
<td>5.3±1.6</td>
</tr>
<tr>
<td></td>
<td>(10–)11–21.5(–24)</td>
<td>(3.2–)3.9–7.5(–9)</td>
</tr>
<tr>
<td>Flower colour</td>
<td>light yellow or flushed with pink</td>
<td>purplish-pink or cream flushed with pink</td>
</tr>
<tr>
<td>Standard length</td>
<td>9.1±0.7</td>
<td>11.8±1.2</td>
</tr>
<tr>
<td></td>
<td>(7.9–)8.5–9.9(–10.3)</td>
<td>(10–)10.4–13.6(–13.8)</td>
</tr>
<tr>
<td>Standard width</td>
<td>2.9±0.3</td>
<td>3.8±0.7</td>
</tr>
<tr>
<td></td>
<td>(2.3–)2.6–3.3(–3.8)</td>
<td>(2.9–)3.2–5.1(–5.4)</td>
</tr>
<tr>
<td>Wing length</td>
<td>9.3±0.6</td>
<td>11.5±1.3</td>
</tr>
<tr>
<td></td>
<td>(8.1–)8.8–10.1(–10.5)</td>
<td>(9.2–)10.1–13.1(–13.8)</td>
</tr>
<tr>
<td>Wing width</td>
<td>1.3±0.2</td>
<td>2.0±0.5</td>
</tr>
<tr>
<td></td>
<td>(1–)1.2–1.6(–1.7)</td>
<td>(1.4–)1.5–2.6(–3.2)</td>
</tr>
<tr>
<td>Wing claw</td>
<td>6.3±0.4</td>
<td>7.3±0.8</td>
</tr>
<tr>
<td></td>
<td>(5.3–)5.8–6.8(–7)</td>
<td>(6–)6.3–8.2(–9)</td>
</tr>
<tr>
<td>Keel length</td>
<td>9.6±0.7</td>
<td>11.5±1.2</td>
</tr>
<tr>
<td></td>
<td>(8–)9–10.5(–10.8)</td>
<td>(9.7–)10.2–12.9(–13.7)</td>
</tr>
<tr>
<td>Staminial tube length (without free filaments</td>
<td>8.0±0.5</td>
<td>9.5±1.0</td>
</tr>
<tr>
<td>and anthers)</td>
<td>(6.6–)7.3–8.7(–8.8)</td>
<td>(8.2–)8.3–10.8(–11)</td>
</tr>
<tr>
<td>Ratio bract length/standard length</td>
<td>2.0±0.4</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td></td>
<td>(1.5–)1.6–2.3(–2.5)</td>
<td>0.6–0.8(–0.9)</td>
</tr>
<tr>
<td>Ratio bract length/calyx length</td>
<td>2.0±0.4</td>
<td>0.8±0.1</td>
</tr>
<tr>
<td></td>
<td>(1.4–)1.6–2.3(–3.0)</td>
<td>(0.6–)0.7–1.0(1.1)</td>
</tr>
</tbody>
</table>

and BM000751285), which can be considered for the second-step typification. These herbarium specimens are complete, well conserved and agree with the protologue and with the current application of the name (Cullen 1968, 1970, 1976; Akeroyd 1986; Bartolucci et al. 2018). The herbarium specimen kept at PAD with barcode HD08734 is selected here as second-step lectotype.
Other names, some of which having priority at species rank, as *A. scardica* Wettst., *A. albana* Wettst., *A. biebersteiniana* Popl., and *A. daghestanica* Chinth. are regarded by some authors (e.g. Roskov et al. 2006) as synonyms of *A. pulchella*. These taxa need further study and/or typification.

- *Anthyllis vulneraria* var. *pusilla* Vis., *in schedis*  
- *Anthyllis vulneraria* var. *pauciflora* Asch. & Huter, *in schedis*

Type (second-step lectotype, here designated; first-step designated by Cullen 1970: 536): Montenegro, Lovcen, 6000, 5/06/1867, Hutern s.n. (PAD barcode HD08734!; isolecotypes B barcode B101113247!, BM barcodes BM000751284! and BM000751285!).

**Discussion.** According to Cullen (1976), in the *A. vulneraria* species complex, it is possible to recognise *Alpestris* and *Vulneraria* aggregates. The new species, according to some morphological characters, such as the upper cauline leaves equifoliolate, lobes of bracts tapering, acute at apex and lateral calyx teeth obscure, adpressed to the upper, belongs to the *Vulneraria* aggregate. The greatest diversity of the complex was found in western and southern Europe: Spain, France and Italy (Roskov et al. 2006). *Anthyllis apennina* can be clearly distinguished from species belonging to *A. vulneraria* complex by small flowers, mainly light yellow-coloured, and bracts longer than flowers. The most similar taxon is *A. pulchella*, a SE European species, occurring in central Apennine and rarely sympatric with *A. apennina* which differs due to its smaller cauline leaves with smaller terminal leaflet, lower number of inflorescences (1–2 vs. 2–10), less divided and smaller bract (5.8–12 mm vs. 12–26 mm), bract shorter than flower (vs. longer than flower), smaller standard, wing and keel. For *A. pulchella*, Akeroyd (1986) reports a corolla, even larger than what we measured, to be 12–14(17) mm long. Furthermore, the calyx in *A. apennina* is smaller and pink-purple only at the apex, while in *A. pulchella*, it is purple at the apex and the coloured part is longer (see Table 3). Other similar taxa are: *A. vulneraria* subsp. *nana*, endemic to central Apennine, that grows in stony pastures, usually above treeline in the alpine belt, which differs from *A. apennina* due to its larger corollas 13–17 mm [vs. (8–)9–10.5(–10.8) mm] usually whitish or pink (vs. light yellow or flushed with pink), and bracts smaller than flowers (vs. longer than flowers); *A. vulneraria* subsp. *vulnerarioides*, a western European species, described from Moncenisio and not occurring in central Apennine (Conti et al. 2016) characterized by stems with patent hairs (vs. appressed sericeous over its whole length), basal leaves hairy on the upper surface (vs. glabrous on the upper side), with 5–11 leaflets and the terminal one slightly larger than the lateral ones (Tison and Foucault 2014; Conti et al. 2016; Fig. 7). Further studies to clarify the taxonomic position of the several taxa currently included within *A. vulneraria* species complex are needed. The new endemic species enriches the already considerable floristic heritage of the central Apennine. Abruzzo Region, which includes the main peaks of the central Apennines, is the fourth Italian Region, after Sicily, Sardinia and Calabria by number
of endemics, but with this new taxon become the third region together with Calabria (Bartolucci et al. in press). This number has increased in recent years thanks to the activity of the Floristic Research Centre of the Apennines (Conti 2007, 2010; Conti and Peruzzi 2006; Peruzzi et al. 2007; Conti and Uzunov 2011; Gallo and Conti 2015; Conti and Bartolucci 2017; Conti et al. 2018, 2019, 2020).

**Additional specimens examined.** *Anthyllis apennina* (paratypes). **Italy. Lazio:** Campo di Grano, La Brecciosa (Pescosolido), pascolo, 1700 m a.s.l., 31/07/1995, *F. Conti* (APP No. 30831); La Brecciosa (Pescosolido), pascolo, 1700 m a.s.l., 31/07/1995, *F. Conti* (APP No. 30833); sentiero Forca di Fao, M. Arcione, M. Boragine (Cittareale, Rieti), pascoli secondari, 1619–1809 m a.s.l., 17/06/2016, *F. Conti, F. Bartolucci & R. Pennesi* (APP No. 57482); da Selvarotonda a Forca di Fao (Cittareale, Rieti), pascoli secondari, lembi di faggeta, 1533–1614 m a.s.l., 17/06/2016, *F. Conti, F. Bartolucci & R. Pennesi* (APP No. 57525); **Abruzzo:** M. Ocre presso l’Acquazzese, pascoli aridi, ca.1400 m a.s.l. 21/07/2014, *F. Conti, B. Petriccione & G. Serafini s.n. (APP Nos 55539, 55537, 55538, 55540, 55541, 55542, 55543, 55544)*; Prati del Sirente (Secinaro), pascoli aridi, 1150 m a.s.l., 07/06/2016, *L. Di Martino & F. Bartolucci* (APP Nos. 59702, 59703, 59704, 59705, 59706, 59707, 59708, 59709, 59710, 59711); M. Calvo, sia Lazio che Abruzzo, presso i ripetitori (Scoppito), pascoli aridi, 1460 m a.s.l., 04/06/2017, *F. Conti & V. Giacanelli* (APP Nos. 59729, 59730, 59801); V.ne di

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**Figure 7.**

- **A** *Anthyllis apennina*, Mt. Tricella, Abruzzo, Italy (photo F. Conti)
- **B** *Anthyllis vulneraria* subsp. *nana*, Monte Focalone, Abruzzo, Italy (photo F. Conti)
- **C** *Anthyllis vulneraria* subsp. *vulnerarioides*, Mont Cenis, Francia (photo G. Pache)
- **D** *Anthyllis pulchella*, Campo Felice, Abruzzo, Italy (photo F. Conti).
Sevice (Maggiano de’ Marsi), 28/06/2017, F. Conti (APP No. 59802); al valico tra S. Colombo e Santo Stefano di Sessanio, lato destro (Barisciano), pascoli aridi, 1300 m a.s.l., 18/06/2017, F. Conti (APP Nos. 59872, 59873, 59874); Colle Biferno, PNALM (Ortona dei Marsi), pascoli aridi, 1300 m a.s.l., 13/06/2017, F. Conti & F. Bartolucci (APP Nos. 59887, 59888); Piani di Pezza fino al laghetto (Rocca di Mezzo), pascoli aridi, 1460 m a.s.l., 19/04/2019, F. Conti, E. Proietti, I. Eckersley, C. Oberprieler & R. Vogt (APP Nos. 64979, 64980); versante meridionale di Pizzo Camarda (L’Aquila), pascoli aridi, 1500 m a.s.l., 16/07/2019, F. Conti, F. Bartolucci & E. Proietti (APP Nos. 65148, 65149, 65150).

**Anthyllis pulchella.** Italy. Lazio: Campo di Grano, La Brecciosa (Pescosolido), 1700 m, 31/07/1995, F. Conti (APP Nos. 30831, 30833); sentiero Forca di Fao, M. Arcione, M. Boragine (Cittareale), pascoli secondari, 1619–1809 m, 17/06/2016, F. Conti, F. Bartolucci & R. Pennesi (APP No. 57492); Abruzzo: M. Secine presso la vetta (Ateleta), pascoli, 1700–1800 m, 19/06/1997, F. Conti (APP No. 30832); M. Genzana (Scanno), prati alti, 2000 m, 19/07/1997, F. Conti (APP No. 35964); ibidem, 07/07/1997, F. Conti (APP No. 36077); Monte Greco – La Capriola (Barrea), 02/08/2001, F. Conti (APP No. 48654); V. ne di Sevice (Maggiano De’ Marsi), 28/06/2017, F. Conti (APP No. 59800); Montagna dei Fiori (Valle Castellana), 05/06/2019, F. Conti (APP Nos. 64950, 64951); Piani di Pezza fino al laghetto (Rocca di Mezzo), pascoli aridi, 1460 m, 19/04/2019, F. Conti, E. Proietti, I. Eckersley, C. Oberprieler & R. Vogt (APP No. 64970); Montenegro. Durmitor, Savin Kuk – Sljeme, substrato calcareo, 2000–2350 m, 08/07/1996, D. Lakušić, F. Conti & G. Tomović, (APP No. 9082); Monte Prokletije, Festuco-Seslerietea, limestone, 1920 m, 16/07/2003, D. Lakušić, F. Conti, Z. Bulić, M. Niketić, G. Ciaschetti, G. Tomović & S. Adžiablahović (APP No. 31711); Montenegro, Lovcen, 6000, 5/06/1867, Huter s.n. (lectotype PAD barcode HD08734; isolectotype B barcode B101113247, BM barcodes BM000751284 and BM000751285); Monte Orjen, 15/07/1868, Th. Pichler (PAD barcode HD08733); Albania. M. Čika tra Llogara e la vetta, pendii rupestri, 1020–1990 m, 23/06/2015, F. Conti, D. Lakušić, R. Di Pietro, N. Kuzmanović, A. Stinca, S. Đurović, I. Janković & R. Pennesi (APP Nos. 56418, 56477, 56498); tra Poliçan e M. Nemërçkë, pendii rupestri e pascoli, 1200–2480 m, 26/06/2015, F. Conti, D. Lakušić, R. Di Pietro, N. Kuzmanović, A. Stinca, S. Đurović, I. Janković & R. Pennesi (APP No. 56949, 57145); Greece. M. Olimpo, presso il Rifugio, 2200 m, 05/08/2009, F. Conti & D. Uzunov (APP No. 56699), ibidem, 2300–2700 m, 06/08/2009, F. Conti & D. Uzunov (APP No. 56727); Turkey. Uludag presso la vetta 2436 m, 09/07/2006, F. Conti & D. Uzunov (APP No. 56764).

**Anthyllis vulneraria** subsp. **nana.** Italy. Marche: Monte Vettore presso la cima 24/07/2013, F. Conti, A. Manzi & P. Minghetti (APP No. 62414); Lazio: sopra le prese dell’ENEL del T. Molinaro (Amatrice), Pascolo, 1350–1600 m, 12/06/2014, F. Bartolucci & F. Conti (APP No. 54814); F.so Piè di Lepre (Amatrice), pascoli, 1450–1800
New species of Anthyllis

m, 12/06/2014, F. Bartolucci & F. Conti (APP No. 54601); Terminillo a W di Sella Iacci 1700 m, 10/06/2003, F. Conti & G. Gottschlich (APP No. 63522); Abruzzo: Gruppo del Gran Sasso, Corno Grande presso la Sella del Brecciaio (L’Aquila), praterie altitudinali, 2400–2500 m, 21/07/1999, F. Conti, D. Lakusie & Ph. Küpf er (APP No. 1048); Lago di Campotosto (Campotosto), pascoli aridi, incolti, 1315–1350 m, 30/05/1999, D. Tinti (APP Nos. 2602–2604); Caselle, bivio Vado di Corno (L’Aquila), festuceti e brachipodieti, 1820 m, 13/06/2003, F. Conti et al. (APP No. 7153); Vallone di Selva Romana (Pennapiedimonte), pascoli – rupi, 1575 m, 22/06/2004, F. Conti & F. Bartolucci (APP Nos. 10726, 10727, 10736); Blockhaus-Monte Focalone (Pennapiedimonte-Caramanico Terme), pascoli sassosi, 2200 m, 28/07/2004, G. D’Orazio (APP No. 12216); loc. Il Pratuccio (Sant’Eufemia a Majella), pascoli sassosi, 1400 m, 22/07/1987, F. Conti & G. Pirone (APP No. 13309); Monte Ocre, valle Canavine, dal bordo superiore della faggeta alla conca di Settacque (Rocca di Cambio), pascoli sassosi, 1570 m, 22/06/2005, F. Conti, F. Bartolucci, L. Bernardo, D. Iamonico, M. Latin i, R. Lorenzetti, I. Londrillo, E. Pellegrini, N. Ranalli, L. Peruzzi, E. Scassellati, D. Tinti & V. Viscosi (APP No. 15317); M. Sirente, tra la faggeta e Val Lupara (Secinaro), pendii rupestri, 1970 m, 20/06/2005, F. Conti, F. Bartolucci, L. Bernardo, D. Di Santo, D. Iamonico, M. Latin i, R. Lorenzetti, N. Ranalli, L. Peruzzi, D. Tinti & V. Viscosi (APP No. 15497); Monte Sirente, valle Majori (Secinaro), Pendii rupestri, 1500–2100 m, 20/06/2005, F. Conti, F. Bartolucci, L. Bernardo, D. Di Santo, D. Iamonico, M. Latin i, R. Lorenzetti, N. Ranalli, L. Peruzzi, D. Tinti & V. Viscosi (APP No. 15549); Gran Sasso, tra Vado di Corno e Valle dell’Inferno (Isola del Gran Sasso), Pascoli, 1950 m, 17/07/2004, F. Conti & F. Bartolucci (APP No. 16617); Gran Sasso – M. Camicia, versante occidentale (Castel del Monte), pascoli, 1800–2000 m, 21/07/1997, F. Conti (APP No. 17536); Gruppo della Laga – Valle del Rio Castellano, Vado di Annibale – Cima Lepri (Valle Castellana), pascoli e praterie, 2119 m, 22/06/2005, S. Cecchetti (APP No. 21299); Gruppo della Laga – Valle del Rio Castellano, Macera della Morte – Pizzitello (Rocca S. Maria), pascoli e praterie, 2200 m, 19/07/2005, S. Cecchetti (APP No. 21300); Gruppo della Laga – Valle del Rio Castellano, Pianaccio (Valle Castellana), praterie, pascoli sassosi, alvei di torrente, 1850–2090 m, 14/07/2005, F. Conti & S. Cecchetti (APP No. 21301); Gruppo della Laga – Valle del Rio Castellano, cascata del Diedro – Pedatelle (Rocca S. Maria), rupi arenacee, pascoli, praterie, 1730 m, 23/06/2005, S. Cecchetti (APP No. 21302); M. di Valle Caprara, Costa dell’Ortella, Gioia dei Marsi (Lecce nei Marsi), pascoli, 1800–1900 m, 15/06/1997, F. Conti & F. Minutillo (APP No. 33406); Monte Focalone (Fara San Martino), 2100–2500 m, 08/08/2008, F. Conti, J. Meister & F. Minutillo (APP No. 36451); Serra Lunga (Villavallelonga), pascoli e faggeta, 1759 m, 15/06/2010, F. Bartolucci & N. Ranalli (APP No. 50080); Campo Pericoli (Pietracamela), Pascoli sassosi, 2200 m, 23/07/2009, F. Bartolucci & M. Iocchi (APP No. 50417); Pizzo Ce falone (L’Aquila), Pascolo – rupi, 2200–2400 m, 20/06/2013, A. Stinca & F. Bartolucci (APP No. 52707); Monte Camicia, south east flank above Rif. Fonte Vetica (Castel del Monte), pascoli, rupi, 1600–2500 m, 16/07/2013, A. Stinca & F. Bartolucci (APP No. 52759); tra la Sella di M. Aquila e la cresta del Duca (L’Aquila), pascoli – rupi,
2200–2300 m, 25/06/2013, A. Stinca & F. Bartolucci (APP No. 52774); presso le Gondole (Santo Stefano di Sessanio), pascoli aridi, 10/05/2013, F. Conti (APP No. 52955); da Campo Imperatore a M. Aquila (L’Aquila), pascoli e rupi, 02/07/2013, A. Stinca & F. Bartolucci (APP No. 53141); Brancastello (L’Aquila), Pascoli, 22/08/2014, F. Conti (APP Nos. 54508, 54511, 54512, 54515); Vallone Fossaceca (Isola del Gran Sasso d’Italia), pascolo, 1200–2200 m, 31/07/2014, F. Conti & F. Bartolucci (APP Nos. 54837, 54838);

Molise: vetta del Monte a Mare (Pizzone), ghiaione, 2160 m, 14/06/1993, F. Conti (APP No. 30837); Alta Valle Pagana (Pizzone), pascolo sommitale, 1900 m, 14/06/1993, F. Conti (APP No. 30838); Valle Fredda, sopra il limite del bosco (Pizzone), prato, 1800–2000 m, 06/07/1993, F. Conti (APP No. 30839); La Metuccia, Monte a Mare (Pizzone), pascolo, 1900 m, 08/07/1992, F. Conti (APP No. 30840); Valle Fredda (Pizzone), pascolo sommitale, 1800–2000 m, 16/06/1993, F. Conti (APP No. 30841); Valle Pagana ed altro circo glaciale adiacente (Pizzone), pascolo, 1900 m, 23/07/1991, F. Conti (APP No. 30842).

**Anthyllis vulneraria subsp. vulnerarioides. Spain.** de Castanezé à Malignieux, 10/08/1893, Saubadre (P barcode P03056343); France. Monêtier-les-Bains à Guy Chevalier, pelouses rocailleuses, 2000 m, 21/08/1901, A. Faure (GAP barcode GAP046961); *ibidem*, 2200 m, 25/07/1905, A. Faure (P barcode P03622952); Monêtier-les-Bains, paturages vers 2200 m, 21/08/1901, A. Faure (P barcode P03069103); *ibidem*, 5/08/1896 (P barcode P03069104); France/Italy: Mont Cenis, s.d., s.coll. (GAP barcode GAP042327); Mont Cenis à Savalin, Huguenin 498 (GAP barcode GAP037228); Moncenis (patta creusa), 1838, s.coll. (TO, epitype); Bardonecchia, Valfréide […] de Aigle, 30/07/1899, Ferrari (TO); Mt. Cenis, 1838, Bonnar (TO).

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**References**


Integrating continental mainland and islands in temperate East Asia: liverworts and hornworts of the Korean Peninsula

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Abstract

The liverwort and hornwort flora of the Korean Peninsula possesses some unique traits arising from the geographic position of the Peninsula, where the mainland flora meets insular flora. This flora is still not exhaustively studied, due not only to political reasons, but also because much less attention has been paid than to adjacent lands by hepaticologists. A checklist presented is based on a study of ca. 15,500 specimens collected by the authors and a review of relevant literature. This study provides the checklist of liverworts and hornworts known from Korea and the geographical distribution of each species within the peninsula. The liverworts and hornworts in Korean flora include 346 taxa (326 species, 16 subspecies and four varieties) in 112 genera and 50 families. Since 2007, 75 taxa of liverworts and four taxa of hornworts are reported as new to the Korean Peninsula, with a number of the new records arising following application of new taxonomic concepts that have become apparent over the last few decades. While compiling the checklist, 42 species, previously reported to Korea, are excluded from the Korean liverwort flora.

Keywords

Anthocerotae, distribution, Hepaticae, Korean peninsula, phytogeography
Introduction

The Korean Peninsula is situated on the easternmost temperate edge of the Pacific Asia mainland. It belongs to the East Asiatic floristic region and it has close floristic relationships with Manchuria (in the broad sense of this term) and Japan (Takhtajan 1986). Korea shows a remarkable variation in climatic conditions regarding temperature and precipitation. In addition, the complex mountain system that covers nearly 70% of the total area and ca. 3,400 islands along the west and south coast create a great diversity of habitats throughout the area. The flora, therefore, shows high diversity, caused by the range of communities from warm temperate, merging subtropical in the southern part to cold temperate and alpine types in the northern and high mountain regions.

The first reports of liverworts for the Korean Peninsula were those by Stephani (1909) – an incidental result obtained in the course of study of Japanese flora by U. Faurie (Bakalin and Katagiri 2014). Since then, Japanese botanists, starting with Nakai (1918), have studied liverworts and hornworts in Korea. Hong (1960a) and Choe (1975) were the first Koreans who revised liverworts and hornworts in Korea (see Taxonomic History below). Since the 1990s, studies on liverworts and hornworts in Korea were generally accomplished by reviews of literature data (Hong 1997; Yamada and Choe 1997; Park and Choi 2007). In some cases, as authors simply provided the lists of taxa without any references even to published papers, the origin of some reports could not be determined. Therefore, despite the existence of many publications dealing with Korean liverworts, the distribution of taxa within the Peninsula and even the certain presence of some species remain questionable. This is in stark contrast to the obvious progress in knowledge of vascular plants over the last several decades as exemplified by several monographic treatments and even some illustrated guidebooks (Lee 1980; Lee 1996; Lee 2006; Park 2007). Previously, the illustrated Flora and Fauna of Korea 24 and Korean Spore Plant 8 (Choe 1980; Kim and Hwang 1991) attempted to fill this gap, but actually they provided only poor data, based on limited amount of collected material and could hardly be regarded as sufficient and satisfactory in the current time. Hence, we attempt a full revision of all available collections, including those newly collected within the past 12 years and literature sources. We provide original information on the distribution of taxa within the Peninsula and arrange them in accordance with the currently accepted taxonomy, supported by recent advances in molecular-genetic research. We stress that the liverwort and hornwort flora, due to unique geological, environmental, and geographical factors, is far from a simple ‘incomplete copy’ of Japanese or North-East China floras (Choi et al. 2010, 2011, 2012a, b, c, 2020a, b; Bakalin et al. 2020a). Moreover, Korean flora possesses many unique geological, environmental, and geographical factors caused by the Peninsula being situated between continental mainland and islands on the migration route of inter-exchanges within various regions in East Asia and even within East and Northeast Asia in the broader context.
Historical background

The history of knowledge about liverworts and hornworts in Korea can be divided into four stages, based on botanists involved at the different time periods (Table 1). The first stage (1900–1930) is the starting stage, the second stage (1930–1960) includes studies conducted mainly by Japanese botanists, the third stage (1960–2007) includes studies by the first Korean professional bryologists Drs. W.H. Hong, D.-M. Choe and Y.H Kim and the last stage (2008–present) includes studies by various botanists in both North and South Korea.

First stage (1900–1930)

Faurie (1846–1915; referenced in Bakalin and Katagiri 2014) was the first who collected liverworts on the Korean Peninsula. In collaboration with Taquet (1873–1952; referenced in Oh 1976), he sampled diverse hepatics and mosses while amassing a large collection of vascular plants. The liverwort collections were studied by Stephani (1909, 1910a, b, c, 1911, 1916, 1917a, b, c, 1922, 1924) and listed in his well-known Species Hepaticarum. Eight species [Frullania fusco-vires, Frullania koreana (= Frullania hamatiloba), Anthoceros koreanus (= Pheoceros carolinianus), Plagiochasma koreanum (= Plagiochasma japonicum), Solenostoma koreanum (= Protosolenostoma fusiiforme), Jungermannia decurrens (= Solenostoma faurieanum), Lepidozia coreana (= Lepidozia subtransversa), and Mastigobryum coreanum (= Bazzania tridens)] from the collection were described by Stephani as new to science and three species [Frullania muscicola, Ptilidiurn sacculatum (= Trichocoleopsis sacculata), and Madototeca tosana (= Porella acutifolia subsp. tosana)] were recorded as new to the Korean Peninsula. Nakai (1918) reported one hepatic [Scapania dentata (= Scapania undulata)] and 31 mosses.

Second stage (1930–1960)

During this time period, Korean hepatics have been studied mostly by Japanese botanists, including Horikawa (1932, 1934a, b, c, d, 1935a, b, c, 1936a, b, c, 1951a, b, 1955), Uno and Takahashi (1940), Hattori (1941, 1943a, b, 1944a, b, 1948, 1950, 1967, 1970, 1975a), Hattori and Mizutani (1958), Hattori et al. (1962a, b), Ando (1955, 1960), Amakawa (1959, 1960), Inoue (1958a, b, 1959a, b, 1962), Yamada

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<th>Phases</th>
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<tr>
<td>First</td>
<td>1900–1930</td>
<td>Stephani F</td>
<td>Faurie U, Taquet E</td>
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<td>Second</td>
<td>1930–1960</td>
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(1979, 1989). Besides, Reimers (1931) studied materials collected by Klautke and listed in his well-known paper, “Ein Beitrag zur Moosflora von Korea”. Nine species [Plagiochila delavayi, Jamesoniella autumnalis (= Syzygiella autumnalis), Mastigobryum bidentatum (= Bazzania bidentula), Blepharostoma trichophyllum, Radula japonica, Frullania jackii (= Frullania davurica), Frullania clavellata (= Frullania appendiculata), Lejeunea cavifolia and Lejeunea compacta] were recorded as new to the Korean Peninsula and one species [Ptilidium sacculatum (= Trichocoleopsis sacculata)] was additionally recorded. Horikawa conducted numerous bryofloristic research studies in Asia. He reported 67 species as new to the Korean Peninsula and one species (Fimbriaria koreana (= Asterella leptophylla)) as new to science (Horikawa 1932, 1934a, b, 1935a, b, 1936a, b, 1951a, b, 1955). Uno and Takahashi (1940) listed four species Brachiolejeunea sandvicensis (= Acrolejeunea sandvicensis), Frullania fauriana, Frullania moniliata subsp. obscura (= Frullania appendiculata) and Madotheca setigera (= Porella caespitans var. cordifolia) from Mt Jiri. Hattori (1941, 1943a, b, 1948, 1950) recorded eight species for Korean Peninsula: Bazzania coreana (= Bazzania tridens), Jungermannia cordifolia (= Jungermannia exsertifolia), Targionia hypophylla, Plagiochila ovalifolia, Frullania nepalensis var. nishiyamensis (= Frullania nepalensis), Riccia fluitans and Riccia glauca. He also studied specimens from Mt. Jiri and Mt. Halla collected by Hong and described a species new to science (Metacalypogeia quelpaertensis (= Eocalypogeia quelpaertensis)) (Hattori et al. 1962a, 1962b). Ando (1955, 1960) recorded three species (Porella vernicosa subsp. vernicosa, P. vernicosa subsp. fauriei (= P. fauriei) and P. vernicosa subsp. gracillima (= P. gracillima)) in his papers on Porella complex. Amakawa (1960) reported one species (Nardia sieboldii (= Nardia assamica)) from Korea. Inoue (1962) described Plagiochila quelpaertensis (= P. ovalifolia) as new to science collected by Hong.

Third stage (1960–2007)

The first Korean botanist who studied and published on liverworts and hornworts was Won Shic Hong (1919–2014; 1960a, b, c, 1962a, b, c, d, 1966, 1997, 2003). He reported 149 taxa in 53 genera and 24 families, based on a study of ca. 5,000 herbarium specimens (Hong 1962a). Additionally, Hong (1997) markedly expanded his list that counts 259 taxa belonging to 76 genera in 37 families on the basis of personal collections and literature records, including those for North Korea (Gao and Cao 1983; Gao and Chang 1983a, b; Koponen et al. 1983; Huneck et al. 1987). Hong also provided identification keys to 263 known or expected taxa in the Korean Peninsula (Hong 2003). Hong (1962a) was the first who compiled the manual for the Korean liverworts, published in English. Hong’s follower, Du Moon Choe (1925–2014; 1975, 1979, 1980, 1983), conducted bryofloristic research studies in South Korea. He published a manual of Korean bryophytes in the Korean language, which includes 201 liverwort taxa in 66 genera (Choe 1980). Later, in collaboration with the Japanese hepaticologist Kohsaku Yamada, 236 taxa of Hepaticae were assembled in a special checklist providing information on distributions of species within administrative provinces of both countries on the Korean Peninsula (Choe and Yamada 1979, 1997, 1998, 2000; Yamada and Choe 1997). In North Korea, Gao and Cao (1983) compiled the list of

Fourth stage (2008-present)

Our own studies on Korean liverworts and hornworts started in 2008 and revealed many new species, including those new to science. As was found previously, the Korean liverwort flora was still poorly understood and peculiar traits of flora of this Peninsula were simply overlooked. Bakalin et al. (2009, 2020a) described *Tritomaria koreana* and *Solenostoma jirisanense* from Mt. Jiri as new to science. Choi et al. (2010, 2011, 2012a, b, c, 2020a, b) continuously reported unrecorded species from the Korean hepatic flora. Concurrently with our research, Lee et al. (2011) published the National List of Species of Korea, including 277 liverworts and eight hornworts, based on literature sources. After Hong (1962a), the number of genera and species of liverworts and hornworts in Korea, based on literature, has been listed in Table 2.

Taking into account that checklists commonly become outdated every 10 years and many new additions have been obtained within the last stage of Korean bryophyte flora recognition, the present checklist marks the new ‘frontier’ in the knowledge of Korean bryophytes that, at the same time, is the starting point for new achievements in this field.

### Materials and methods

Materials for this study, which include approximately 15,500 specimens, were collected mostly by Choi, with a short participation in the field research by Bakalain between October 2007 and May 2020 at various sites in Korea (Table 3, Figure 1).
All the specimens are kept in Jeonbuk National University Herbarium (JNU) and Herbarium of the Botanical Garden-Institute (VBGI). The unsurveyed areas in the present study were investigated by a review of relevant reliable literature (Hong 1997, 2003; Kim and Hwang 1991; Yamada and Choe 1997) and herbarium specimens (G, HIRO, NICH, PE, VLA, VBGI). The analysis of the distribution pattern was based on floristic elements (latitudinal type) and area type (longitudinal types) identified for each occurring species in Bakalin (2010). Nomenclature mostly follows Söderström et al. (2016) with some updates from recent literature (Solenostomataceae (Bakalin et al. 2020a), Apopellia (Schütz et al. 2016) etc.). The Pseudolophozia concept was followed after Konstantinova and Vilnet (2009) despite in the World liverwort checklist (Söderström et al. 2016) this genus is regarded as the synonym of Barabilophozia.

### Results

The liverwort and hornwort flora of Korea includes 346 taxa (326 species, 16 subspecies and four varieties) belonging to 112 genera and 50 families. The list includes 75 taxa of liverworts and four hornworts reported as new to the Korean Peninsula within the last twelve years. Two species of liverworts are endemic to Korea. *Solenostoma jirisanense* Bakalin et Choi S.S. was described as new to science from Mt. Jirisan. The striking characteristics of *S. jirisanense* are red to purple pigmentation of shoots, suddenly turned up perianth in the female branches and frequent biconcentric oil-bodies (Bakalin et al. 2020a). *Marsupella koreana* Bakalin et Fedosov was described as new to science from Mt. Jirisan, Mt. Deogyusan and Mt. Gayasan (Bakalin et al. 2019). The striking characteristics of the *M. koreana* are conduplicate leaves, purple pigmentation of shoots, narrowly revolute leaf margin and plants loosely dilated to the perianth.

While compiling the hepatic flora, 42 species, previously reported for Korea, are excluded from the Korean liverwort flora. Amongst them, 14 species (*Calypogeia granulata* Inoue, *Cephalozia hamatiloba* Steph., *Delavayella serrata* Steph., *Gongylanthus ericetorum* (Raddi) Nees, *Jungermannia plagiochilacea* Grolle, *Lopholejeunea subfuscata*...
Liverworts and hornworts of Korean Peninsula

(Nees) Schiffn., *Marchantia pinnata* Steph., *Metalejeunea cucullata* (Reinw., Blume etNess) Grolle, *Moerckia japonica* Inoue, *Plagiochila delavayi* Steph., *Radula chinensis* Steph., *Riccia frostii* Austin, *Riccia nipponica* S.Hatt. and *Scapania ligulata* Steph.) were reported for the Korean flora by Park and Choi (2007) on an unclear basis (no references to literature were provided at all). Since we were not able to find the location of vouchers and the original sources for these reports, we exclude them from the flora. *Lopholejeunea subfusca* (Nees) Schiffn. was reported by Hong (1962a) from Mt. Jiri. The distribution of *L. subfusca* covers tropical and subtropical areas, so its occurrence in Mt. Jirisan is doubtful. The plants most probably belong to *Acanthocoleus yoshinaganus* (S.Hatt.) Mizut., which is relatively common on Mt. Jiri, but it was not recorded by Hong (1962a). *Porella pinnata* L., *Lejeunea cavifolia* Steph. and *Riccardia incurvata* Lindb. were reported by Kim and Hwang (1991) from the northern part of Korea. However, the distribution of these three species is European-North American and hardly occurred in East Asia. The first one probably belongs to *Porella grandiloba*, whereas the second may belong to *Lejeunea japonica* and the last may belong to any *Riccardia* species (most probably *R. multifida*). See excluded and doubtful records below for the rest of the details.

In the analysis of area types (longitudinal type), 168 taxa (48.6%) are East Asian, 92 (26.6%) are circumpolar, 31 (9.0%) are broadly Asian, 21 (6.1%) are multi-areal and 13 (3.8%) are amphioceanic (Table 4). This result distinctly shows that the Korean Peninsula belongs to the Eastern Asia floristic region (Takhtajan 1986).

In an analysis of flora elements (latitudinal), 82 taxa (23.76%) are temperate, 52 (15.0%) are temperate-subtropical, 49 (14.2%) are subtropical, 48 (13.9%) are arctic-boreal, 32 (9.2%) are boreal-temperate, 28 (8.1%) are boreal and 19 (5.5%) are cosmopolitan (Table 5). Temperate floristic elements occurred in the largest proportion, followed by a large number of temperate-subtropical elements. The subtropical species are mainly distributed in Jeju Island and the southern part of the Korean Peninsula. The arctic-boreal species are mainly distributed in high mountains of the northern part in Korea and rarely distributed on the peaks of Mt. Halla, Mt. Jiri and Mt. Seorak. They presumably should be common in the highest elevations of North Korea, but we do not have any information on this issue.

<table>
<thead>
<tr>
<th>Area type (longitudinal types)</th>
<th>Taxa</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphioceanic</td>
<td>13</td>
<td>3.8</td>
</tr>
<tr>
<td>Amphipacific</td>
<td>7</td>
<td>2.0</td>
</tr>
<tr>
<td>Asia</td>
<td>31</td>
<td>9.0</td>
</tr>
<tr>
<td>Asian-American</td>
<td>6</td>
<td>1.7</td>
</tr>
<tr>
<td>Asian-Euro</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Circumpolar</td>
<td>92</td>
<td>26.6</td>
</tr>
<tr>
<td>Disjunctive</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Eastern Asia</td>
<td>168</td>
<td>48.6</td>
</tr>
<tr>
<td>Eastern Asia-American</td>
<td>3</td>
<td>0.9</td>
</tr>
<tr>
<td>South-eastern Asia</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Multi-area</td>
<td>21</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Table 4. The longitude fractional composition of the Korean liverworts and hornworts.
Table 5. The latitude fractional composition in Korean liverworts and hornworts within other regions.

<table>
<thead>
<tr>
<th>Floristic elements (latitudinal types)</th>
<th>Taxa</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctic</td>
<td>22</td>
<td>6.4</td>
</tr>
<tr>
<td>Arctic-boreal</td>
<td>48</td>
<td>13.9</td>
</tr>
<tr>
<td>Boreal</td>
<td>28</td>
<td>8.1</td>
</tr>
<tr>
<td>Boreal-temperate</td>
<td>32</td>
<td>9.2</td>
</tr>
<tr>
<td>Temperate</td>
<td>82</td>
<td>23.7</td>
</tr>
<tr>
<td>Temperate-subtropical</td>
<td>52</td>
<td>15.0</td>
</tr>
<tr>
<td>Subtropical</td>
<td>49</td>
<td>14.2</td>
</tr>
<tr>
<td>Subtropical-tropical</td>
<td>14</td>
<td>4.0</td>
</tr>
<tr>
<td>Multizone</td>
<td>19</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Checklist of the Liverworts and Hornworts of the Korean Peninsula (Alphabetical List)

This checklist includes 346 taxa and, amongst them, marked with an asterisk (*), are new records for the Korean Peninsula obtained from 2007. Open circles (°) indicate the species was not collected or observed by ourselves, but found in trustworthy papers. The localities for every species in the Korean Peninsula are listed, based on the specimens identified by the authors and on the following literature cited in brackets. The abbreviations for the provinces of Korean Peninsula are as follows (Figure 1), CB: Chungcheongbuk-do, CN: Chungcheongnam-do, GB: Gyeongsangbuk-do, GN: Gyeongsangnam-do, GG: Gyeonggi-do, GW: Gangwon-do, HB: Hamgyeongbuk-do, HN: Hamgyeongnam-do, HWN: Hwanghaenam-do, HWB: Hwanghaebuk-do, JB: Jeollabuk-do, JG: Jagang-do, JN: Jeollanam-do, JJ: Jeju-do, PB: Pyeonganbuk-do, PN: Pyeongannam-do, YG: Yanggang-do. The synonyms in the checklist are cited very occasionally if the species were recorded in literature under that name. All specimens examined are deposited in JNU, KB and VBGI. The genera are arranged alphabetically, as are the species within the genus. Nomenclature mostly follows Söderström et al. (2016) with some updates from recent literature mentioned above.

Anthocerotae

*Anthoceros* L. (Anthocerotaceae)


* Anthoceros angustus* Steph. – JJ [Jeju-si, Tamla valley, 10 Apr 2012, Choi 120320 (JNU)]

* Anthoceros subtilis* Steph. – JJ [Jeju-si, Tamla valley, 10 Apr 2012, Choi 121015 (JNU)]
Figure 1. The surveyed areas in the Korean Peninsula

**Folioceros D.C.Bharadwaj** (Anthocerotaceae)

*Folioceros fuciformis* (Mont.) D.C.Bhardwaj – JJ [Jeju-si, Tamla valley, 25 Sep 2012, Choi 120971b (JNU)]
Notothylas Sull. ex A.Gray (Notothylaceae)


*Notothylas temperata* J.Haseg. – CN [Yamada and Choe 2002]

Phaeoceros Prosk. (Notothylaceae)


Megaceros Campb. (Dendrocerotaceae)

*Megaceros flagellaris* (Mitt.) Steph. – JJ [Seogwipo-si, Dongsu Brigde, 2 Nov 2011, Choi 111485 (JNU)]

Hepaticae

Acanthocoleus R.M.Schust. (Lejeuneaceae)


*Acrobolbus* Nees (Acrobolbaceae)


*Acrolejeunea* (Spruce) Schiffn. (Lejeuneaceae)


**Alobiellopsis** R.M.Schust. (Cephaloziaceae)

*Alobiellopsis parvifolia* (Steph.) R.M.Schust. – JJ [Jeju-si, Mulyeongari, 19 Sep 2011, Choi 110973 (JNU)]

**Anastrepta** (Lindb.) Schiffn. (Lophoziaceae)

*Anastrepta orcadensis* (Hook.) Schiffn. – HN [Kim and Hwang 1991], Korea [Hong 1997, 2003]

**Anastrophyllum** (Spruce) Steph. (Lophoziaceae)


*Anastrophyllum michauxii* (F.Weber) H.Buch – GW [Inje-gun, Mt. Seolak, Jungecheong, 21 Sep 2009, Choi 5152 (JNU)]

**Aneura** Dumort. (Aneuraceae)

*Aneura maxima* (Schiffn.) Steph. – JJ [Seogwipo-si, Bolrae Oreum, 5 Sep 2012, Choi 120753 (JNU)], JN [Yeoam-gun, Mt. Weolchul, Dogapsa Temple, 1 Dec 2010, Choi 9074 (JNU)], GB [Ulsan-si, Mt. Jeongjok, Mujechi 1 neup, 30 Sep 2010, Choi 8304 (JNU)].

**Aneura pinguis** (L.) Dumort. – JJ [Jeju-si, Musu stream, Goangryeong 2nd Bridge, 18 Mar 2012, Choi 120112 (JNU)], JN [Haenam-gun, Mt. Duryun, Duryunsan Temple]

*Anthelia* (Dumort.) Dumort. (Antheliaceae)

_Anthelia juratzkana_ (Limpr.) Trevis. – JJ [Seogwipo-si, Baekrokdam, Northwestern wall, 7 Sep 2012, Choi 120810 (JNU)]

_Apopellia_ (Grolle) Nebel & D. Quandt (Pelliaceae)


_Asterella_ P. Beauv. (Aytoniaceae)

_Asterella cruciata_ (Steph.) Horik. – CN [Choe 1975 as _Asterella chichibuensis_], GW [Yeongweol-gun, River donggang, near the Donggang, 29 Sep 2009, Choi 5250 (JNU)], Korea [Choe 1980 as _Asterella odora_, Choe and Choi 1980 as _Asterella chichibuensis_ and _Asterella odora_]

_Asterella leptophylla_ (Mont.) Grolle – GN [Sancheong-gun, Mt. Jiri, Jangsanri valley, 13 Jun 2009, Choi 3675 (JNU)], GW [Jeongseon-gun, River Donggang, near

*Barbilophozia Loeske* (Anastrophyllaceae)


*Bazzania Gray* (Lepidoziaceae)


* Bazzania imbricata* (Mitt.) S.Hatt. – GN [Hamyang-gun, Mt. Jiri, Hansin stream, 12 Oct 2019, Bakalin & Choi Kor-79-6-19 (VBGI)].

*Bazzania japonica* (Sande Lac.) Lindb. – JJ [Jeju-si, Mt. Halla, Baekrokdam, 21 Sep 2012, Choi 120888b (JNU)]

*Bazzania manczurica* Bakalin – GW [Jeongseon-gun, Gohan-eup, Mt. Hambaek, 23 Jun 2017, Bum 170346 (JNU)]

*Bazzania parabidentula* Bakalin – GG [Taebaeksi, Hyeol-dong, Mt. Taebaek, Danggol valley, 24 Jun
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**Bazzania trilobata** (L.) Gray – GN [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8159 (JNU)], GG [Hong 1960c, Choe 1980], GW [Inje-gun, Mt. Seolak, Bongjeongam, 14 Oct 2010, Choi 8592 (JNU); Hong and Kim 1960;
Hong 1962a, 1966; Choe 1975, 1980; Kim and Hwang 1991; Kim et al. 1995],
YG [Kim and Hwang 1991], Korea [Choe and Yamada 1974; Choe and Choi

Biantheridion (Grolle) Konstant. et Vilnet (Anastrophyllaceae)

*Biantheridion undulifolium* (Nees) Konstant. et Vilnet –YG [Gao and Chang
as *Jamesoniella undulifolia* (Nees) Müll.Frib.]

Blasia L. (Blasiaceae)

*Blasia pusilla* L. – JJ [Jeju-si, Tamla valley, 10 Apr 2012, *Choi 120305* (JNU)], GB
[Hong 1962a, Choe 1980], GG [Hong and Kim 1961a; Hong 1962a, c; Choe
1980], GW [Hong and Kim 1960; Hong 1962a; Choe 1980], HB [Kim and
Hwang 1991], Korea [Choe and Yamada 1974; Choe and Choi 1980; Gao and

Blepharostoma (Dumort.) Dumort. (Pseudolepicoleaceae)

*Blepharostoma epilithica* Vilnet et Bakalin – GW [Inje-gun, Mt. Seolak, *Bakalin
Kor-11-16-11* (VBGI); Bakalin et al. 2020b]

*Blepharostoma minor* Horik. – JJ [Jeju-si, Musu stream, 28 Oct 2010, *Choi 8834*
(JNU); Horikawa 1951b; Hattori et al 1962a; Hong 1966; Choe 1980; Song
and Yamada 2006], JN [Goheung-gun, Is. Seongdudo, shoreline, 20 May 2011,
*Choi 110608* (JNU); Hong 1966; Song and Yamada 2009b], JB [Hong 1966,
(JNU); Hattori et al. 1962b; Choe 1980], GB [Ulleung-gun, Seonginbong, 20
Oct 2010, *Choi 8742* (JNU); Hong 1966; Choe 1980], CN [Choe 1979], CB
[Hong 1962d, 1966], GG [Hong 1966, Choe 1980], GW [Inje-gun, Mt. Seolak,
Hangyeoryeong, 21 Sep 2009, *Choi 5060* (JNU); Horikawa 1951b, Kim et al.
1995], HWN [Kim and Hwang 1991], PB [Kim and Hwang 1991], YG [Kim
and Hwang 1991], HB [Kim and Hwang 1991], Korea [Shin 1968, 1970; Choe and Yamada 1974; Choe and Choi 1980; Hong
1997, 2003]

*Blepharostoma trichophyllum* (L.) Dumort. – JJ [Jeju-si, Jindalrae shelter, 28 Oct
2011, *Choi 111189* (JNU); Horikawa 1934d, 1935b, 1951b; Hong and Kim
1961b; Hattori et al 1962a; Hong 1962a, 1966; Choe 1980; Song and Yamada
2006], JN [Hong 1966, Song and Yamada 2009b], GN [Geochang-gun, Mt.
Namdeogyu, top of mountain, 11 Nov 2010, *Choi 8982* (JNU); Hong and Yoo
1961; Hattori et al. 1962b; Hong 1962a; Choe 1980], GB [Hong 1962a, 1966],
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**Calycularia Mitt.** (Calyculariaceae)


**Calypogeia Raddi** (Calypogeiaceae)

*Calypogeia angusta* Steph. – **GN** [Sancheong-gun, Mt. Jiri, Rotari shelter, 14 Jun 2009, *Choi* 3689a (JNU)]


*Calypogeia japonica* Steph. – **JJ** [Seogwipo-si, Erimok valley, 6 Sep 2012, *Choi* 120785 (JNU)]


*C. yoshinagana* Steph. – JJ [Hattori et al. 1962a as Calypogeia tosana var. yoshinagana, Hong 1962a as Calypogeia tosana var. yoshinagana], Korea [Choe and Yamada 1974 as Calypogeia tosana var. yoshinagana]

*Cavicularia* Steph. (Blasiaceae)

*Cavicularia densa* Steph. – JJ [Jeju-si, Goangryeongcheon stream, 14 May 2012, Choi 120467 (JNU)]

*Cephalozia* (Dumont.) Dumort. (Cephaloziaceae)

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**Cephalozia otaruensis** Steph. – **JJ** [Jeju-si, Jindalrae shelter, 28 Oct 2011, Choi 111215 (JNU); Song and Yamada 2006], **JN** [Goheung-gun, Is. Seongdudo, shoreline, 20 May 2011, Choi 110614 (JNU)], **JB** [Jeongeup-si, Mt. Naengjae, Meokbaengigol valley, 28 Jun 2010, Choi 7433 (JNU)], **GN** [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8115 (JNU); Hattori et al. 1962b as Cephalozia bicuspidata subsp. otaruensis, Song and Yamada 2009b], **GB** [Ulsan-si, Mt. Jeongjok, Mujechi 4 neup, 30 Sep 2010, Choi 8303 (JNU)], **CN** [Choe 1979 as Cephalozia bicuspidata subsp. otaruensis], **GG** [Hong 1962a, 1966 as Cephalozia bicuspidata subsp. otaruensis], **GW** [Inje-gun, Mt. Seolak, Jungcheong, 21 Sep 2009, Choi 5127; Choe 1980 as Cephalozia bicuspidata subsp. otaruensis], **JG** [Kim and Hwang 1991], **HN** [Kim and Hwang 1991], **HB** [Kim and Hwang 1991], Korea [Inoue 1974, 1981 as Cephalozia otaruensis Choe and Yamada 1974; Choe and Choi 1980 as Cephalozia bicuspidata subsp. otaruensis, Hong 1997, 2003]

**Cephaloziella** (Spruce) Schiffn. (Cephaloziellaceae)

**Cephaloziella divaricata** (Sm.) Schiffn. – **JN** [Wando-gun, Is. Bogil, ridge, 16 Nov 2010, Choi 9011 (JNU)], **GN** [Sancheong-gun, Mt. Jiri, below Cheonwangbong, 15 Jun 2009, Choi 3786 (JNU)], **GB** [Hong 1966 as Cephaloziella byssacea, Choe 1980, 1983 as Cephaloziella byssacea], **GW** [Inje-gun, Mt. Seolak, Socheong, 21 Sep 2009, Choi 5186 (JNU)], Korea [Choe and Choi 1980 as Cephaloziella byssacea, Hong 1997, 2003]


Cephaloziella spinigera (Lindb.) Jørg. – JJ [Seogwipo-si, Bolrae Oreum, 5 Sep 2012, Choi 120749 (JNU)], GN [Hamcheon-gun, Mt. Hwangmae, ridge, 3 Aug 2010, Choi 7499 (JNU)], GG [Choe and Yamada 1997 as Cephaloziella subdentata], Korea [Hong 2003]

*Cephaloziella varians* (Gottsch.) Steph. – JN [Jangheung-gun, Mt. Cheongoan, top of mountain, 19 May 2011, Choi 110533 (JNU)], GN [Namhae-gun, Mt. Geum, top of mountain, 21 May 2011, Choi 110649]

Cheilolejeunea (Spruce) Steph. (Lejeunaceae)

*Cheilolejeunea japonica* (Horik.) W.Ye et R.L.Zhu – GW [Sokcho-si, Mt. Seolak, 9 Sep 2009, Choi 5142 (JNU)]

Cheilolejeunea nipponica (S.Hatt.) S.Hatt. – JJ [Jeju-si, Musu stream, Goangryeong 2nd Bridge, 18 Mar 2012, Choi 120106 (JNU); Song and Yamada 2006]

Cheilolejeunea obtusifolia (Steph.) S.Hatt. – JJ [Jeju-si, Musu stream, Goangryeong 2nd Bridge, 18 Mar 2012, Choi 120133 (JNU)], JN [Jangheung-gun, Mt. Cheongoan, top of mountain, 19 May 2011, Choi 110542 (JNU); Hong 1966, Song and
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*Chiastocaulon* Carl (Plagiochilaceae)

°*Chiastocaulon dendroides* (Nees) Carl – PN [Gao and Chang 1983a, b as *Plagiochila dendroides*], JG [Kim and Hwang 1991 as *Plagiochila dendroides*], Korea [Hong 1997, 2003 as *Plagiochila dendroides*]

*Chiloscyphus* Corda (Lophocoleaceae)


Clevea Lindb. (Cleveaceae)


Cololejeunea (Spruce) Steph. (Lejeuneaceae)

°*Cololejeunea denticulata* (Horik.) S.Hatt. – GW [Kim et al. 1995], Korea [Hong 1997, 2003]


°*Cololejeunea kodamae* Kamim. – JJ [Hong and Kim 1961b; Hattori et al. 1962a; Hong 1962a, 1966; Inoue 1976; Choe 1980; Song and Yamada 2006], GG [Hong 1966; Choe 1980], Korea [Mizutani 1961; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]


**Cololejeunea trichomanis** (Gottsche) Steph. – **GG** [Hong 1966 as *Cololejeunea goebelii*, Choe 1980, 1983 as *Cololejeunea goebelii*, Korea [Choe and Choi 1980 as *Cololejeunea goebelii*, Hong 1997, 2003 as *Cololejeunea goebelii*]

**Conocephalum Hill** (Conocephalaceae)

**Conocephalum japonicum** (Thunb.) Grolle – **JJ** [Jeju-si, Gwangryeongcheon stream, 4 May 2012, Choi 120425c (JNU); Horikawa 1935a as *Conocephalum supradecompositum*, Hattori et al. 1962a as *Conocephalum supradecompositum*, Choe 1975 as *Conocephalum supradecompositum*, Song and Yamada 2006], **JB** [Namwon-si, Mt. Jiri, Simwon valley, 20 Jun 2009, Choi 3971 (JNU)], **GN** [Hong 1962a as *Conocephalum supradecompositum*], **GB** [Cheongsong-gun, Mt. Juwang, Jeolgol, 9 Nov 2010, Choi 8923 (JNU); Hong 1962c as *Conocephalum supradecompositum*], **CN** [Choe 1980 as *Conocephalum supradecompositum*], **GG** [Hong 1962a as *Conocephalum supradecompositum*], **GW** [Jeongseon-gun, River Donggnag, Limstone, 7 Sep 2011, Choi 110900 (JNU); Hong 1962a as *Conocephalum supradecompositum*], **KB** [Kim et al. 1995, Choe 1975, 1980 as *Conocephalum supradecompositum*], **PN** [Gao and Chang 1983a, b as *Conocephalum supradecompositum*], **PB** [Kim and Hwang 1991 as *Conocephalum supradecompositum*], **JG** [Kim and Hwang 1991 as *Conocephalum supradecompositum*], **HB** [Kim and Hwang 1991 as *Conocephalum supradecompositum*], Korea [Horikawa 1939 as *Conocephalum supradecompositum*, Iwatsuki and Mizutani 1972 as *Conocephalum supradecompositum*, Inoue 1974 as *Conocephalum supradecompositum*, Choe and Yamada 1974 as *Conocephalum supradecompositum*, Choe and Choi 1980 as *Conocephalum supradecompositum*, Gao and Chang 1981 as *Conocephalum supradecompositum*, Aur and Zhang 1985 as *Conocephalum supradecompositum*, Li 1985 as *Conocephalum supradecompositum*, Long and Grolle 1990; Hong 1997, 2003]

**Conocephalum salebrosum** Szweyk., Buczk. et Odryzk. – **JJ** [Jeju-si, Gwangryeongcheon stream, 4 May 2012, Choi 120461 (JNU); Horikawa 1935a as *Conocephalum conicum*, Hattori et al. 1962a as *Conocephalum conicum*, Song and Yamada 2006 as *Conocephalum conicum*], **JN** [Gurye-gun, Mt. Jiri, Nogodan, 19 Sep 2009, Choi 5044 (JNU)], **JB** [Buangun, Mr. Naebyen, Beadrock near road, 10 Mar 2009, Choi 3376 (JNU)], **GN** [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8124 (JNU); Song and Yamada 2009a as *Conocephalum salebrosum*], **GB** [Cheongsong-gun, Mt. Juwang, Jeolgol, 9 Nov 2010, Choi 8921 (JNU); Horikawa 1955], **CN** [Choe 1979 as *Conocephalum conicum*], **GG** [Hong and Kim 1961a as *Conocephalum conicum*, Hong 1962a as *Conocephalum conicum*], **GW** [Hwancheon-gun, Cypripedium japonicum area, 24 Jul 2009, Choi 4145; Hong 1962a as *Conocephalum conicum*, Kim and Hwang 1991 as *Conocephalum conicum*, Kim et al. 1995 as *Conocephalum conicum*], **HWN** [Kim and Hwang 1991 as *Conocephalum conicum*], **PB** [Kim and Hwang 1991 as *Conocephalum conicum*], **PN** [Horikawa 1935a as *Conocephalum conicum*, Gao and Chang 1983a, b as *Conocephalum conicum*], **JG**
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**Cryptolophocolea L. Söderstr., Crand.-Stotl., Stotler et Váňa** (Lophocoleaceae)


**Cylindrocolea R.M.Schust.** (Cephaloziellaceae)

*L*Cylindrocolea kiaeri (Austin) Váňa – GN [Sancheong-gun, Sicheon-myeon, Mt. Jiri, Jungsansri valley, 10 Nov 2019, Choi 1910844a (JNU)], CB [Boeun-gun, Mt. Sokri, Cheonwhangbong area, 18 Oct 2019, Choi 1910568 (JNU)]


**Diplophyllum (Dumort.) Dumort.** (Scapaniaceae)

*Diplophyllum albicans* (L.) Dumort. – JN [Seogwipo-si, Mt. Halla, Baekrokdam, 8 Aug 2010, Choi 7761 (JNU)], JN [Gurye-gun, Mt. Jiri, Nogodan, 29 Apr 2009, Choi 3521 (JNU); Hong 1962a, 1966; Choe 1983; Song and Yamada 2009b], JB
[Jeongeup-si, Mt. Naejang, Geumseon valley, 16 Mar 2009, Choi 3494 (JNU)],


**Douinia (C.E.O.Jensen) H.Buch** (Scapaniaceae)


**Drepanolejeunea (Spruce) Steph.** (Lejeuneaceae)

*Drepanolejeunea angustifolia* (Mitt.) Grolle – **JJ** [Jeju-si, Baekrokdam, 28 Oct 2011, Choi 111242 (JNU)], **GN** [Hamcheon-gun, Mt. Gaya, top of mountain, 28 Apr 2009, Choi 4371 (JNU)].

**Dumortiera Nees** (Dumortieraceae)

*Dumortiera hirsuta* (Sw.) Nees – **JJ** [Jeju-si, Musu stream, 28 Oct 2010, Choi 8829 (JNU); Horikawa 1935a; Hattori et al. 1962a; Hong 1962a; Choe 1975, 1980; Miller et al. 1983; Song and Yamada 2006], **JN** [Haenam-gun, Mt. Duryun, Taehengsa Temple valley, 18 May 2011, Choi 110458 (JNU)], **JB** [Choe 1980], **CN** [Choe 1979], **GG** [Choe 1980], **Korea** [Shin 1970; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

**Eocalypogeia (R.M.Schust.) R.M.Schust.** (Calypogeiaceae)

*Eocalypogeia quelpaertensis* (S.Hatt. et Inoue) R.M.Schust. – **JJ** [Jeju-si, Musu stream, 28 Oct 2010, Choi 8844 (JNU); Hattori et al. 1962a as Metacalyogeia quelpaertensis, Hong 1966 as Metacalyogeia quelpaertensis, Iwatsuki and Mizutani 1972 as Metacalyogeia quelpaertensis, Choe 1975, 1980, 1983 as Metacalyogeia quelpaertensis, Inoue 1986 as Metacalyogeia quelpaertensis, Song and Yam-
Fossombronia Raddi (Fossombroniaceae)


Frullania Raddi (Frullaniaceae)


°Frullania aoshimensis Horik. – GN [Song and Yamada 2009a]

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°Frullania brotheri Steph. – Korea [Choe 1980; Choe and Choi 1980; Hong 1997, 2003]

*Frullania crispiplicata Yuzawa et S.Hatt. – JJ [Seogwipo-si, Bolrae Oreum, 5 Sep 2012, Choi 120750 (JNU)], GN [Namhae-gun, Mt. Geum, 21 May 2011, Choi 110646 (JNU)]

Frullania davurica Hampe ex Gottsche, Lindenb. et Nees – JJ [Jeju-si, Musu stream, Goangryeong 2nd Bridge, 17 Mar 2012, Choi 120079 (JNU); Hong 1966, Song and Yamada 2006], JN [Hong 1962a, 1966 as Frullania jackii subsp. japonica, Song and Yamada 2009b], JB [Hong 1966 as Frullania jackii subsp. japonica], GN [Hong and Yoo 1961 as Frullania japonica, Song and Yamada 2009a], GB [Hong 1966 as Frullania jackii subsp. japonica], CN [Hong 1966 as Frullania jackii subsp. japonica], CB [Hong 1962a as Frullania jackii subsp. japonica, Hong 1962d as Frullania japonica], GG [Hong 1960b as as Frullania japonica, Hong and Kim 1961a as Frullania jackii, Hong 1962a, 1966 as Frullania jackii subsp. japonica], GW [Hong 1966 as Frullania jackii subsp. japonica, Kim et al. 1995], HWN [Kim
and Hwang 1991], PN [Gao and Chang 1983a, b], PB [Kim and Hwang 1991],
JG [Kim and Hwang 1991], YG [Kim and Hwang 1991], HN [Kim and Hwang
1991], HB [Kim and Hwang 1991], Korea [Reimers 1931 as Frullania jackii,
Horikawa 1934a, 1939 as Frullania japonica, Kamimura 1961 as Frullania jackii
subsp. japonica, Iwatsuki and Mizutani 1972 as Frullania jackii subsp. japonica,
Choe and Yamada 1974 as Frullania jackii subsp. japonica, Inoue 1976 as Frul-
nania jackii, Inoue 1981, Choe and Choi 1980 as Frullania jackii subsp. japonica,
Hattori and Lin 1985, Li 1985 as Frullania jackii subsp. japonica, Chao and Lin
1992a, b; Hong 1997, 2003]

Miller et al. 1983, Song and Yamada 2006], JN [Jangheung-gun, Mt. Cheongoan,
valley, 19 May 2011, Choi 110512 (JNU)], GN [Namhae-gun, Mt. Geum, top of
mountain, 21 May 2011, Choi 110640 (JNU); Song and Yamada 2009a], Korea
Chao and Lin 1991, 1992b; Choe and Yamada 1974; Choe and Choi 1980; Hong
1997, 2003]

Frullania diversitexta Steph. – JJ [Choe 1980, Song and Yamada 2006], JN [Hong
1962a, 1966; Choe 1980; Song and Yamada 2009b], JB [Muju-gun, Mt. Deogyu,
25 Jun 2008, Choi 10680 (JNU)], GN [Hong and Yoo 1961; Hattori et al. 1962b;
Hong 1966; Choe 1980; Song and Yamada 2009a], GG [Hong 1962a, 1966, Choe
1980], Korea [Kamimura 1961; Iwatsuki and Mizutani 1972; Hattori and Lin
1985; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

Frullania ericoides (Nees) Mont. – JJ [Choe 1980; Song and Yamada 2006], JN
[Song and Yamada 2009b], JB [Hong 1966 as Frullania squarrosa, Choe 1980],
GN [Song and Yamada 2009a ], CN [Hong 1962a, 1966 as Frullania squarrosa,
Choe 1979], GG [Hong 1966 as Frullania squarrosa, Choe 1980], GW [Hong
1962a as Frullania squarrosa, Kim et al. 1995], HWN [Kim and Hwang 1991],
PN [Kim and Hwang 1991], PB [Kim and Hwang 1991], JG [Kim and Hwang
1991], YG [Kim and Hwang 1991], HN [Kim and Hwang 1991], HB [Kim and
Hwang 1991], Korea [Kamimura 1961 as Frullania squarrosa, Li 1985 as Frulla-
nia squarrosa, Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

Frullania fauriana Steph. – JU [Seogwipo-si, Bolrae Oreum, 5 Sep 2012, Choi 120748
(JNU)], JN [Uno and Takahashi 1940, Son and Yamada 2009b], GN [Hong and
Yoo 1961], GB [Hong 1966; Choe 1980, 1983], Korea [Hong 1962a; Shin 1968;
Miller et al. 1983; Choe and Choi 1980; Hong 1997, 2003]

Frullania fuscovirens Steph. – JJ [Jeju-si, Tamla valley, 25 Sep 2012, Choi 120998
(JNU)], YG [Kim and Hwang 1991], Korea [Stephani 1910b; Hattori 1980 as
Frullania valida var. fuscovirens, Hattori and Lin 1985; Hong 1997, 2003]


Frullania inflexa Mitt. – GW [Hong 1962a as Frullania delavayi], Korea [Hong 1997, 2003]


Frullania muscicola Steph. – JJ [Jeju-si, Hancheon Bridge, 14 Mar 2012, Choi 120003 (JNU); Hattori et al. 1962a; Hong 1962a, 1966; Choe 1980 as Frullania muscicola var. inuena, Song and Yamada 2006], JN [Hwasun-gun, Psilotun nudum area, 1 Aug 2009, Choi 4202 (JNU); Hong 1962a, 1966; Song and Yamada 2009b], JB [Muju-gun, Mt. Jeoksang, below Waterfall, 25 Mar 2009, Choi 3411 (JNU); Hong 1966], GN [Geoje-si, Oryung reservoir, 16 Mar 2011, Choi 110012 (JNU); Hong and Yoo 1961; Hattori et al. 1962b; Song and Yamada 2009a], GB [Yeongju-si, Mt. Sobaek, Birobong area, 2 Sep 2009, Choi 4310 (JNU); Hong 1962a as Frullania muscicola var. inuena, Hong 1966], CN [Gongju-si, Mt. Gyeryong, Temple Donghaksa valley, 8 Jul 2009, Choi 4122 (JNU); Choe 1972, 1979], CB [Hong 1962a, d], GG [Hong 1962a, 1966 as Frullania muscicola var. inuena, Choe 1980 as Frullania muscicola var. inuena], GW [Inje-gun, Mt. Seolak, Hangyeoryeong, 28 Aug 2009, Choi 4274 (JNU); Hong 1962a, 1966; Kim et al. 1995], HWN [Kim


°*Frullania parvistipula* Steph. – **JN** [Song and Yamada 2009b], **GN** [Song and Yamada 2009a], **GB** [Choe and Yamada 2000], **HN** [Kim and Hwang 1991], **Korea** [Hong 2003]

*Frullania pedicellata* Steph. – **JJ** [Jeju-si, Sumeunmulbyengdwi, 26 Aug 2010, Choi 8031 (JNU); Hong 1966, Song and Yamada 2006], **JN** [Goheung-gun, Is. Oenarodo, shoreline, 20 May 2011, Choi 110600 (JNU)], **GB** [Namwon-si, Mt. Jiri, Jeongryeongchi area, 26 Aug 2009, Choi 4208 (JNU)], **GN** [Hapcheon-gun, Mt. Gaya, Baekwondong area, 8 Sep 2009, Choi 4342 (JNU); Hong 1962a], **CN** [Choe 1972, 1979, 1980], **CB** [Yeongdong-gun, Mt. Minjuji, Forest lodge, 19 May 2012, Choi 120588 (JNU)], **GG** [Hong and Kim 1961a; Choe 1980], **GW** [Jeongseon-gun, River Donggang, near their Donggang, 17 Aug 2010, Choi 4280 (JNU); Hong 1962a], **Korea** [Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]


*Frullania schensiana* C.Massal. – **JJ** [Jeju-si, Sumeunmulbyengdwi, 26 Aug 2010, Choi 8021 (JNU); Choe 1980], **JN** [Hong 1962a, 1966; Choe 1980; Song and
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Fuscocephaloziopsis Fulford (Cephaloziaeae)


**Fuscocephaloziopsis leucantha** (Spruce) Váňa et L.Söderstr. – **GN** [Hamyang-gun, Mt. Jiri, Cheonwngbong, 29 Sep 2010, *Choi 8260* (JNU); Choe 1980], **CN** [Choe 1980 as *Cephalozia leucantha*], **GW** [Inje-gun, Mt. Seolak, Bongjeongam, 14 Oct 2010, *Choi 8598* (JNU); Kim and Hwang 1991 as *Cephalozia leucantha*, Kim et al. 1995 as *Cephalozia leucantha*], **JG** [Kim and Hwang 1991 as *Cephalozia leucantha*], **YG** [Kim and Hwang 1991 as *Cephalozia leucantha*], **Korea** [Choe and Choi 1980 as *Cephalozia leucantha*, Hong 1997, 2003 as *Cephalozia leucantha*]


**Geocalyx Nees** (Geocalycaceae)


**Gymnomitrion Corda** (Gymnomitriaceae)

**Gymnomitrion commutatum** (Limpr.) Schiffn. – **JJ** [Seogwipo-si, Baekrokdam, Northwestern wall, 7 Sep 2012, *Choi 120924* (JNU)]

**Gymnomitrion faurianum** (Steph.) Horik. – **JJ** [Jeju-si, Mt. Halla, Baekrokdam, 8 Aug 2010, *Choi 7759* (JNU)], **GW** [Sokcho-si, Mt. Seolak, Jungcheong, 21 Sep 2009, *Choi 5148* (JNU)]

*Gymnomitrion noguchianum* S.Hatt. – **JJ** [Seogwipo-si, Mt. Halla, Baekrokdam, 6 Sep 2012, *Choi 120819* (JNU)]

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**Haplomitrium Nees** (Haplomitriaceae)

*Haplomitrium mnioides* (Lindb.) R.M.Schust. – JJ (Jeju-si, Hyodon stream, 7 Aug 2010, Choi 7613 (JNU)).

**Harpanthus Nees** (Geocalycaceae)


*Harpanthus scutatus* (F.Weber et D.Mohr) Spruce – GN (Sancheong-gun, Mt. Jiri, Cheonwnagbong, 15 Jun 2009, Choi 3763a (JNU)).

**Hattoria R.M.Schust.** (Lophoziaceae)

*Hattoria yakushimensis* (Horik.) R.M.Schust. – GN (Hapcheon-gun, Mt. Gaya, Sangwangbong, 8 Sep 2009, Choi 4383 (JNU)).

**Hattorianthus R.M.Schust. et Inoue** (Moerckiaceae)


**Herbertus Gray** (Herbertaceae)


*Heteroscyphus Schiffn.* (Lophocoleaceae)


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Hygrobiella Spruce (Hygrobiellaceae)

Hygrobiella laxifolia (Hook.) Spruce – JJ [Jeju-si, Musu stream, 19 Mar 2012, Choi 120175 (JNU); Hattori et al 1962a; Song and Yamada 2006], Korea [Iwatsuki and Mizutani 1972; Choe and Yamada 1974; Choe and Yamada 1974; Choe 1980; Choe and Choi 1980; Hong 1997, 2003]


Isopaches H.Buch (Lophoziaceae)


Jubula Dumort. (Jubulaceae)


Jungermannia L. (Jungermanniaceae)


*Jungermannia borealis* Damsh. et Váňa – *GB* [Ulleung-gun, Bongrae waterfall 19 Oct 2010, *Choi 8702* (JNU)]


*Jungermannia pumila* With. – *JJ* [Seogwipo-si, Suak valley, 29 Oct 2010, *Choi 9938b* (JNU)].

*Kurzia* G.Martens (Lepidoziaceae)

**Lejeunea Lib.** (Lejeuneaceae)


**Lejeunea japonica** Mitt. – **JJ** [Jeju-si, Musu stream, 19 Mar 2012, Choi 120180 (JNU); Mizutani 1961; Hattori et al. 1962a; Hong 1962a, 1966; Song and Yamada 2006], **JN** [Goheung-gun, Is. Seongdudo, shoreline, 20 May 2011, Choi 110604 (JNU)], **GN** [Hattori et al. 1962b; Hong 1962a, 1966; Song and Yamada 2009a], **JB** [Buan-gun, Mt. Naebyen, Jikso Waterfall, 10 Mar 2009, Choi 3314 (JNU); Hong 1966], **GN** [Geoje-si, Oryung reservoir, 16 Mar 2011, Choi 110011 (JNU); Hat-


*Lejeunea pallidevirens* S.Hatt. – JN [Park and Choi 2007]


*Lepidozia (Dumort.) Dumort.* (Lepidoziaceae)

*Lepidozia fauriana* Steph. – JJ [Hong 1966; Choe 1980, 1983; Song and Yamada 2006], Korea [Choe and Choi 1980; Hong 1997, 2003]

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Liochlaena Nees (Delavayellaceae)

Liochlaena subulata (A.Evans) Schljakov – JJ [Jeju-si, Mt. Halla, Seongpanak- Baeokrokdam, 8 Aug 2010, Choi 7744 (JNU); Horikawa 1934b, 1935b as Hoplozia lanceolata, Hattori 1944a; Hong 1966 as Jungermannia lanceolata subsp. stephanii, Song and Yamada 2006 as Jungermannia subulata], JN [Hong 1962a, 1966 as Jungermannia lanceolata subsp. stephanii, Song and Yamada 2009b as Jungermannia subulata], JB [Jangsu-gun, Mt. Jangan, Banghwadong valley, 30 Apr 2009, Choi 3581 (JNU); Hong 1966 as Jungermannia lanceolata subsp. stephanii], GN [Hattori et al. 1962b as Jungermannia lanceolata subsp. stephanii], GB [Yeongju-si, Mt. Sobaek, Birobong area, 2 Sep 2009, Choi 4295 (JNU); Hong 1962a, 1962c, 1966 as Jungermannia lanceolata subsp. stephanii], GG [Hong 1962a, 1966 as Jungermannia lanceolata subsp. stephanii], GW [Inje-gun, Mt. Seolak, Hangyeoryeong, 28 Aug 2009, Choi 4256 (JNU); Hong 1962a, 1966 as Jungermannia lanceolata subsp. stephanii], HWN [Kim and Hwang 1991 as Jungermannia lanceolata], PN [Kim and Hwang 1991 as Jungermannia lanceolata], JG [Kim and Hwang 1991 as Jungermannia lanceolata], YG [Gao and Chang 1983a, b as Jungermannia lanceolata], PB [Kim and Hwang 1991 as Jungermannia lanceolata], Korea [Váňa 1969, 1973b as Jungermannia subulata, Choe and Yamada 1974 as Jungermannia subulata, Kitagawa 1978 as Jungermannia subulata, Choe and Choi 1980 as Jun-
germannia subulata, Miller et al. 1983 as Jungermannia subulata, Long and Grolle 1990 as Jungermannia subulata, Hong 1997, 2003 as Jungermannia subulata

**Lophocolea (Dumort.) Dumort.** (Lophocoleaceae)


**Lophocolea itoana** Inoue – JJ [Choe 1980], GW [Inje-gun, Mt. Seolak, Socheong shelter valley, 11 May 2011, Choi 110249 (JNU); Hong 1962a; Hong 1966; Choe 1980; Kim et al. 1995], YG [Kim and Hwang 1991], Korea [Choe and Choi 1980; Hong 1997, 2003]

**Lophocolea minor** Nees – JJ [Jeju-si, Sumeunmulbyengdwi, 26 Aug 2010, Choi 8028 (JNU); Horikawa 1934d; Hong and Kim 1961b; Hattori et al. 1962a; Hong

*Lophozia* (Dumort.) Dumort. (Lophoziaceae)


*Lophozia lantratovae* Bakalin – GW [Sokcho-si, Mt. Seolak, 14 Oct 2010, Choi 8613 (JNU)]


*Lophoziopsis* Konstant. et Vilnet (Lophoziaceae)

Lunularia Adans. (Lunulariaceae)

*Lunularia cruciata* (L.) Dumort. ex Lindb. – JJ [Jeju-si, Hyodon stream, 30 Oct 2011, *Choi 110361b* (JNU)], this taxon is an introduced weedy species from Mediterranean

Makinoa Miyake (Makinoaceae)


*Mannia androgyna* (L.) A.Evans – GW [Yeongwol-gun, Yeongwol-eup, Donggang River, elev. 353 m, 4 Oct 2019, *Choi 1910004* (JNU)]

*Mannia fragrans* (Balb.) Frye et L.Clark – GW [Yeongwol-gun, Yeongwol-eup, Donggang River, elev. 353 m, 4 Oct 2019, *Choi 1910005* (JNU)]


*Mannia triandra* (Scop.) Grolle – GW [Yeongwol-gun, Yeongwol-eup, Donggang River, elev. 337 m, 26 Apr 2015, *Bakalin Kor-20-1-15* (VBGI)]

Marchantia L. (Marchantiaceae)

**Marchantia paleacea subsp. paleacea** Bertol. – **JJ** [Seogwipo-si, Cheonjiyeon Valley, 20 Mar 2012, Choi 120217 (JNU)], **JN** [Choe 1975; Song and Yamada 2009b], **GW** [Hong 1962a; Gao and Chang 1983a, b; Kim and Hwang 1991], **PN** [Kim and Hwang 1991], **PB** [Kim and Hwang 1991], **Korea** [Choe and Yamada 1974; Hong 1997, 2003]


**Marchantia polymorpha subsp. polymorpha** L.– **GW** [Hongcheon-gun, Mt. Odae, Jilmaeneap (swamp), 5 Jul 2019, Choi 197020 (JNU)]

*Marchantia polymorpha subsp. montivagans* Bischl. et Boissel.-Dub. – **JB** [Muju-gun, Mt. Deogyu, 24 Jun 2008, Choi 10671 (JNU)]

**Marchantia polymorpha subsp. ruderalis** Bischl. et Boissel.-Dub. – **JJ** [Jeju-si, Musu stream, 19 Mar 2012, Choi 120199 (JNU)], **JN** [Gurye-gun, Mt. Jiri, Nogodan, 19 Sep 2009, Choi 5041 (JNU); Song and Yamada 2009b], **GB** [Ulleung-gun, Mireukbong, 21 Oct 2010, Choi 8794 (JNU)], **CN** [Choe 1979], **GG** [Hong and Kim 1961a; Hong 1962a], **GW** [Inje-gun, Mt. Seolak, Jungcheong, 21 Sep 2009, Choi 5136 (JNU); Gao and Chang 1983a, b; Kim et al. 1995], **PN** [Gao and Chang 1983a, b], **All the provinces** [Kim and Hwang 1991; Choi 1980], **Korea** [Horikawa 1939; Hattori 1944a; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

**Marsupella Dumort.** (Gymnomitriaceae)


*Marsupella koreana* Bakalin et Fedosov – **JJ** [Jeju-do, Mt. Halla, Choi 111147], **JN** [Haenam-gun, Mt. Dureun, 5 Feb 2009, Choi 3058 (JNU)], **JB** [Muju-gun Mt.


*Marsupella vermiformis* (R.M.Schust.) Bakalin et Fedosov – JJ [Seogwipo-si, Mt. Halla, elev. 1861 m, 21 Sep 2012, Choi 120911 (JNU, VBGI)]

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May 2011, Choi 110295 (JNU); Kim et al. 1995, YG [Kim and Hwang 1991], Korea [Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

*Mesoptychia (Lindb.) A.Evans* (Jungermanniaceae)


*Metacalypogeia (S.Hatt.) Inoue* (Calypogeiaceae)


*Metasolenostoma Bakalin et Vilnet* (Solenostomataceae)

*Metasolenostoma ochotense* Vilnet et Bakalin – JJ [Seogwipo-si, Hannam Experimental forest, 476 m, Choi 111730 (JNU)], JN [Jeollanam-do, Heuksando, Choi site2-3 (JNU)] JB [Jeollabuk-do, Mt. Deogyu, Choi 633 (JNU)]

*Metzgeria Raddi* (Metzgeriaceae)


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**Microlejeunea** (Spruce) Steph. (Lejeuneaceae)


**Mylia** Gray (Myliaceae)


Myriocoleopsis Schiffn. (Lejeuneaceae)

Myriocoleopsis minutissima (Sm.) R.L.Zhu, Y.Yu et Pócs – JJ [Jeju-si, Seogeomeun Oreum, 21 Jun 2011, Choi 110830 (JNU); Song and Yamada 2006 as Cololejeunea minutissima], JN [Wando-gun, Is. Bogil, ridge, 16 Nov 2010, Choi 9019], GW [Yeongwol-gun, River donggang, near the Donggang, 29 Sep 2009, Choi 5246 (JNU); Kim and Hwang 1991 as Cololejeunea minutissima], Korea [Hong 1997, 2003 as Cololejeunea minutissima]

Nardia Gray (Gymnomitriaceae)


*Nardia subclavata* (Steph.) Amakawa – CN [Nonsan-si, Mt. Daedun, 31 Mar 2009, Choi 3371 (JNU)]

Neoorthocaulis L.Söderstr., De Roo et Hedd. (Anastrophyllaceae)


Neotrichocolea S.Hatt. (Neotrichocoleaceae)

*Neotrichocolea bissetii* (Mitt.) S.Hatt. – GN [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8198 (JNU)]

Nipponolejeunea S.Hatt. (Jubulaceae)

Nipponolejeunea pilifera (Steph.) S.Hatt. – JN [Gurye-gun, Mt. Jiri, Nogodan, 29 Apr 2009, Choi 3573 (JNU); Hong 1962a, 1966; Song and Yamada 2009b], JB [Mun-
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Nipponolejeunea subalpina (Horik.) S.Hatt. – GW [Inje-gun, Mt. Seolak, Socheong stony field, 12 May 2011, Choi 110265 (JNU); Choe 1980 as Cephaloziella jishibae, Choe and Yamada 1974 as Cephaloziella jishibae, Choe and Choi 1980 as Cephaloziella jishibae, Hong 1997, 2003 as Cephaloziella jishibae]

Nowellia Mitt. (Cephaloziaceae)


Odontoschisma (Dumort.) Dumort. (Odontoschismataceae)


Pallavicinia Gray (Pallaviciniaceae)

Pallavicinia subciliata (Austin) Steph. – JJ [Jeju-si, Musu stream, 28 Oct 2010, Choi 8828 (JNU)]
**Pedinophyllum Lindb. ex Nordst.** (Plagiochilaceae)


**Pellia Raddi** (Pelliaceae)

°**Pellia epiphylla** (L.) Corda – **HWN** [Kim and Hwang 1991], **HWB** [Kim and Hwang 1991], **PB** [Kim and Hwang 1991], **YG** [Kim and Hwang 1991], **HN** [Gao and Chang 1983a, b; Yamada and Choe 1997], **HB** [Kim and Hwang 1991], **Korea** [Hong 1997, 2003]

Plagiochasma Lehm. (Aytoniaceae)


Plagiochila (Dumort.) Dumort. (Plagiochilaceae)


*Plagiochila furcifolia* Mitt. – JJ [Jeju-si, Bijarim, 2 May 2012, Choi 120431 (JNU)]

Plagiochila gracilis Lindenb. et Gottsche – JJ [Hattori et al. 1962a as Plagiochila firma subsp. rhizophora, Hong 1962a as Plagiochila rhizophora, Song and Yamada 2006], JN [Hong 1962a as Plagiochila rhizophora, Choe 1980 as Plagiochila firma subsp. rhizophora, Song and Yamada 2009b], GN [Hamyang-gun, Mt. Jiri, Cheonwnagbong, 29 Sep 2010, Choi 8234 (JNU); Hattori et al 1962b as as Plagiochila firma subsp. rhizophora, Choe 1980 as Plagiochila firma subsp. rhizophora], GW [Inje-gun, Mt. Seolak, Hangyeoryeong, 21 Sep 2009, Choi 5068 (JNU); Hong 1962a, 1962b as Plagiochila rhizophora, Choe 1980 as Plagiochila firma subsp. rhizophora,], Korea [Choe and Yamada 1974 as Plagiochila firma subsp. rhizophora, Choe and Choi 1980 as Plagiochila firma subsp. rhizophora, Hong 1997, 2003]

Plagiochila hakkodensis Steph. – JJ [Jeju-si, Seogeomeun Oreum, 20 Sep 2011, Choi 111005 (JNU); Hattori et al. 1962a; Hong 1962a; Choe 1980; Song and Yamada 2006], JN [Hong 1962a ], GN [Sancheong-gun, Mt. Jiri, below Cheonwangbong, 15 Jun 2009, Choi 3818 (JNU); Hong 1962a; Choe 1980; Song and Yamada 2009a], GG [Hong 1962a], GW [Hong 1962a; Kim and Hwang 1991], Korea [Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

**Plagiochila parvifolia** Lindemb. – **JN** [Sinan-gun, Is. Gageo, Mt. Doksil, 2 Mar 2010, Choi 7187 (JNU); Hong 1962a, 1966 as Plagiochila yokogurenensis, Song and Yamada 2009b], **CN** [Horikawa 1951a; Hattori et al. 1962b as Plagiochila yokogurenensis], **JN** [Sinan-gun, Is. Gageodo, Bolyeem seashore 22 Apr 2012, Choi 120401 (JNU); Hong 1962a, 1966 as Plagiochila satoi, Song and Yamada 2009b], **JB** [Jeongeup-si, Mt. Naejang, Geumseon valley, 16 Mar 2009, Choi 3454 (JNU)], **GN** [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8147 (JNU); Hattori et al. 1962b as Plagiochila satoi, Hong 1966 as Plagiochila satoi, Song and Yamada 2009a], **GB** [Ulleung-gun, Mireukbong, 21 Oct 2010, Choi 8791 (JNU); Hong 1966 as Plagiochila satoi].


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**Plagiochila semidecurrens** (Lehm. et Lindenb.) Lindenb. – **JJ** [Hattori et al. 1962a as *Plagiochila semidecurrens var. grossidens*, Hong 1962a, 1966; Song and Yamada 2006], **JN** [Hong 1962a, 1966 as *Plagiochila semidecurrens var. grossidens*, Song and Yamada 2009b], **GN** [Hamyang-gun, Mt. Jiri, Cheonwangbong area, 11 Oct 2019, Choi 1910268 (JNU); Hattori et al. 1962b as *Plagiochila semidecurrens var. grossidens* Choe 1980], **PB** [Kim and Hwang 1991], **HB** [Kim and Hwang 1991], **Korea** [Iwatsuki and Mizutani 1972; Choe and Yamada 1974; Inoue 1976; Choe and Choi 1980; Hong 1997, 2003]


Plagiochilion S.Hatt. (Plagiochilaceae)

Plagiochilion mayebarae S.Hatt. – JJ [Jeju-si, Mt. Halla, Baekrokdam, 8 Aug 2010, Choi 7764 (JNU); Choe and Yamada 1998], GN [Hamyang-gun, Mt. Jiri, Cheonwnagbong, 28 Sep 2010, Choi 9132 (JNU); Choe and Yamada 1998; Song and Yamada 2009b]

Plectocolea (Mitt.) Mitt. (Solenostomataceae)

Plectocolea comata (Nees) S.Hatt. – JJ [Jeju-si, Che Oruem, 27 Aug 2010, Choi 8061 (JNU)], JN [Haenam-gun, Mt. Duryun, Taehengsa Temple valley, 18 May 2011, Choi 110495 (JNU)], GB [Choe 1980 as Jungermannia comata], CB [Choe 1980 as Jungermannia comata], GG [Choe 1980 as Jungermannia comata], CB [Choe 1980 as Jungermannia comata], GW [Hong and Kim 1961a as Jungermannia comata, Hong 1962a as Jungermannia comata, Choe 1980 as Jungermannia comata], Korea [Váňa 1972 as Jungermannia comata, Choe and Yamada 1974 as Jungermannia comata, Choe and Choi 1980 as Jungermannia comata, Miller et al. 1983 as Jungermannia comata, Hong 1997, 2003 as Jungermannia comata]

Plectocolea erecta Amakawa – JJ [Mt. Halla, elev. 1,687 m, Choi 110379 (JNU)], JN [Choe 1980 as Jungermannia erecta], JB [Muju-gun, Mt. Deogyu, 7 Jun 2008, Choi 614 (JNU)], GN [Hapcheon-gun, Mt. Gaya, top of mountain, elev. 1,350 m, 22 Jun 2010, Choi 7424a (JNU)], GB [Ulleung-gun, Jeodong, Bongrae waterfall, Choi site4-224 (JNU)], CN [Nonsan-si, Mt. Daedun, elev. 343 m, Choi 3366 (JNU)], GW [Inje-gun, Mt. Seolak, Ssangyoung waterfall, 14 Oct 2010, elev. 937 m, Choi 8628 (JNU); Kim et al. 1995 as Jungermannia erecta], Korea [Hong 2003 as Jungermannia erecta]

*Plectocolea granulata* (Steph.) Bakalin – JJ [Seogwipo-si, Sumeunmulbyeng dwi, elev. 992 m, 26 Aug 2010, Choi 8019 (JNU)]

*Plectocolea grossitexta* (Steph.) S.Hatt. – JJ [Seogwipo-si, Sumeunmulbyengdw i, elev. 992 m, 26 Aug 2010, Choi 8057 (JNU)]

Plectocolea infusca var. infusca Mitt. – JJ [Seogwipo-si, Bolrae Oreum, elev. 1,230 m, 1 Nov 2011, Choi 111429 (JNU); Hong 1966 as Jungermannia infusca, Miller et al. 1983 as Jungermannia infusca, Song and Yamada 2006 as Jungermannia infusca], JN [Haenam-gun, Mt. Dureun, elev. 262 m, 18 May 2011, Choi 110500 (JNU); Hong 1962a, 1966 as Jungermannia infusca, Song and Yamada 2009b as Jungermannia infusca], JB [Muju-gun, Mt. Deogyu, 7 Jun 2008, Choi 596 (JNU); Hong 1966 as Jungermannia infusca], GN [Mt. Hwangmae, elev. 908 m, 3 Aug 2010, Choi 7500 (JNU)], GB [Mt. Sinbul, elev. 987 m, 1 Oct 2010, Choi 8328 (JNU);
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Hong 1966 as *Jungermannia infusca*, CN [Hong 1962a, 1966 as *Jungermannia infusca*], GG [Hong 1962a, 1966 as *Jungermannia infusca*], GW [Hong 1966 as *Jungermannia infusca*], PN [Kim and Hwang 1991 as *Jungermannia infusca*], JG [Kim and Hwang 1991 as *Jungermannia infusca*], Korea [Váňa and Inoue 1983 as *Jungermannia infusca*], Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003 as *Jungermannia infusca*


*Plectocolea kurilensis* (Bakalin) Bakalin et Vilnet – JJ [Seogwipo-si, Bolrae Oreum, elev. 1,230 m, Choi 120737 (JNU)]


*Plectocolea tortedixylx* (Steph.) S.Hatt. – **JB** [Namwon-si, Jirisan Mt., elev. 1,300 m, Choi 6071 (JNU)], **GN** [Sancheong-gun, Mt. Jiri, Jungsanri valley, 16 Jun 2009, Choi 3856 (JNU)].

Plectocolea truncata (Nees) Herzog – **JJ** [eju-si, Che Oruem, 27 Aug 2010, Choi 8059 (JNU)], **CN** [Gyeryong-si, Mt. Gyeryong, elev. 290 m, Temple Donghaksa valley, 8 Jul 2009, Choi 4096 (JNU)], **GG** [Hong 1962a, 1966 as Jungermannia tsukushinensis], **GW** [Choe 1980, 1983 as Jungermannia truncata], **Korea** [Choe and Yamada 1974 as Jungermannia truncata, Hattori 1975 as Jungermannia virgata, Choe and Choi 1980 as Jungermannia truncata, Hong 1997, 2003 as Jungermannia truncata].

Plectocolea virgata Mitt. – **JJ** [Seogwipo-si, Hyodon stream, 29 Oct 2011, Choi 111260 (JNU); Hattori et al. 1962a as Jungermannia virgata, Hong 1962a; Hong 1966 as Jungermannia virgata, Choe 1980 as Jungermannia virgata, Song and Yamada 2006 as Jungermannia virgata], **JN** [Hattori et al. 1962b as Jungermannia virgata, Hong 1962a as Jungermannia virgata, Song and Yamada 2009b as Jungermannia virgata], **GN** [Hattori et al. 1962b as Jungermannia virgata, Choe 1980 as Jungermannia virgata], **Korea** [Choe and Yamada 1974 as Jungermannia virgata, Choe and Choi 1980 as Jungermannia virgata, Váňa and Inoue 1983 as Jungermannia virgata, Hong 1997, 2003 as Jungermannia virgata].

Plicanthus R.M.Schust. (Anastrophyllaceae)

Plicanthus birmensis (Steph.) R.M.Schust. – **JJ** [Jeju-si, Seogeomeun Oreum, 20 Sep 2011, Choi 111022b (JNU)], **JN** [Goheung-gun, Is. Oenaro, Mt. Bongrae, valley, 20 May 2011, Choi 110595 (JNU); Song and Yamada 2009b], **JB** [Jangsu-gun, Mt. Jangan, Banghwadong valley, 30 Apr 2009, Choi 3580 (JNU)], **GN** [Geoje-si, Oryung reservoir, 16 Mar 2011, Choi 110105 (JNU); Horikawa 1951a as Temnoma birmense], **GB** [Cheongsong-gun, Mt. Juwang, The 2nd waterfall, 8 Nov 2010, Choi 8916 (JNU)], **CN** [Choe 1975, 1979 as Chandonanthus birmensis], **GG** [Hong 1960b as Temnoma birmense; Hong 1962a, 1966 as Chandonanthus birmensis, Choe 1975 as Chandonanthus birmensis], **GW** [Inje-gun, Mt. Seolak, Baekdamsam Temple valley, 11 May 2011, Choi 110112 (JNU); Choe 1975, Gao and Chang 1983a, 1983b as Chandonanthus birmensis, Kim et al. 1995 as Chandonanthus birmensis], **HN** [Kim and Hwang 1991 as Chandonanthus birm-

Porella L. (Porellaceae)


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°**Porella stephaniana** (C.Massal.) S.Hatt. – GW [Yeongweol-gun, River Donggang, 17 Aug 2010, Choi 7937 (JNU)]
**Porella subobtusa** (Steph.) S.Hatt. – **JN** [Haenam-gun, Mt. Duryun, Taehengsa Temple valley, 18 May 2011, Choi 110460 (JNU)], **GB** [Hong 1966 as *Porella setigera* var. *subobtusa*, Choe 1980], **GW** [Hong 1962a as *Porella setigera* var. *subobtusa*], **Korea** [Choe and Choi 1980; Hong 1997, 2003]


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Preissia Corda (Marchantiaceae)

*Preissia quadrata* (Scop.) Nees – GW [Jeongseon-gun, River Donggnag, Limstone, 7 Sep 2011, Choi 110901 (JNU)]

Protosolenostoma (Amakawa) Bakalin et Vilnet (Solenostomataceae)

Protosolenostoma fusiforme (Steph.) Vilnet et Bakalin – JJ [Seogwipo-si, Borle Oreum, elev. 1,230 m, 1 Nov 2011, Choi 111411 (JNU); Stephani 1917b as Solenostoma koreanum; Amakawa 1960 as Jungermannia koreana, Hong 1966 as Jungermannia koreana, Váňa 1975 as Solenostoma koreanum, Choe 1980, 1983 as Jungermannia fusiformis, Song and Yamada 2006 as Jungermannia fusiformis], JN [Song and Yamada 2009b as Jungermannia fusiformis], JB [Muju-gun, Mt. Deogyu, Choi 1039 (JNU)], GN [Gurye-gun, Mt. Jiri, Nogodan, 19 Sep 2009, Choi 5042 (JNU); Song and Yamada 2009a as Jungermannia fusiformis], Korea [Iwatsuki and Mizutani 1972 as Jungermannia koreana, Choe and Yamada 1974 as Jungermannia koreana, Choe and Choi 1980 as Jungermannia fusiformis, Hong 1997, 2003 as Jungermannia fusiformis]

Pseudolophozia Konstant. et Vilnet (Anastrophyllaceae)


Ptilidium Nees (Ptilidiaceae)


**Radula Dumort.** (Radulaceae)


*Radula brunnea* Steph. – JJ [Seogwipo-si, Mt. Halla, Baekrokdam, 7 Aug 2012, *Choi 120814a* (JNU)]


Radula obtusiloba Steph. – JJ [Jeju-si, Gwangryeongcheon stream, 4 May 2012, Choi 120507 (JNU); Hong 1962a; Song and Yamada 2006], JN [Hong 1966; Song and Yamada 2006b], GN [Hattori et al. 1962b; Choe 1980], GB [Cheongsong-gun, Mt. Juwang, The 2nd waterfall, 8 Nov 2010, Choi 8918 (JNU)], GW [Inje-gun, Mt. Seolak, Kkeucheong, 21 Sep 2009, Choi 5103 (JNU); Hong 1962a, b, 1966; Yamada 1979; Choe 1980; Kim et al. 1995], YG [Yamada 1989], HN [Kim and Hwang 1991], HB [Kim and Hwang 1991], Korea [Aur and Zhang 1985; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]


Radula tokiensis Steph. – JJ [Seogwipo-si, Dongheung-dong valley 15 Oct 2012, Choi 121124 (JNU); Hong 1966; Song and Yamada 2006], JN [Haenam-gun, Mt. Duryun, Taehengsa Temple valley, 18 May 2011, Choi 110471 (JNU); Hong 1966], JB [Buan-gun, Mt. Naebyeon, Namyeochi, 10 Mar 2009, Choi 3333 (JNU); Hong 1966], GN [Geoje-si, Oryung reservoir, 16 Mar 2011, Choi 110020 (JNU); Hong 1966], GB [Hong 1966], CN [Gongju-si, Mt. Gyeryong, Temple Dohakhasa valley, 8 Jul 2009, Choi 4075 (JNU); Yamada 1979; Choe 1980], CB [Yamada 1979], GG [Hong 1962a, 1966], GW [Hong 1966], Korea [Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

Reboulia Raddi (Aytoniaceae)


Riccardia Gray (Aneuraceae)


Riccardia chamedryfolia (With.) Grolle – JJ [Choe 1980, Song and Yamada 2006], JN [Sancheon-si, Mt. Jogyeo, Seonamsa Temple, 7 Dec 2010, Choi 9111 (JNU)],
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GN [Choe 1980], GB [Ulsan-si, Mt. Jeongjok, Mujechi 1 neup, 30 Sep 2010, Choi 8308 (JNU)], Korea [Choe and Choi 1980; Hong 1997, 2003]

*Riccardia glauca* Furuki – JJ [Seogwipo-si, Hyodon stream, 7 Aug 2010, Choi 7631 (JNU)]


*Riccardia nagasakiensis* (Steph.) S.Hatt. – JJ [Jeju-si, Mt. Halla, Tamla valley, 25 Sep 2012, Choi 6042 (JNU)]


*Riccia* L. (Ricciaceae)

*Riccia beyrichiana* Hampe – JJ [Jeju-si, Gujwa-eup, Gimnyeong-ri, Manjangul lava tube, 18 Jan 2020, Choi 201063 (JNU)]

*Riccia bifurca* Hoffm. – JJ [Jeju-si, Gujwa-eup, Gimnyeong-ri, near Manjangul lava tube, 18 Jan 2020, Choi 201065b (JNU)]


Ricciocarpos Corda (Ricciaceae)


Scapania (Dumort.) Dumort. (Scapaniaceae)

**Scapania apiculata** Spruce – **JN** [Gurye-gun, Mt. Jiri, Nogodan, 19 Sep 2009, Choi 5038 (JNU)], **GW** [Taebaek-si, Mt. Taebaek, Janggunbong, 15 Sep 2009, Choi 4460 (JNU)], **YG** [Gao and Chang 1983a, b], **HN** [Kim and Hwang 1991], Korea [Hong 1997, 2003]

°**Scapania carinthiaca** J.B. Jack ex Lindb. – **GW** [Kim et al. 1995], **YG** [Gao and Chang 1983a, 1983b], **HN** [Kim and Hwang 1991], Korea [Hong 1997, 2003]


**Scapania curta** (Mart.) Dumort. – **JJ** [Hattori et al. 1962a, Hong 1962a, Song and Yamada 2006], **JT** [Hong 1962a, 1966; Song and Yamada 2009b], **GN** [Hattori et al. 1962b; Choe 1980], **GG** [Hong 1966; Choe 1980], **GW** [Hwacheong-un, Sangseo-myeon, Guun-ri, 2 Sep 2012, Kim Hwacheon-6 (JNU, KB)], Korea [Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

**Scapania integerrima** Steph. – **JJ** [Jeju-si, Musu stream, Goangryeong 2nd Bridge, 17 Mar 2012, Choi 120074c (JNU); Hong 1966 as *Scapania stephanii*, Song and Yamada 2006 as *Scapania ligulata*], **JN** [Goheung-gun, Mt. Palyeoung, Forest lodge valley, 23 Jun 2009, Choi 4024 (JNU); Hong 1966 as *Scapania stephanii*, Song and Yamada 2009b as *Scapania ligulata*], **JB** [Buan-gun, Mt. Naebyen, Beadrock near road, 10 Mar 2009, Choi 3355 (JNU); Hong 1966 as *Scapania stephanii*], **GN** [Geochang-gun, Mt. Namdeogyu, top of mountain, 11 Nov 2010, Choi 8968 (JNU)], **GB** [Hong 1966 as *Scapania stephanii*], **CN** [Gongju-si, Mt. Gyeryong, Temple Donghaksa valley, 8 Jul 2009, Choi 4087 (JNU); Choe 1979 as *Scapania stephanii*], **GG** [Hong 1962a, 1966 as *Scapania stephanii*, Choe 1980, 1983], **GW** [Inje-gun, Mt. Seolak, Bongjeongam valley, 11 May 2011, Choi 110168 (JNU); Hong 1962a as *Scapania stephanii*, Kim and Hwang 1991 as *Scapania stephanii*, Kim et al. 1995 as *Scapania stephanii*], Korea [Choe and
Yamada 1974 as *Scapania stephanii*, Choe and Choi 1980 as *Scapania stephanii*,
Hong 1997, 2003 as *Scapania stephanii*

*Scapania irrigua* (Nees) Nees – JJ [Jeju-si, Mt. Halla, Seongpanak- Baekrokdam,


*Scapania scandica* (Arnell et H.Buch) Macvicar – GW [Inje-gun, Mt. Seolak, Socheong stony field, 12 May 2011, *Choi 110268* (JNU)]

*Scapania sphaerifera* H.Buch et Tuom – GW [Inje-gun, Mt. Seolak, Jungcheongbong stony field, 12 May 2011, *Choi 110308* (JNU)]

*Scapania subalpina* (Nees ex Lindenb.) Dumort. – GW [Inje-gun, Mt. Seolak, Baekdamsa Temple, 28 Aug 2009, *Choi 5277* (JNU)]

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Schistochilopsis (N.Kitag.) Konstant. (Lophoziaceae)


Solenostoma Mitt. (Solenostomataceae)

*Solenostoma cyclops* (S.Hatt.) R.M.Schust. – **GN** [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, *Choi 8204* (JNU)]

**Solenostoma faurieanum** (Beauverd) R.M.Schust. – **JJ** [Quelpaert (=Jeju Island) 1906 *U. Faurie* (No. 106) G00115348 (Holotype; G); Stephani 1917c as *Jungermannia decurrens*, Amakawa 1960 as *Jungermannia fauriana*, Hong 1962a, 1966 as *Jungermannia fauriana*, Choe 1980, 1983 as *Jungermannia fauriana*, Song and Yamada 2006 as *Jungermannia fauriana*, Korea [Choe and Yamada 1974 as *Jungermannia fauriana*, Choe and Choi 1980 as *Jungermannia fauriana*, Hong 1997, 2003 as *Jungermannia fauriana*]

*Solenostoma jirisanense* Bakalin et S.S. Choi – **GN** [Mt. Jiri, elev. 1,620 m, *Choi 3747-3* (Holotype: JNU)]

*Solenostoma minutissimum* (Amakawa) Bakalin – **JJ** [Seogwipo-si, Bolre Oreum, elev. 1,230 m, 5 Sep 2012, *Choi 120745* (JNU)]

*Solenostoma obscurum* (A. Evans) R.M.Schust. – **GW** [Inje-gun, Mt. Seolak, Socheong shelter valley, elev. 1,407 m, 12 May 2011, *Choi 110353* (JNU)]

*Solenostoma purpuratum* (Mitt.) Steph. var. *koponenii* Bakalin et Li Wei – **JJ** [Goangryeongcheon stream, elev. 766 m, 14 May 2012, *Choi 120375* (JNU)]


**Solenostoma rotundatum** Amakawa – **JJ** [Seogwipo-si, Donnaeko stream, elev. 172 m, 31 Oct 2011, *Choi 111381* (JNU); Hong 1966 as *Jungermannia harana*, Song and Yamada 2006 as *Jungermannia rotundata*, **JN** [Goheung-gun, Is. Oenarodo, Mt. Bongrae, elev. 120 m, 20 May 2011, *Choi 110580* (JNU); Hong 1966 as *Jungermannia harana*, Song and Yamada 2009b as *Jungermannia rotundata*, **JB** [Muju-gun, Mt. Deogyu, 27 Jun 2008, *Choi 865* (JNU); Hong 1966 as *Jungermannia harana*, **CN** [Gyeongbuk-si, Mt. Gyeryong, elev. 290 m, *Choi 4091* (JNU), **GN** [Hapcheon-gun, Mt. Gaya, elev. 585 m, *Choi 4355* (JNU)], **GB** [Youngju-si, Mt. Sobaek, elev.
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569 m, Choi 4304 (JNU); Hong 1966 as Jungermannia harana, GG [Hong 1962a, 1966 as Jungermannia harana], GW [Jeongseon-gun, Mt. Haembaek, Choi 4147 (JNU)], Korea [Choe and Yamada 1974 as Jungermannia harana, Choe and Choi 1980 as Jungermannia harana, Hong 1997, 2003 as Jungermannia rotundata]

**Solenostoma sunii** Bakalin et Vilnet – JJ [Seogwipo-si, Bolre Oreum, elev. 1,230 m, Choi 111425 (JNU)], JB [Muju-gun, Mt. Drogyu, 30 Jun 2008, Choi 878 (JNU)]

**Jungermannia harana** R.Br. [Sancheong-gun, Mt. Jiri, Jangsanri valley, elev. 848 m, 13 Jun 2009, Choi 3653 (JNU); Choi 1983 as Jungermannia pyriflora var. major, CN [Choe 1980, 1983 as Jungermannia pyriflora var. major], GG [Hong 1962a, 1966 as Jungermannia pyriflora var. major], GW [Hong 1962a as Jungermannia pyriflora var. major], Korea [Choe and Choi 1980 as Jungermannia pyriflora var. major, Hong 1997 as Jungermannia pyriflora var. major]

**Jungermannia pyriflora** var. major (Hedw.) Brid. – GW [Jangseong-gun, Mt. Dunsan, Choe 3653 (JNU); Choe 1983 as Jungermannia pyriflora var. major, CN [Choe 1980, 1983 as Jungermannia pyriflora var. major], GG [Hong 1962a, 1966 as Jungermannia pyriflora var. major], GW [Hong 1962a as Jungermannia pyriflora var. major], Korea [Choe and Choi 1980 as Jungermannia pyriflora var. major, Hong 1997 as Jungermannia pyriflora var. major]

**Jungermannia rotundata** R.Br. – GW [Jeongseon-gun, Mt. Haembaek, Choi 4147 (JNU)]

**Jungermannia arenosa** (Hedw.) Brid. – GG [Hong 1962a, 1966 as Jungermannia harana, GW [Jeongseon-gun, Mt. Haembaek, Choi 4147 (JNU)], Korea [Choe and Yamada 1974 as Jungermannia harana, Choe and Choi 1980 as Jungermannia harana, Hong 1997, 2003 as Jungermannia rotundata]

**Spruceanthus Verd.** (Lejeuneaceae)

*Spruceanthus pearsonii* (Spruce) R.M.Schust. – GW [Sokcho-si, Mt. Seolak, 13 May 2011, Choi 110394 (JNU)]

**Sphenolobopsis** R.M.Schust. et N.Kitag. (Anastrophyllaceae)

*Sphenolobopsis pearsonii* (Spruce) R.M.Schust. – GW [Sokcho-si, Mt. Seolak, 13 May 2011, Choi 110394 (JNU)]

**Sphenolobus** (Lindb.) Berggr. (Anastrophyllaceae)

*Sphenolobus minutus* (Schreb. ex D.Crantz) Berggr. – GW [Inje-gun, Mt. Seolak, Jungcheong, 21 Sep 2009, Choi 5143 (JNU); Kim et al. 1995 as Anastrophyllum minutum], PB [Kim and Hwang 1991 as Anastrophyllum minutum], JG [Kim and Hwang 1991 as Anastrophyllum minutum], YG [Kim and Hwang 1991 as Anastrophyllum minutum], HB [Kim and Hwang 1991 as Anastrophyllum minutum], Korea [Hong 1997, 2003 as Anastrophyllum minutum]

*Sphenolobus saxicola* (Schrad.) Steph. – GN [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8170 (JNU)], GW [Inje-gun, Mt. Seolak, Jungcheong, 21 Sep 2009, Choi 5134 (JNU)], HN [Kim and Hwang 1991 as Anastrophyllum minutum], Korea [Hong 1997, 2003 as Anastrophyllum saxicola]

**Spruceanthus Verd.** (Lejeuneaceae)


*Spruceanthus semirepandus* (Nees) Verd. – JN [Sinan-gun, Is. Gageodo Mt. Doksil 2 Mar 2010, Choi 7188 (JNU)]
Syzygiella Spruce (Adelanthaceae)


Syzygiella nipponica (S.Hatt.) K.Feldberg, Váňa, Hentschel et Heinrichs – JJ [Seogwipo-si, Yeongsil valley, 12 Oct 2012, Choi 121062 (JNU)]

Targonia L. (Targioniaceae)


Tetralophozia (R.M.Schust.) Schljakov (Anastrophyllaceae)

*Tetralophozia filiformis* (Steph.) Urmi – GN [Hamyang-gun, Mt. Jiri, Chilseon valley, 28 Sep 2010, Choi 8162 (JNU)], GW [Inje-gun, Mt. Seolak, Bongjeongam valley, 11 May 2011, Choi 110169 (JNU)]

Trichocolea Dumort. (Trichocoleaceae)


**Trichocoleopsis S.Okamura** (Neotrichocoleaceae)


**Trilophozia (R.M.Schust.) Bakalin** (Lophoziaceae)


**Trilophozia Schiffn. ex Loeske** (Lophoziaceae)

[Kim and Hwang 1991], HB [Kim and Hwang 1991], Korea [Hattori 1975a; Choe and Yamada 1974; Choe and Choi 1980; Hong 1997, 2003]

*Tritomaria koreana* Bakalin, S.S.Choi et B.Y.Sun – GN [Hamyang-gun, Mt. Jiri, Cheonwnagbong, 29 Sep 2010, Choi 8225 (JNU)]

*Tuzibeanthus S.Hatt.* (Lejeuneaceae)


*Wiesnerella Schiffn.* (Wiesnerellaceae)

*Wiesnerella denudata* (Mitt.) Steph. – JJ [Jeju-si, Musu stream, 28 Oct 2010, Choi 8833 (JNU); Horikawa 1934b; Miller et al. 1983; Hong 1962a; Song and Yamada 2006], Korea [Hattori 1944a; Iwatsuki and Mizutani 1972; Choe and Yamada 1974; Inoue 1976; Choe and Choi 1980; Choe 1983; Hong 1997, 2003]

*Xenochila R.M.Schust.* (Delavayellaceae)


Excluded and doubtful records

*Bazzania bidentula* (Steph.) Yasuda – This species was recorded as for JJ [Hong 1962a], GW [Hong 1962a], Korea [Reimers 1931 as Mastiogbryum bidentulum Steph.]; however, all records of this taxon from temperate East Asia should belong to *B. parabidentula* (Bakalin 2016a).

*Bazzania flaccida* (Dumort.) Grolle – This species was recorded for Korea [Hong 2003], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

*Calycularia crispula* Mitt. – This species was recorded for GN [Hattori et al. 1962b], JG [Kim and Hwang 1991], Korea [Iwatsuki and Mizutani 1972], however, as it was shown by Konstantinova and Mamontov (2010) all reports of the species from the Russian Far East, Korea and Japan belong to *C. laxa*. 
**Calypogeia azurea** Stotler et Crotz – This species was recorded for JJ [Hong 1966 as *Calypogeia trichomanis*, Choe 1975, 1980 as *Calypogeia trichomanis*, Song and Yamada 2006], JN [Hong 1962a, 1966 as *Calypogeia trichomanis*, Song and Yamada 2009b], GN [Choe 1975, 1980 as *Calypogeia trichomanis*], PB [Kim and Hwang 1991 as *Calypogeia trichomanis*], YG [Kim and Hwang 1991 as *Calypogeia trichomanis*], HN [Kim and Hwang 1991 as *Calypogeia trichomanis*], Korea [Choe and Yamada 1974 as *Calypogeia trichomanis*, Choe and Choi 1980 as *Calypogeia trichomanis*, Hong 1997, 2003], however, as it was recently shown, all reports of this species from temperate East Asia refer to *Calypogeia orientalis* Buczowska & Bakalin (Buczowska et al. 2018).

**Calypogeia granulata** Inoue – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Cephalozia hamatifiloba** Steph. – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist. Also, this species is a southerly distributed taxon stretching to Indochina.

**Cololejeunea latilobula** (Herzog) Tixier. – This species was recorded for Korea [Hong 1997, 2003], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Conocephalum conicum** (L.) Dumort. – This species was recorded for JJ [Horikawa 1935a], JN [Hong 1962a], GG [Hong 1962a], GW [Hong 1962a], All the provinces [Choe 1980, Kim and Hwang 1991], however, this is mainly a European species (Szweykowski et al. 2005), whereas all reports from East Asia belong to *Conocephalum salebrosum* Szweyk., Buczk. et Odrzyk.

**Delavayella serrata** Steph. – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Diplophyllum obtusifolium** (Hook) Dumort. – This species was recorded for GW [Kim and Hwang 1991], however, records of this taxon from North Asia should belong to *Diplophyllum sibiricum* Vilnet et Bakalin (Bakalin and Vilnet 2018).

**Fossombronia foveolata var. cristula** (Austin) R.M.Schust. – This species was recorded for Korea [Hong 1997], however, all reports of this species from temperate East Asia referable to *Fossombronia japonica* Schiffn. (Borovichev and Bakalin 2017).
**Fossombronia cristula** Austin – This species was recorded for Korea [Choe 1983], however, all reports of this species from temperate East Asia refer to *Fossombronia japonica* Schiffn. (Borovichev and Bakalin 2017)

**Frullania bolanderi** Austin – This species was recorded for GW [Kim and Hwang 1991], HN [Kim and Hwang 1991], HB [Kim and Hwang 1991], Korea [Choe 1980; Hong 1997, 2003], however, this is an endemic to North America (Mamontov et al. 2020), whereas all reports from East Asia belong to *Frullania austinii* J.J. Atwood, Vilnet, Mamontov et Konstant.

**Gongylanthus ericetorum** (Raddi) Nees – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Gymnomitrion concinnatum** (Lightf.) Corda – This species was recorded for YG [Kim and Hwang 1991], PN [Kim and Hwang 1991], Korea [Hong 1997, 2003], however, all reports of this species from temperate East Asia refer to *Gymnomitrion faurianum* (Steph.) Horik. (Bakalin 2016b)

**Gymnomitrion corallioides** Nees – This species was recorded for JJ [Choe 1980, 1982, 1983; Song and Yamada 2006], Korea [Choe and Choi 1980; Hong 1997, 2003], however, all reports of this species from temperate East Asia refer to *Gymnomitrion faurianum* (Steph.) Horik. (Bakalin 2016b)

**Gymnomitrion revolutum** (Nees) H.Philib – This species was recorded for YG [Kim and Hwang 1991 as Marsupella revoluta], Korea [Hong 1997, 2003 as Marsupella revoluta]. Not confirmed. The records from Korea probably belong to *Gymnomitrion parvitextum* (Steph.) Mamontov, Konstant. et Potemkin.

**Jungermannia cordifolia** Hook. nom. nud. – This species was recorded for HWN [Kim and Hwang 1991], however, the records from Korea are erroneous and probably belong to *Jungermannia exsertifolia* Steph.

**Lejeunea cavifolia** (Ehrh.) Lindb. – This species was recorded from GW [Kim et al. 1995], PB [Kim and Hwang 1991], YG [Gao and Chang 1983a, b; Kim and Hwang 1991], HN [Kim and Hwang 1991], HB [Kim and Hwang 1991], Korea [Reimers 1931; Choe and Choi 1980; Hong 1997, 2003]. However, as it was shown by M. Mizutani (1961) *L. cavifolia* was reported for many times in Japan, but all or nearly all reports are belonging to *L. japonica*. Almost the same situation applies to this species in the Russian Far East: although it was many times reported, but all reports are based on *L. japonica* (Bakalin 2019). Within the Korean Peninsula we checked many specimens and we did not find ‘true’ *L. cavifolia*, which is probably limited to Europe and North America.
**Lepidozia filamentosa** (Lehm. et Lindenb.) Lehm. et Lindenb. – This species was recorded for **GW** [Hong 1962a], however, if the narrow species treatment would be adopted in the group, this name should be referred to *L. subtransversa* in East Asia, whereas ‘true’ *L. filamentosa* occurs in western North America.

**Lopholejeunea subfusca** (Nees) Schiffn. – This species was recorded for **JN** [Hong 1962a], **Korea** [Hong 1966, 1997, 2003; Choe and Yamada 1974], however, the distribution of *L. subfusca* covers tropical and subtropical areas, so its occurrence in Mt. Jiri of Jeollanam-do province is doubtful. The plants most probably belong to *Acanthocoleus yoshinagana* (S. Hatt.) Mizut., which is relatively common on Mt. Jiri, but it was not recorded by Hong (1962a).

**Marchantia pinnata** Steph. – This species was recorded for **Korea** [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Marsupella emarginata** (Ehrh.) Dumort. – This species was recorded for **PB** [Kim and Hwang 1991 as], **HN** [Kim and Hwang 1991], **HB** [Kim and Hwang 1991], however, the records from Korea are erroneous and probably belong to *Marsupella tubulosa* Steph.

**Marsupella sphacelata** (Giesecke ex Lindenb.) Dumort. – This species was recorded for **GW** [Kim and Hwang 1991], **YG** [Kim and Hwang 1991], **Korea** [Hong 2003], however, the records from Korea are erroneous and probably belong to *Marsupella apertifolia* Steph.

**Metalejeunea cucullata** (Reinw., Blume et Nees) Grolle – This species was recorded for **Korea** [Park and Choi 2007]; however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Metzgeria consanguinea** Schiffn. – This species was recorded for **JG** [Kim and Hwang 1991], **YG** [Kim and Hwang 1991], **HN** [Gao and Chang 1983a, b], **Korea** [Shin 1970; Iwatsuki and Mizutani 1972; Choe and Yamada 1974; Choe 1975, 1980; Choe and Choi 1980; Inoue 1981; Hong 1997], however, the records from Korea are misidentified *Metzgeria temperata* (Kuwahara 1976).

**Odontoschisma grosseverrucosum** Steph. – This species was recorded for **GW** [Kim and Hwang 1991], however, the record from Korea is erroneous and probably belongs to *Odontoschisma pseudogrosseverrucosum* Gradst., Aranda et Vanderp.

**Plagiochasma intermedium** Lindenb. et Gottsche – This species was recorded for **GG** [Hong 1962a], **Korea** [Choe and Yamada 1974], however, the report refers to *Plagiochasma pterospermum* C. Massal.
**Plaiochila delavayi** Steph. – This species was recorded for Korea [Reimers 1931, Park and Choi 2007], however, the records from Korea and Japan are doubtful and probably belong to *Plagiochila ovalifolia* Mitt. (Hattori 1949; So 2001).

**Plectocolea flagellata** S.Hatt. This species was recorded for GG [Hong 1966, 1997, 2003 as *Jungermannia flagellata* (S.Hatt.) Amakawa]. Not confirmed. The species is a Japanese temperate lowland endemic (Yakushima Island, Kyushu), and may be easily recognized due to its common ventral leafless geotropic stolons and botryoidal oil-bodies (Bakalin et al. 2020a [Solenostomataceae]).

**Plectocolea hyalina** (Lyell) Mitt. – This species was recorded for CB [Choe 1980, 1983 as *Jungermannia hyalina* Lyell], GG [Hong 1966, 1997, 2003 as *Jungermannia hyalina*], GW [Kim et al. 1995 as *Jungermannia hyalina*], JN [Bakalin 2014], however, the plants most probably belong to *Metasolenostoma ochotense* and *Plectocolea infusca* (Bakalin et al. 2020a [Solenostomataceae]).

**Plectocolea otiana** S.Hatt. – This species was recorded for GG [Hong 1962a as *Jungermannia otiana*], GW [Choe and Yamada 1974, 1962a as *Jungermannia otiana*]. Not confirmed. The species is a Japanese temperate lowland endemic and may be easily recognized due to its monoicous inflorescence (Bakalin et al. 2020a [Solenostomataceae]).

**Plectocolea horikawana** Amakawa – This species was recorded for JB [Choi et al. 2012c as *Solenostoma horikawanum*], however, the species is based on misidentification of weakly developed, prostrate modification of *Plectocolea virgata* (Bakalin et al. 2020a [Solenostomataceae]).

**Porella pinnata** L. – This species was recorded for GW [Kim et al. 1995], JG [Kim and Hwang 1991], HN [Kim and Hwang 1991], however, the distribution of this species is European and hardly occurred in East Asia.

**Radula boryana** (F.Weber) Nees ex Mont. – This species was recorded for JJ [Hong 1962a], JN [Hong 1962a], GG [Hong 1962a], GW [Hong 1962a]; however, there reports belong to *R. auriculata* or *R. chinensis* (Yamada 1979), whereas true *R. boroyana* is an African taxon.

**Radula chinensis** Steph. – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

**Riccardia incurvata** Lindb. – This species was recorded for HWN [Kim and Hwang 1991], HB [Kim and Hwang 1991], however the distribution of these three species is European-North American and hardly occurred in East Asia.
Riccia frostii Austin – This species was recorded for Korea [Amnokgang River: Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

Riccia nipponica S.Hatt. – This species was recorded for Korea [Park and Choi 2007], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

Sandeothallus japonicus (Inoue) Crand.-Stotl. et Stotler – This species was recorded for Korea [Park and Choi 2007 as Moerckia japonica Inoue], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

Scapania ligulata Steph. – This species was recorded for Korea [Park and Choi 2007 as Scapania stephanii Müll.Frib.], however, we identified as S. parvitexta, S. intergerrima and S. parvides in Korean specimens. The taxonomy of Scapania sect. Stephanii is quite controversial; we checked all available materials of Scapania in Korea and found S. parvitexta, S. intergerrima and S. parvides, but not S. ligulata.

Solenostoma plagiochilaceum (Grolle) Váňa et D.G.Long – This species was recorded for Korea [Park and Choi 2007 as Jungermannia plagiochilacea Grolle], however, we were not able to find the references to literature and the location of vouchers; we exclude this species from the checklist.

Synonyms

Anastrophyllum minutum (Schreb. ex D.Crantz) R.M.Schust. ≡ Sphenolobus minutus
Anastrophyllum reichardtii (Gottsche) Steph. = Anastrophyllum assimile
Anastrophyllum saxicola (Schrad.) R.M.Schust ≡ Sphenolobus saxicola
Anthoceros koreanus Steph. = Phaeoceros carolinianus
Anthoceros laevis L. ≡ Phaeoceros laevis
Apometzgeria pubescens (Schrank) Kuwah. ≡ Metzgeria pubescens
Archilejeunea kiushiana (Horik.) Verd. ≡ Spruceanthus kiushianus
Athalamia nana (Shimizu et S.Hatt.) S.Hatt. ≡ Clevea nana
Asterella chichibuensis Shimizu et S.Hatt. = Asterella cruciata
Asterella gracilis (EWeber) Underw. ≡ Mannia gracilis
Asterella koreana (Horik.) Horik. ≡ Asterella leptophylla
Asterella ludwigii (Schwägr.) Underw. = Mannia gracilis
Asterella odora S.Hatt. = Asterella cruciata
Barbilophozia attenuata (Mart.) Loeske ≡ Neoorthocaulis attenuatus
Barbilophozia gracilis (Schleich.) Müll.Frib. ≡ Neoorthocaulis attenuatus
Bazzania albicans Steph. = Bazzania tridens
Bazzania denudata subsp. ovifolia (Steph.) S.Hatt. = Bazzania denudata
Bazzania ovifolia (Steph.) S.Hatt. = Bazzania denudata
Brachiolejeunea sandvicensis (Gottsche) A.Evans ≡ Acrolejeunea sandvicensis
Calypogea trichomanes (L.) Corda nom. rej. = Calypogea azurea
Cephalozia bicuspidata subsp. otaruensis (Steph.) S.Hatt. ≡ Cephalozia otaruensis
Cephalozia catenulata (Huebener) Lindb. ≡ Fuscocephaloziopsis catenulata
Cephalozia nipponica S.Hatt. ≡ Fuscocephaloziopsis catenulata subsp. nipponica
Cephalozia catenulata subsp. nipponica (S.Hatt.) Inoue ≡ Fuscocephaloziopsis catenulata subsp. nipponica
Cephalozia leucantha Spruce ≡ Fuscocephaloziopsis leucantha
Cephalozia lunulifolia (Dumort.) Dumort. ≡ Fuscocephaloziopsis lunulifolia
Cephaloziella byssacea (Roth.) Warnst. = Cephaloziella divaricata
Cephaloziella echinata S.Hatt. = Cephaloziella spinicaulis
Cephaloziella goebelii (Schiffn.) Schiffn. = Cephaloziella trichomanis
Cephaloziella minuta (Mitt.) Steph. = Cephaloziella longifolia
Cephaloziella minutissima (Sm.) Schiffn. = Myriocoleopsis minutissima
Cephaloziella revurvfolia Steph. ≡ Cylindrocolea recurvifolia
Chandonanthus birmensis (Steph.) Horik. ≡ Odontochisma jishibae
Chandonanthus hirtellus (F. Weber) Mitt. ≡ Plicanthus hirtellus
Cheilolejeunea imbricata (Nees) S.Hatt. = Cheilolejeunea trapezia
Cololejeunea aoshimensis (Horik.) S.Hatt. = Cololejeunea planissima
Cololejeunea goebelii (Schiffn.) Schiffn. = Cololejeunea trichomanis
Cololejeunea minuta (Mitt.) Steph. = Cololejeunea longifolia
Cololejeunea minutissima (Sm.) Schiffn. = Myriocoleopsis minutissima
Conocephalum supradecompositum (Lindb.) Steph. = Conocephalum japonicum
Dicranolejeunea yoshinagana (S.Hatt.) Mizut. ≡ Acanthocoleus yoshinaganus
Diplophyllum pleaturn Lindb. ≡ Douinia plicata
Euosmolejeunea auriculata Steph. = Lejeunea compacta
Fimbriaria koreana Horik. = Asterella leptophylla
Frullania brittoniae subsp. truncatifolia (Steph.) R.M. Schust. et S.Hatt. = Frullania mucicola
Frullania clavellata Mitt. = Frullania appendiculata
Frullania delavayi Steph. = Frullania inflexa
Frullania jackii Gottsche = Frullania davurica
Frullania jackii Gottsche subsp. japonica (Sande Lac.) S.Hatt = Frullania davurica
Frullania japonica Sande Lac. = Frullania davurica
Frullania koreana Steph. = Frullania hamatifolia
Frullania meybarae S.Hatt. = Frullania inflata
Frullania moniliata (Reinw., Blume et Nees) Mont. auct. = Frullania appendiculata
Frullania moniliata subsp. obscura Verd. = Frullania appendiculata
Frullania mucicola var. inuena (Steph.) Kamim. = Frullania mucicola
Frullania nepalensis var. nishiyamensis (Steph) S.Hatt. = Frullania nepalensis
Frullania nishiyamensis Steph = Frullania nepalensis
Frullania osumiensis var. orbiculata Kamim. = Frullania osumiensis
Frullania squarrosa (Reinw., Blume et Nees) Dumort. = Frullania ericoides
Frullania tamarisci subsp. monilata (Reinw., Blume et Nees) Kamin. = Frullania appendiculata
Frullania tamarisci subsp. obscura (Verd.) S.Hatt. = Frullania appendiculata
Herbertus hutchinsiae subsp. schusteri H.A.Mill. et Scott. = Herbertus aduncus
Herbertus pusillus (Steph.) S.Hatt. = Herbertus aduncus
Heteroscyphus bescherellei (Steph.) S.Hatt. = Heteroscyphus coailitus
Iwatsukia jishibae (Steph.) N.Kitag. ≡ Odontoschisma jishibae
Jamesoniella autumnalis (DC.) Steph. ≡ Syzygiella autumnalis
Jubula japonica Steph. ≡ Jubula hutchinsiae subsp. japonica
Jungermannia amakawana Grolle = Liochlaena subulata
Jungermannia comamta Ness ≡ Plectocolea comata
Jungermannia cordifolia subsp. excertifolia (Steph.) Amakawa ≡ Jungermannia excertifolia
Jungermannia cylindrica (Steph.) S.Hatt. = Liochlaena subulata
Jungermannia decurrens Steph. = Solenostoma faurianum
Jungermannia erecta (Amakawa) Amakawa ≡ Plectocolea erecta
Jungermannia fauriana Beauverd ≡ Solenostoma faurianum
Jungermannia fusiformis (Steph.) Steph. ≡ Protosolenostoma fusiforme
Jungermannia harana (Amakawa) Amakawa = Solenostoma rotundatum
Jungermannia koreana (Steph.) Amakawa = Protosolenostoma fusiforme
Jungermannia infusca (Mitt.) Steph. ≡ Plectocolea infusca var. infusca
Jungermannia infusca var. ovalifolia (Amakawa) Amakawa ≡ Plectocolea ovalifolia
Jungermannia infusca var. ovicalyx (Steph.) Amakawa auct. = Plectocolea infusca var. recondita
Jungermannia lanceolata subsp. stephanii Amakawa = Liochlaena subulata
Jungermannia radicellosa (Mitt.) Steph. = Plectocolea radicellosa
Jungermannia rotundata (Amakawa) Amakawa = Solenostoma rotundatum
Jungermannia polyanthos L. = Chiloscyphus polyanthos
Jungermannia pyriflora Steph. = Solenostoma pyriflorum
Jungermannia pyriflora var. major (S.Hatt.) Amakawa = Solenostoma sunii
Jungermannia subulata Evans = Liochlaena subulata
Jungermannia tristis Nees = Jungermannia atrovirens
Jungermannia truncata Nees = Plectocolea truncata
Jungermannia tsukushinensis (Amakawa) Amakawa = Plectocolea truncata
Jungermannia virgata (Mitt.) Steph. ≡ Plectocolea virgata
Leiocolea heterocolpos (Theod. ex Hartm.) H.Buch ≡ Mesoptychia heterocolpos
Leiocolea mayebarae (S.Hatt.) Furuki et Mizut. = Mesoptychia mayebarae
Lejeunea auriculata (Steph.) S.Hatt. = Lejeunea compacta
Lejeunea claviflora (Steph.) S.Hatt. = Lejeunea neelgherriana
Lejeunea rotundistipula (Steph.) S.Hatt. = Lejeunea parva
Lejeunea vaginata Steph. = Lejeunea discreta
Lejeunea ulicina (Taylor) Gottsche, Lindenb. et Nees = Microlejeunea ulicina
Lepidozia coreana Steph. = Lepidozia subtransversa
Leptocolea longilobula Horik. = Cololejeunea raduliloba
Lophocolea compacta Mitt. ≡ Cryptolophocolea compacta
Lophocolea cuspidata (Nees) Limpr. ≡ Lophocolea bidentata
Lophozia alpestirs (Schleich.) A.Evans nom. rej. = Pseudolophozia sudetica
Lophozia cornuta (Steph.) S.Hatt. ≡ Schistochilopsis cornuta
Lophozia heterocolpos (Thed. in Hartm.) Howe ≡ Mesopychia heterocolpos
Lophozia incisa (Schrad.) Dumort. ≡ Schistochilopsis incisa
Lophozia porphyroleuca (Nees) Schiffn. auct. non = Lophozia guttulata
Lophozia fauriana Steph. = Lophozia guttulata
Lophozia longiflora (Nees) Schiffn. = Lophozia guttulata
Lophozia mayebarae (S.Hatt.) N.Kitag. = Mesopychia mayebarae
Lophozia undulata Horik. = Schistochilopsis cornuta
Madotheca setigera (Steph.) S.Hatt. = Porella caespitans var. cordifolia
Madotheca tosana Steph. ≡ Porella acutifolia subsp. tosana
Madotheca ulophylla Steph. ≡ Porella ulophylla
Madotheca vernicosa (Lindb.) Steph. ≡ Porella vernicosa
Macvicaria ulophylla (Steph.) S.Hatt. ≡ Porella ulophylla
Macrodiplophyllum plicatum (Lindb.) Perss. ≡ Douinia plicata
Marchantia tosana Steph. ≡ Marchantia emarginata subsp. tosana
Marsupella commutata (Limpr.) Bernet ≡ Gymnomitrion commutatum
Marsupella emarginata subsp. tubulosa (Steph.) N.Kitag. ≡ Marsupella tubulosa
Marsupella parvitexta Steph. = Gymnomitrion commutatum
Marsupella revoluta (Nees) Dumort. = Gymnomitrion revolutum
Mastigobryum bidentulum Steph. ≡ Bazzania bidentula
Mastigobryum coreanum Steph. = Bazzania tridens
Metacalyptogea quelpaertensis S.Hatt et Inoue = Eocalypogeia quelpaertensis
Metzgeria conjugata Lindb. = Metzgeria lindbergii
Metzgeria conjugata subsp. japonica (S.Hatt.) Kuwah. = Metzgeria lindbergii
Metzgeria decipiens (C.Massal) Schiffn. = Metzgeria furcata
Metzgeria fauriana Steph. = Metzgeria furcata
Metzgeria fruticulosa (Dicks.) A.Evans auct. = Metzgeria temperata
Metzgeria hamata Lindenb. = Metzgeria leptoneura
Metzgeria quadrideriata A.Evans = Metzgeria furcata
Microlepidozia makinoana (Steph.) S.Hatt. ≡ Kurzia makinoana
Moerckia erimona (Steph.) S.Hatt. ≡ Hattorianthus erimonus
Nardia sieboldii (Sande Lac.) Steph. = Nardia assamica
Notothylas japonica Horik. = Notothylas orbicularis
Pedinolejeunea aoshimensis (Horik.) P.C.Chen et P.C.Wu ≡ Cololejeunea planissima
Pedinophyllum interruptum subsp. truncatum (Steph.) Inoue ≡ Pedinophyllum truncatum
Pedinophyllum interruptum var. jungermannioides (Steph.) Inoue = Pedinophyllum truncatum
Pedinophyllum major-perianthium Gao et Chang = Pedinophyllum truncatum
Liverworts and hornworts of Korean Peninsula

Pellia endiviifolia (Dicks.) Dumort. = Apopellia endiviifolia
Pellia fabbroniana Raddi = Apopellia endiviifolia
Phaeoceros laevis subsp. carolinianus (Michx.) Prosk. = Phaeoceros carolinianus
Phaeoceros miyakeanus (Schiffn.) J.Haseg. = Phaeoceros laevis
Physocolea leptolejeuneoides Schiffn. = Cololejeunea longifolia
Plagiochasma koreanum Steph. = Plagiochasma japonicum
Plagiochila acanthophylla subsp. japonica (Sande Lac.) Inoue = Plagiochila sciophila
Plagiochila asplenioides subsp. ovalifolia (Mitt.) Ínoue = Plagiochila ovalifolia
Plagiochila dendroides (Nees) Lindenb. = Chiastocalon dendroides
Plagiochila firma Mitt. subsp. rhizophora (S.Hatt.) Ínoue = Plagiochila gracilis
Plagiochila japonica Sande Lac. = Plagiochila sciophylla
Plagiochila ovalifolia var. miyoshiana (Steph.) S.Hatt. = Plagiochila ovalifolia
Plagiochila ovalifolia var. orbicularis S.Hatt. = Plagiochila ovalifolia
Plagiochila quelpaertensis Inoue = Plagiochila ovalifolia
Plagiochila rhizophora S.Hatt. = Plagiochila gracilis
Plagiochila satoi S.Hatt. = Plagiochila pellsterolides
Plagiochila semidecurrens var. grossidens Herzog = Plagiochila semidecurrens
Plagiochila yokogurensis Steph. = Plagiochila sciophila
Porella caespitans var. setigera (Steph.) S.Hatt. = Porella caespitans var. cordifolia
Porella campylophylla subsp. tösana (Steph.) S.Hatt. = Porella acutifolia
Porella densifolia var. fallax = Porella densifolia
Porella oblongifolia var. takakii (S.Hatt.) Ínoue = Porella oblongifolia
Porella setigera (Steph.) S.Hatt. = Porella caespitans var. cordifolia
Porella setigera var. subobtusa (Steph.) S.Hatt. = Porella subobtusa
Porella tösana (Steph.) S.Hatt. = Porella acutifolia subsp. tösana
Porella vernicosa subsp. fauriei (Steph.) M.Hara = Porella fauriei
Porella vernicosa subsp. gracillima (Mitt.) Ando = Porella gracillima
Porella vernicosa fo. spinulosa (Steph.) S.Hatt. = Porella spinulosa
Ptilidium sacculatum (Mitt.) Steph. = Trichocoleopsis sacculata
Ptychocoleus nipponicus S.Hatt. = Acrolejeunea pusilla
Riccardia pinguis (L.) Gray = Aneura pinguis
Riccia glauca var. subinermis (Lindb.) Warnst. = Riccia glauca
Scapania dentata Dumort. = Scapania undulata
Scapania parvitexta var. minor S.Hatt. = Scapania parvidens
Scapania spinosa Steph. = Scapania ciliata
Scapania stephanii Müll.Frib. = Scapania integerrima
Solenostoma cordifolium (Dumort.) Steph. = Jungermannia exsertifolia subsp. cordifolia
Solenostoma decurrens (Steph.) S.Hatt. = Solenostoma faurianum
Solenostoma koreanum Steph. = Protosolenostoma fusiforme
Temnoma birmense (Steph.) Horik. = Plicanthus birmensis
Tritomaria quinquedentata (Huds.) H.Buch = Trilophozia quinquedentata
Trocholejeunea sandvicensis Mizut. = Acrolejeunea sandvicensis
Discussion

The infra-regional differences inside Korea are quite significant, the richest liverwort flora being found in Jeju-do Province that houses 223 taxa. Although other provinces are less rich taxonomically, they commonly house some unique species not occurring in other administrative subunits in Korea. This is strongly evident in Gangwon Province which houses several calciphilous taxa not found in other Provinces, including Mannia androgyna, *M. fragrans*, Mesoptychia ussuriensis, Lejeunea neelgherriana, Porella stephaniana etc.

Some observations could be made in the course of comparison of Korean flora with the flora of adjacent lands, including Japan, the Russian Far East and China. The differences are most significant with the Russian Far East flora and reflect the far more northern position of the Russian Far East in comparison with the Korean Peninsula. The differences with other adjacent countries are smaller. The defined series of taxa of temperate and subtropical distribution known in Korea are absent in the Russian Far East: Acrobolbus ciliatus, *Acrolejeunea pusilla*, *Anastrepta orcadensis* etc. Some taxa, present in Korean peninsula, but absent in the Russian Far East, belong to the broadly Sino-Himalayan element, including Gymnomitrion revolutum (although the occurrence of this species in Korea is uncertain). Certain taxa, like *Mannia gracilis* and Bazzania manczurica, are known in all compared flora, with the exception of China. However, such taxa should likely be found in China in further studies. The differences with Japanese flora are minor and include some northern elements present in Korea, but absent in Japan, like Biantheridion undulifolium and Cephalozia ambiguа (this report may be doubted), recorded in Chanbai Mt. in the northernmost North Korea or even southwards, like Cephaloziella hampeana, *C. varians*, Isopaches bicrenatus and Scapania sphaerifera (the latter three taxa are also not known in China). Cephalozia lacinulata – a rare boreal species is also known in the China mainland and Korea, but not known in Japan. Porella chinensis is another ‘continental’ species not known in Japan, although present in other adjacent flora. The temperate Pacific Cavicularia densa is not known, either in China and the Russian Far East, but is present in Korea and Japan. Radula brunnea, Japanese-Korean-Kuril Island-British Columbia taxon is not known in China. Syzygiella nipponica, a mainly Japanese species, is not known in China, although present in the Russian Far East and Korea.

Therefore, Korean hepatic flora includes several species present westwards and, for those, the Korean Peninsula is the most eastern outpost. The opposite situation occurs with some ‘Japanese’ taxa and for those, Korea is the western most outpost. Besides, some taxa, occurring northwards in the Russian Far East, penetrate the Korean Peninsula, but were not present (at least were never recorded) in Japan and China. Despite the relatively small size of the Peninsula, it houses two narrow endemic taxa of liverworts hitherto not known outside Korea. These facts show the great value of the Korean Peninsula for the conservation of natural resources and genetic potential of East Asian biota.
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