Two new and one unrecorded natural hybrids between
Asplenium ruprechtii and related taxa (Aspleniaceae)

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(Received 3 December 2015; Revised 9 December 2015; Accepted 9 December 2015)

거미고사리와 유연종과의 2 신교잡종과 1 미기록교잡종 (꼬리고사리과)

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ABSTRACT: Two new and one unrecorded hybrids of the genus Asplenium were newly found in Korea. They were proved to be hybrid based on intermediate morphology between putative parents. The first hybrid is A. × uiryeongse C.S. Lee & K. Lee (Aspleniaceae), nom. nov. (vernacular name: geo-mi-sa-cheol-go-sa-ri). This new hydrid is a cross between the Asian walking fern, A. ruprechtii and A. pekinens in Uiryeong-gil, Mt. Bukansan, Seoul, Korea. The other new one occurs in Mt. Seongsan in Yeoncheon-gun, Gyeonggi-do, Korea, A. × montanus C.S. Lee & K. Lee, nom. nov. (vernacular name: san-kko-ri-go-sa-ri) which might have experienced multiple hybridization events between A. ruprechtii × A. trichomanes and A. incisum following the hybrid between A. ruprechtii and A. trichomanes. In addition, one unrecorded hybrid, A. × kitazawae Kurata & Hutoh (vernacular name: geo-mi-dol-dam-go-sa-ri), reported first from Japan, is found in natural habitats in Do-dong, Daegu-si, and is a hybrid, between the Asian walking fern and A. sarelli. These hybrid taxa grow in sympatric regions with both putative parental species. The diagnostic characters for each taxon and evidence for their hybridization have been suggested. Descriptions, illustrations, and photographs of these hybrid taxa in their habitats are provided from Korea.

Keywords: Asplenium × uiryeongse, A. × montanus, new hybrid, A. × kitazawae, unrecorded hybrid.

적요: 거미고사리속의 두 개의 신교잡종과 한 개의 미기록교잡종이 발견되었다. 이들 종들의 형태적 형질에 있어 부모종들의 중간형태를 보였다. 거미사철고사리(A. × uiryeongse)는 서울 북한산 우이령길에서 발견되었고 거미고사리와 사철고사리의 교잡에 의해 형성되었다. 다른 교잡종, 산꼬리고사리(A. × montanus)는 경기도 연천군, 성산에서 발견되었고, 거미고사리와 차꼬리고사리가 교잡에 의해 만들어지고 다시 거미고사리와의 중복교잡에 의해 형성되었다. 아울러 거미고사리 종의 거미돌담고사리(A. × kitazawae)는 대구 도동에서 발견되었고, 거미고사리와 돌담고사리의 교잡에 의해 형성되었다. 이들 교잡종들은 부모종들과 같은 장소에서 자란다. 각 분류군의 형질을 분석해 교잡종임을 입증해 보였으며, 이들에 대한 기재, 도화 및 자생지의 서식 사항을 수록하였다.

주요어: 거미사철고사리, 산꼬리고사리, 거미돌담고사리, 신교잡종, 미기록종

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The genus *Asplenium* L. (Aspleniaceae) includes about 700 taxa worldwide, and 15–21 taxa of *Asplenium* are known to be distributed in Korea (Park, 1975; Lee, 1980; Lee, 2006; Kim and Sun, 2007; Lee and Lee, 2015). This genus is well characterized by rhizome erect or shortly creeping, and densely scaly throughout or on stipe base, fronds clustered or remote, lamina simple to 4-pinnate and costa usually with all basal basiscopic veins present, linear indisium, echinate spore, n = 36 (Murakami and Schaal, 1994; Iwatsuki, 1995; Lin and Viane, 2012).

Hybridization in natural biological processes occurs frequently among closely related species, and leads to plant speciation (Rieseberg and Ellstrand, 1993; Rieseberg and Wendel, 1993; Arnold, 1997; Rieseberg, 1997). Interspecific gene flow may proceed only to the formation of F₁ due to factors such as hybrid sterility. If hybrids reproduce, they may backcross with parents at the site of hybridization and create a hybrid swarm. Long-term hybrid swarms can be maintained in different ways (Anderson, 1949; Arnold, 1997). Natural hybridization between parental taxa occurs at a sufficiently high frequency (Ellstrand et al., 2007). Documentation of hybridization has traditionally been based on morphological characters that are intermediate between parental types or that combine parental characters (Grant, 1981; Rieseberg and Ellstrand, 1993; Kramer, 1990; Iwatsuki, 1995). Natural hybridization occurs frequently in *Asplenium* (Lovis, 1973; Kramer, 1990; Iwatsuki, 1995). Hybrids can be identified easily by their aborted spores and intermediate morphology (Reichstein, 1981; Lovis and Reichstein, 1985; Jessen, 1995).

Asian walking fern, *Asplenium ruprechtii* Sa. Kurata, produces a sterile hybrid or fertile allotetraploid hybrid with *A. incisum* Thunb. (Lovis et al., 1972; Ching and Iwatsuki, 1982). It is known to form a hybrid with *A. incisum* as *A. castaneo-viride* Baker from Korea (Kwon et al., 2009). In addition to the above hybrid taxon, we newly found two new natural hybrids and an unrecorded hybrid with *A. pekinense* Hance, *A. trichomanes* L., *A. incisum*, and *A. sarelii* Hooker among 19 taxa in Korea. One hybrid taxon, *Asplenium × uiryeongse*, nom. nov., with about 20 individuals per 2 m², was collected from a forest in Uiryeong-gil, Mt. Bukansan, Seoul. The scientific name was assigned based on its habitat, and the local name was designated as ‘geo-mi-sa-cheol-go-sa-ri’ based on its parent names.

We compared and analyzed morphological characters between *Asplenium* hybrid taxa and related taxa of *Asplenium* in order to elucidate their taxonomic relationship.

**Taxonomic Treatment**

*Asplenium × uiryeongse* C.S. Lee & K. Lee, hybrid nov. (Figs. 1, 2, 6)

Korean name: Geo-mi-sa-cheol-go-sa-ri (거미사철고사리)  
TYPE: Korea. Seoul, Mt. Bukansan, elev. 178 m, 27 Aug. 2013, C.S. Lee & K. Lee 13082701 (holotype, EWH: isotype, KB) (Fig. 1)

Winter green herb, on rock or epiphytic, height 5–15 cm. Rhizomes short gathering, 1.2–1.5 mm diameter, scaly; scales 3–5 mm long, 0.3–0.5 mm wide, narrowly lanceolate, blackish, almost entire. Stipes clustered, 1–3 cm long, 1–1.2 mm wide, green, base densely scaly, with reduced scales like hair toward rachis or subglabrous; lamina 1–2-pinnatifid, 4–12 cm long, 1.2–2.5 cm wide, linear-lanceolate, the apex abruptly to gradually reduced, firmly herbaceous; rachis green, sparsely scaly like hair...
(0.8–1.0 mm long, 0.010–0.015 mm wide), narrowly winged in upper lamina; lateral pinnae 8–12 pairs, oblong, basal basiscopic margin serrate, apex a little acuminate, 0.7–1.4 cm long, 0.4–0.7 cm wide, short-petiolulate (1.0–1.5 mm long); ultimate segments linear lanceolate, 3–4 mm long, 1–2 mm wide on basal pinnae, margin short toothed, never overlap; veins in abaxial surface protruded, 1 or 2 times forked; indusium slightly lacerate; sori 1.5–3.0 mm long; spores abortive.

Habitat: On the rock near mountain stream.

Distribution: Uiryeong-gil, Mt. Bukansan, Seoul, Korea

Note: Gross morphology of putative parental species, *A. ruprechtii* and *A. pekinense*, and their putative hybrid, *Asplenium × uiryeongse*, are shown in Figs. 1, 2, and 6. Typical *Asplenium × uiryeongse* has intermediate characters between the parents such as narrowly winged upper rachis, 1–2-pinnatifid lamina, shorter pinna stalk, shape of pinna and pinnule, and serration of indusium margin (Table 1, Figs. 1, 2, and 6). *Asplenium × uiryeongse* has some characters of *A. ruprechtii*, such as entire scale margin, no shorter base of lamina, and stipe length, as well as characters similar to *A. pekinense*, such as oblong pinna, needle shaped pinnule segment, and lacerated margin of indusium.

Hybrids are known to have morphological characters intermediate between their parents as well as combining characters from each of the parents, although sometimes hybrids display characters not found in either parent (Grant, 1981; Rieseberg and Ellstrand, 1993). The putative hybrid *Asplenium × uiryeongse* displays all of these inheritance patterns of parental characters. Furthermore, this taxon is an allotriploid hybrid (3x) of both putative parental species, *A. ruprechtii* (2x) and *A. pekinense* (4x) based on Flow Cytometry data and chloroplast *rbcL* and *rps4-trnS* sequence data (Lee et al., unpubl.).

The new scientific name was assigned based on its habitat, which it occurs in Uiryeong-gil of Mt. Bukansan and the new local name ‘geo-mi-sa-cheol-go-sa-ri’ was given to the new taxon based on its parent’s names. This hybrid was found in Korea with *Asplenium ruprechtii* Sa. Kurata, *Asplenium pekinense* Hance, *Cheilanthes argentea* (S.G. Gmel) Kunze, *Quercus mongolica* Fisch. ex Ledeb., *Robinia pseudoacacia* L., *Rhododendron mucronulatum* Turcz, and *Deutzia uniflora* Shirai in a forest of Mt. Bukansan, Seoul, Korea.

*Asplenium × montanus* C.S. Lee & K. Lee, hybrid nov. (Figs. 3, 4, 6)

Korean name: San-kko-ri-go-sa-ri (산꼬리고사리)

TYPE: Korea. Geonggi-do, Yeoncheon-gun, Mt. Seongsan, elev. 468 m, 20 Sep. 2014, C.S. Lee & K. Lee 14092001 (holotype, EWH; isotype, KB, KH)

Winter green herb, on soils or rocks with many soils, height 5–12 cm. Rhizomes short gathering, 1.0–1.2 mm in diameter, scaly; scales 3–5 mm long, 0.5–0.7 mm wide, lanceolate, blackish brown, entire. Stipes clustered, 1–4 cm long, 1–1.2 mm wide, green, base densely scaly, with reduced scales like hair toward rachis; lamina 1-pinnate, 3–8 cm long, 1.3–2.0 cm wide, linear-lanceolate, the apex abruptly to gradually reduced, firmly herbaceous; rachis green, sparsely scaly like hair (0.3–1.0 mm long), winged in upper lamina; lateral pinnae 8–12 pairs, oblong or oblong-ovate, margin crenate, apex obtuse, 0.6–1.0 cm long, 0.5–0.7 mm wide, short-petiolulate (0.8–1.0 mm long), basal pinna largely serration two or three, never overlap; veins 2 or 3 times forked; indusium slightly lacerate; sori 1.5–3 mm long; spores abortive.

Habitat: On soils or rocks with rich soils under forests of high location of mountain.

Distribution: Mt. Seongsan, Yeoncheon-gun, Gyeonggi-do, Korea

Note: Gross morphology of putative parental species, *A. ruprechtii*, *A. trichomanes* and *A. incisum*, and their putative
Table 1. Comparative morphological characters between hybrids and related parents of *Asplenium*.

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>A. ruprechtii</em></th>
<th><em>A. pekinense</em></th>
<th><em>A. × uiryeongse</em></th>
<th><em>A. trichomanes</em></th>
<th><em>A. incisum</em></th>
<th><em>A. × montanus</em></th>
<th><em>A. sarelii</em></th>
<th><em>A. × kitazawae</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale margin</td>
<td>entire</td>
<td>toothed</td>
<td>almost entire</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
<td>entire</td>
</tr>
<tr>
<td>Scale shape in stipe base</td>
<td>deltoid-lanceolate, acuminate apex</td>
<td>lanceolate, long tailed apex</td>
<td>lanceolate, long tailed apex</td>
<td>narrowly lanceolate, acute apex</td>
<td>narrowly lanceolate, acute apex</td>
<td>lanceolate, acute apex</td>
<td>deltoid lanceolate, long tailed apex</td>
<td>lanceolate, acute apex</td>
</tr>
<tr>
<td>Pinnation of lamina</td>
<td>simple</td>
<td>2−3-pinnatifid</td>
<td>1−2-pinnatifid</td>
<td>1-pinnated</td>
<td>1−2-pinnate</td>
<td>1-pinnated</td>
<td>2−3-pinnatifid</td>
<td>1−2-pinnatifid</td>
</tr>
<tr>
<td>Shape of lamina</td>
<td>linear or lanceolate</td>
<td>deltoid or oblong</td>
<td>linear lanceolate</td>
<td>linear lanceolate</td>
<td>linear lanceolate</td>
<td>linear lanceolate</td>
<td>deltoid or oblong</td>
<td>oblong lanceolate</td>
</tr>
<tr>
<td>Quality of lamina</td>
<td>sub-coriaceous</td>
<td>firmly herbaceous</td>
<td>firmly herbaceous</td>
<td>herbaceous</td>
<td>thinly herbaceous</td>
<td>firmly herbaceous</td>
<td>herbaceous</td>
<td>firmly herbaceous</td>
</tr>
<tr>
<td>Stalk length of pinna</td>
<td>no pinnae</td>
<td>2−3 mm</td>
<td>1−1.5 mm</td>
<td>1−1.5 mm</td>
<td>1−1.5 mm</td>
<td>1−1.5 mm</td>
<td>2−4 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Shape of pinna</td>
<td>no pinnae</td>
<td>oblong or oblong-ovate</td>
<td>oblong</td>
<td>oblong or oblong-ovate</td>
<td>oblong or oblong-ovate</td>
<td>oblong or oblong-ovate</td>
<td>oblong or oblong-ovate</td>
<td>oblong or oblong-ovate</td>
</tr>
<tr>
<td>Apex of pinna</td>
<td>no pinnae</td>
<td>shallowly acuminate</td>
<td>obtuse</td>
<td>obtuse</td>
<td>obtuse</td>
<td>obtuse</td>
<td>shallowly acuminate</td>
<td>obtuse</td>
</tr>
<tr>
<td>Stalk length of pinnule</td>
<td>no pinnule</td>
<td>&gt;1 mm</td>
<td>&gt; 1 mm</td>
<td>no pinnule</td>
<td>0-1mm</td>
<td>no pinnule</td>
<td>more than 1mm</td>
<td>no pinnule</td>
</tr>
<tr>
<td>Margin of pinnule or pinnule segment</td>
<td>no pinnae or pinnule</td>
<td>needle shaped, long toothed</td>
<td>short toothed</td>
<td>crenate</td>
<td>crenate</td>
<td>crenate</td>
<td>short toothed</td>
<td>crenate</td>
</tr>
<tr>
<td>Overlapping pinnules</td>
<td>no pinnule</td>
<td>never overlap</td>
<td>never overlap</td>
<td>no pinnule</td>
<td>overlap</td>
<td>no pinnule</td>
<td>overlap</td>
<td>no pinnule</td>
</tr>
<tr>
<td>Length of indusium</td>
<td>1.5−4 mm</td>
<td>1.5−3 mm</td>
<td>1.5−3 mm</td>
<td>1−1.5 mm</td>
<td>1.5−3 mm</td>
<td>1.5−3 mm</td>
<td>1.0−1.5 mm</td>
<td>1.0−1.5 mm</td>
</tr>
<tr>
<td>Margin of indusium</td>
<td>entire</td>
<td>lacerate</td>
<td>slightly lacerate</td>
<td>lacerate</td>
<td>almostly entire</td>
<td>lacerate</td>
<td>entire</td>
<td>entire</td>
</tr>
<tr>
<td>Shape of sorus</td>
<td>linear</td>
<td>linear</td>
<td>oblong-linear</td>
<td>oblong</td>
<td>oblong-linear</td>
<td>oblong-linear</td>
<td>linear</td>
<td>linear</td>
</tr>
<tr>
<td>Presence of gemma</td>
<td>present</td>
<td>absent</td>
<td>absent</td>
<td>present</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>Habitat</td>
<td>on rock</td>
<td>on rock</td>
<td>on rock</td>
<td>on rock</td>
<td>on soils or soiled rock</td>
<td>on soils or soiled rock</td>
<td>on rock</td>
<td>on rock</td>
</tr>
</tbody>
</table>
hybrid, \( A. \times \text{montanus} \), are shown in Figs. 3, 4, and 6. Typical \( A. \times \text{montanus} \) has characters intermediate between the parents such as winged in upper rachis, 1-pinnate lamina, lamina quality, shape of pinna, and serration of indusium margin (Table 1, Figs. 3, 4, 6). \( Asplenium \times \text{montanus} \) has some characters of \( A. \text{ruprechtii} \), such as entire scale margin and shape of scale in stipe base, and no shorter base of lamina. It also has characters similar to \( A. \text{trichomanes} \), such as oblong pinna, crenate pinna margin, and lacerated margin of indusium, as well as to \( A. \text{incisum} \) such as shape of basal pinna of lamina and soils or rocks with soil habitats.

The putative hybrid, \( A. \times \text{montanus} \) displays all of these inheritance patterns of parental characters. Furthermore, this taxon (4x) occurred by reticulate evolution as a double hybrid between three putative parental species, \( A. \text{ruprechtii} \) (2x), \( A. \text{trichomanes} \) (4x), and \( A. \text{incisum} \) (2x) based on Flow Cytometry data and chloroplast \( rbcL \) and \( rps4-trnS \) sequence data (Lee et al., unpubl.).

The new scientific name was assigned based on its habitat, which it occurs in forest of mountain, and the new local name ‘san-kko-ri-go-sa-ri’ was given to the new taxon based on habitat, mountain. This hybrid found in Korea with \( Asplenium \).
Two new and one unrecorded natural hybrids between *Asplenium ruprechtii* and related taxa

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*Asplenium × kitazawae* Kurata & Hutoh

Korean name: geo-mi-dol-dam-go-sa-ri (거미돌담고사리) (Figs. 5, 6)


Winter green herb, on rock or epiphytic, height 7–16 cm. Rhizomes short gathering, 1.2–1.5 mm in diameter, scaly; scales 4–5 mm long, 0.8–0.9 mm wide, lanceolate, blackish, entire. Stipes clustered, 1–4 cm long, 1–1.2 mm wide, green, the lowest base purplish, base densely scaly, with reduced scales like hair toward rachis; lamina 1–2-pinnatifid, 6–13 cm long, 1.8–3.5 cm wide, oblong-lanceolate or lanceolate, the apex abruptly to gradually reduced, firmly herbaceous; rachis green, sparsely scaly like hair (0.8–1.0 mm long), winged in upper lamina; lateral pinnae 8–14 pairs, oblong, ovate or deltoid-lanceolate, asymmetrical, basal pinnae equal or slightly shorter than next, basiscopic upper side auriculate, usually basal basiscopic side serrate, apex obtuse or shallowly acuminate, 0.7–2.0 cm long, 0.4–0.7 cm wide, short-petiolulate (1.0–1.5 mm long), margin crenate, some overlap; veins 1 or 2 times

Fig. 6. Two new and one unrecorded hybrids with each putative parent of *Asplenium* from Korea. A–C. Part of each lamina of *A. ruprechtii*, *A. pekinense*, and *A. × uiryeongse* with parents; E–G. Part of each lamina of *A. trichomanes*, *A. incisum*, and *A. × montanus*; H. Habit of *A. × montanus* with parents; I–K. Part of each lamina of *A. ruprechtii*, *A. sarelii*, and *A. × kitazawae*; L. Habit of *A. × kitazawae* with parents.
forked; indusium entire; sori 1.0–1.5 mm long; spores abortive.

Habitat: In forests of mountain.

Distribution: Do-dong, Daegu-si, Korea.

Note: The newly reported taxon in Korea, *Asplenium × kitazawae*, is known as a hybrid of *A. ruprechtii* and *A. sarelii* from Japan (Iwatsuki, 1995). Gross morphology of putative parental species, *A. ruprechtii*, *A. sarelii*, and their putative hybrid, *A. × kitazawae*, are shown in Figure 5 and 6. Typical *A. × kitazawae* has intermediate characters between the parents such as shape of scale in stipe base, winged in upper rachis, 1–2-pinnatifid lamina, lamina quality, shape and margin of pinna (Table 1, Figs. 5, 6). *Asplenium × kitazawae* has some characters of *A. ruprechtii*, such as narrow lamina, shorter stipe, and shorter indusium. It also has characters similar to *A. sarelii* such as serrated lamina, oblong or deltoid pinna, no gemma in apex of lamina.

The putative hybrid, *A. × kitazawae* displays all of these inheritance patterns of parental characters. Furthermore, this taxon is an alloidioploid or allotetraploid hybrid (2x, 4x) of both putative parental species, *A. ruprechtii* (2x) and *A. sarelii* (6x) based on Flow Cytometry data and chloroplast *rbcL* and *rps4-trnS* sequence data (Lee et al., unpubl.).

The local name was designated as ‘geo-mi-dol-dam-go-sa-ri’ from based on its parent name. It was found in Korea with *Asplenium ruprechtii* Sa. Kurata, *Asplenium sarelii* Hook., *Platyclusus orientalis* (L.) Franco, *Selaginella tamariscina* (P Beauv.) Spring, *Pyrosia linearifolia* (Hook.) Ching, and *Rhododendron mucronulatum* Turcz in a forest of Dodong, Daegu-si, Korea.

**Acknowledgments**

This research was supported by grants from “The Survey of new and unrecorded taxa in vascular plants (NIBR No. 2014-02-001)” founded by the Ministry of Environment, Korean Government.

**Literature Cited**


