Taxonomic recognition of *Saussurea maximowiczii* var. *triceps* on Jeju Island

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ABSTRACT: A morphological and molecular survey was conducted to determine the taxonomic status of *Saussurea maximowiczii* var. *triceps* on Jeju Island. Although it tends to be smaller than *S. maximowiczii* with regard to typical quantitative characters of vegetative organs, including the plant height and leaf size, these two taxa cannot be distinguished from each other based on major reproductive characters, including the involucre and florets. Molecular data support the contention that *S. triceps* and *S. maximowiczii* are monophyletic taxa. *Saussurea maximowiczii* var. *triceps* is found to be an ecological phenotype of *S. maximowiczii* that has adapted particularly to the windy highlands of Hallasan Mountain on Jeju Island.

Keywords: *Saussurea triceps*, ecophene, highland, Jeju Island

It was not until the middle of the 19th century that Korean plants became known to the Western plant taxonomists. At that time, plant specimens collected by A. Schlippenbach (1854, East Coast), R. Oldham (1863, South Coast), Y. Hanabusaya (1883–1884), A. W. Carles (1885, Seoul, Incheon, Busan), and R. P. U. Faurie (1900–1907, nationwide) were sent to Leningrad in Russia, KEW Gardens in London, and the University of Tokyo where they were used in various studies. In particular, French Father Emile Joseph Taquet (1873–1952) collected large amount of plant specimens in Hallasan Mountain of Jeju Island from 1907 to 1910 and sent them to France. Thereafter, many of his specimens were studied by two contemporary French taxonomists, H. Lévêille and E. Vaniot.

Based on Taquet's specimens (*Taquet 1017*, 7 Aug 1908, Yongsil Hallaisan Corea) collected in Yeongsil, Hallasan Mountain, *Saussurea triceps* H. Lév. & Vaniot was described as a new species of *Saussurea*. The former is short in height (15–25 cm) with hairy involucre and many bracteal leaves at the upper stem. Since then, S. Kitamura of Kyoto University who studied Asteraceae in Northeast Asia treated it as a variety of *S. maximowiczii* Herd. (see Kitamura, 1937). In a monographic study of *Saussurea*, S. Lipschitz treated *S. triceps*

as a synonym of *S. maximowiczii* (see Lipschitz, 1979). Since then, taxonomic status of *S. triceps* has been controversial among researchers and literatures, treating it as a synonym of *S. maximowiczii* (Chen & Shin, 1999) or a variety of *S. maximowiczii* (Lee, 1996; Im and Lee, 1999). In high elevation of Hallasan Mountain, there are many plants with dwarf forms that have adapted to high mountain winds and low temperatures. *S. triceps* is mainly featured by a dwarf plant that is assumed to be an ecophene. Thus, taxonomic identity of *S. triceps* needs to be confirmed based on plants collected from the type locality.

Materials and Methods

Morphological study

To identify geographical distribution of *S. maximowiczii* and *S. triceps*, we investigated specimens deposited in herbaria of National Institute of Biological Resources (KB), Korea National Arboretum (KH), Chonnam National University (CNU), and Jeju National University (JNUB). To determine the range of intra- and inter- population variations of *S. maximowiczii* and *S. triceps*, we collected specimens of *S.*

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maximowiczii from Seonwangsan Mountain population (elev. 200 m, 11 individuals) at Doam-myeon, Hwasun-gun, Jeollanam-do and specimens of *S. triceps* from 1,100-m altitude highland population (elev. 1,100 m, 6 individuals) at Seogwipsi, Jeju Island. A total of 53 individuals derived from Hwasun, Seonwangsan Mountain population and Jeju 1,100-m highland population, CNU (15 collections) and JNUB (21 collections) were examined for their morphological traits such as stem length, leaves, involucre, and florets to determine the range of morphological variations of *S. maximowiczii* and *S. triceps* (Table 1). In Eorimok (high elevation of Hallasan Mountain), 1,100-m altitude wetlands, and Yeongsil, we conducted on-site study regarding ecophene plants.

Molecular study

1. Plant samples

In the present study, 18 species and 29 taxa of *Saussurea* distributed across the Korean peninsula were used (Table 2). All plant samples endemic to Korea were collected from July 2013 to August 2017. We collected *S. maximowiczii* from Biseulsan Mountain (Daegu), Mudeungsan Mountain (Gwangju), Baegunsan Mountain (Chonnam), and Chilbosan Mountain (Gyeonggi-do). We also collected *S. triceps* from Hallasan Mountain (Jeju's 1,100-m altitude highland). For *S. myokoensis*, its field collection was difficult. Therefore, specimens deposited in KH were used. *Carduus crispus* (GenBank accession EF010530) was used as an outgroup (Table 2).

Table 1. Examined specimen and each morphological character.

Specimen Number	Locality	Stem		Leaf blade		Involucre		Floret		Achene (mm)	Pappus (mm)
		Width (mm)	Height (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	NP (mm)	WP (mm)		
max CNU 222071	JN, Jangseong, Mt. Ibamsan	5.8	136	39	12	97	5.6	6.7	4.5	6.2	8.2
max CNU 222072	JN, Jangseong, Mt. Ibamsan	5.1	125	23	8.2	106	5.9	6	4.3	5.3	8
max CNU 222073	JN, Jangseong, Mt. Ibamsan	6.7	138	32	10	89	5.4	6.9	4.6	5.5	7.2
max CNU 222074	JN, Jangseong, Mt. Ibamsan	5.2	110	31	9.8	113	6.2	6.9	4.5	5.2	8.6
max CNU 010017	JN, Suncheon, Mt. Jogyesan	4.1	98	21	6.7	112	5.9	5.5	3	5.4	8.2
max CNU 384686	JN, Sinan, Josamji	2.9	112	14	4.2	97	5.8	5.6	3.1	5.4	8.6
max CNU 059303	JN, Sinan, Isl. Aphaedo	2.7	80	16	5.5	108	6	5.6	3.2	6.3	8.6
max CNU 010018	JN, Suncheon, Mt. Jogyesan	4.2	65	15	4.4	121	5.7	6.8	3.6	6	8.2
max CNU 074404	GG, Hwasong	5.4	117	31	10.2	107	5.7	5.7	3.5	6.1	7.5
max CNU 040247	JN, Haenam, Dusolbong	3.5	86	19	6.5	124	5.8	5.6	3.5	5.3	8.3
max CNU 040248	JN, Sinan, Isl. Imjado	2.7	32	8	3.2	104	5.6	6.1	3.6	5.6	7.3
max CNU 057246	JN, Haenam, Mt. Geumgangsán	6	127	27	9.1	121	5.7	6.3	3.7	5.5	7.7
max CNU 050988	JN, Gangjin, Mt. Jujaksan	2.8	117	16	5.6	121	6.3	5.5	3	5.9	8.5
max CNU 099394	JB, Sunchang, Mt. Chuwolsan	3	94	14	4.5	119	6.1	6.2	3.4	5.8	8.4
max CNU 013190	JN, Sinan, Mt. Hwahaksan	2.7	45	7	3.3	112	4.9	5.7	3.3	5.7	7.9

Table 1. Continued.

Specimen Number	Locality	Stem		Leaf blade		Involucre		Floret		Achene (mm)	Pappus (mm)
		Width (mm)	Height (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	NP (mm)	WP (mm)		
max HS 1	JN, Hwasun, Mt. Seonwangsan	3.4	86	30	13	9	4.7	6.7	4.4	5.9	8.1
max HS 2	JN, Hwasun, Mt. Seonwangsan	5.4	100	22	11	11.6	4.2	5.9	3.8	5.6	8
max HS 3	JN, Hwasun, Mt. Seonwangsan	5.2	97	28	14	12.1	4.6	6.9	4.5	6.2	8.3
max HS 4	JN, Hwasun, Mt. Seonwangsan	3.2	80	27	15	-	-	-	-	-	-
max HS 5	JN, Hwasun, Mt. Seonwangsan	3.3	82	25	11	10.6	4.1	6.5	4.4	6	8.2
max HS 6	JN, Hwasun, Mt. Seonwangsan	3.5	107	26	11.5	11.2	3.9	6.3	4.1	5.6	7.7
max HS 7	JN, Hwasun, Mt. Seonwangsan	3.8	67	22	9	12	5.2	6.5	4.3	5.8	7.6
max HS 8	JN, Hwasun, Mt. Seonwangsan	6.4	134	28	16.5	11.7	4.6	5.7	3.7	6.1	8
max HS 9	JN, Hwasun, Mt. Seonwangsan	4.1	128	23	13.5	10	4.1	6	4	6.2	8.5
max HS 10	JN, Hwasun, Mt. Seonwangsan	3.2	60	22	9.5	10.2	4.1	6.4	4.2	5.3	7.8
max HS 11	JN, Hwasun, Mt. Seonwangsan	3.8	106	29	13.5	10.5	4.2	-	-	-	-
tri 1100 1	JJ, 1100 Highland	1.4	23	6	2.2	-	-	-	-	-	-
tri 1100 2	JJ, 1100 Highland	1.5	26	6	1.8	-	-	-	-	-	-
tri 1100 3	JJ, 1100 Highland	2.3	48	8	3.3	-	-	-	-	-	-
tri 1100 4	JJ, 1100 Highland	2.4	20	5	1.8	11	4.6	6.9	4.5	6.3	8.4
tri 1100 5	JJ, 1100 Highland	2.1	22	5	1.7	-	-	-	-	-	-
tri 1100 6	JJ, 1100 Highland	2	15	7	2.6	-	-	-	-	-	-

Table 1. Continued.

Specimen Number	Locality	Stem		Leaf blade		Involucre		Floret		Achene (mm)	Pappus (mm)
		Width (mm)	Height (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	NP (mm)	WP (mm)		
tri JJU 009951	JJ, 1100 Highland	1.9	9	5	1.7	11.3	4.3	6.7	4.1	6	8.6
tri JJU 0013993	JJ, 1100 Highland	2.9	22	5	1.8	10.7	5.6	5.7	3.6	5.9	8.1
tri JJU 0013984	JJ, 1100 Highland	2.3	36	10	4	10.6	5	5.9	4	6.1	8.1
tri JJU 010922	JJ, 1100 Highland	2.7	30	7	2.4	10	4.8	-	-	-	-
tri JJU 0013982	JJ, 1100 Highland	3.1	30	7	2.3	10.3	4.9	6.2	4.1	5.7	7.7
tri JJU 0013999	JJ, 1100 Highland	2.2	56	10	3.7	11.4	5.1	5.5	3.3	6.1	8
tri JJU 0003697	JJ, 1100 Highland	1.4	17	6	2.6	10.9	4.1	6	4	5.8	7.8
tri JJU 011118	JJ, 1100 Highland	1.3	22	6	1.2	11.2	5.1	6.2	4.3	6.1	8.1
tri JJU 0013936	JJ, 1100 Highland	3.9	47	-	-	11.4	6	-	-	-	-
tri JJU 0013997	JJ, 1100 Highland	2.6	26	8	4	12	6.4	6.7	4.4	5.7	7.6
tri JJU 0013988	JJ, 1100 Highland	1.7	33	7	2.6	12.2	4.8	6	3.9	5.8	7.7
tri JJU 0019050	JJ, 1100 Highland	2	36	7	3	11.4	5.5	6.7	4.1	6.1	8
tri JJU 0019064	JJ, 1100 Highland	2.7	29	9	3.5	12.4	5.9	6.9	4.2	5.9	7.9
tri JJU 0013980	JJ, 1100 Highland	2	49	10	4.8	10.3	4.2	6.1	4.1	6.4	8.4
tri JJU 0005776	JJ, 1100 Highland	2.9	31	9	5.1	11.4	4.6	5.9	4.1	5.5	7.3
tri JJU 0013986	JJ, Mansudong-san	2.3	32	10	3.4	11.1	4.5	6.1	4.2	5.4	7.5
tri JJU 0013995	JJ, Eorimok	2.6	38	8	3.2	9.8	4.6	5.6	3	6.2	8.1
tri JJU 0001404	JJ, Eorimok	2	23	6	2	9.8	5	5.9	3.7	6	8
tri JJU 0001401	JJ, summit of Mt. Hallasan	2.3	45	12	9.2	10.3	4.3	6.5	4.1	5.5	7.2
tri JJU 009947	JJ, Sangumburi	3	68	13	4	10.7	4.2	6.2	4.3	5.7	7.8
tri JJU 009946	JJ, Sangumburi	2.6	58	11	4.3	10.4	4.2	-	-	-	--

NP, narrow part of floral tube; WP, wide part of floral tube; max, *S. maximowiczii*; tri, *S. maximowiczii* var. *triceps*; JN, Jeollanam-do; JB, Jeollabuk-do; JJ, Jeju-do; CNU, Herbarium of Chonnam National University; JJU, Herbarium of Jeju National University; HS, Hwasun population; 1100, Jejudo Isl. 1100-m altitude Highland.

Table 2. List of samples used in this study.

Abbreviation	Taxa	Locality
DD	<i>Saussurea calcicola</i> Nakai	Pyeongchang-gun, Gangwon-do
DH	<i>Saussurea chabyoungsanica</i> H. T. Im	Taebaek-si, Gangwon-do
SA	<i>Saussurea diamantica</i> Nakai	Yangyang-gun, Gangwon-do
HB	<i>Saussurea eriophylla</i> Nakai	Jeongseon-gun, Gangwon-do
HA	<i>Saussurea gracilis</i> Maxim.	Gapyeong-gun, Gyeonggi-do
GA	<i>Saussurea gracilis</i> Maxim.	Hapcheon-gun, Gyeongsangnam-do
HA	<i>Saussurea grandicapitula</i> W. Lee et H. T. Im	Gapyeong-gun, Gyeonggi-do
AS	<i>Saussurea grandifolia</i> Maxim.	Inje-gun, Gangwon-do
EL	<i>Saussurea grandifolia</i> Maxim.	Ulleung-gun, Gyeongsangbuk-do
GR	<i>Saussurea macrolepis</i> (Nakai) Kitam.	Namwon-si, Jeollabuk-do
BS	<i>Saussurea maximowiczii</i> Herder	Dalseong-gun, Daegu
MD	<i>Saussurea maximowiczii</i> Herder	Buk-gu, Gwangju
BU	<i>Saussurea maximowiczii</i> Herder	Gwangyang-si, Jeollanam-do
CD	<i>Saussurea maximowiczii</i> Herder	Hwaseong-si, Gyeonggi-do
JJ	<i>Saussurea maximowiczii</i> var. <i>triceps</i>	Seogwipo-si, Jeju-do
BL	<i>Saussurea mongolica</i> (Franch.) Franch.	Jeongseon-gun, Gangwon-do
DD	<i>Saussurea mongolica</i> (Franch.) Franch	Pyeongchang-gun, Gangwon-do
MH	<i>Saussurea myokoensis</i> Kitam.	Korea National Arboretum specimen
OR	<i>Saussurea odontolepis</i> Sch. Bip. ex Herder	Yeongwol-gun, Gangwon-do
TA	<i>Saussurea odontolepis</i> Sch. Bip. ex Herder	Taejeon-gun, Chungcheongnam-do
HS	<i>Saussurea polylepis</i> Nakai	Sinan-gun, Jeollanam-do
HD	<i>Saussurea polylepis</i> Nakai	Sinan-gun, Jeollanam-do
GY	<i>Saussurea pulchella</i> (Fisch.) Fisch. ex Colla	Jeongseon-gun, Gangwon-do
OD	<i>Saussurea pulchella</i> (Fisch.) Fisch. ex Colla	Hongcheon-gun, Gangwon-do
HA	<i>Saussurea seoulensis</i> Nakai	Gapyeong-gun, Gyeonggi-do
KD	<i>Saussurea seoulensis</i> Nakai	Pocheon-si, Gyeonggi-do
AS	<i>Saussurea tanakae</i> Franch. & Sav. ex Maxim.	Inje-gun, Gangwon-do
DH	<i>Saussurea tanakae</i> Franch. & Sav. ex Maxim.	Taebaek-si, Gangwon-do
JJ	<i>Saussurea taquetii</i> H. Lév. & Vaniot	Seogwipo-si, Jeju-do

2. DNA extraction and PCR

Both fresh and dried samples (stored in silica gel) of each plant material were collected prior to DNA extraction. Total genomic DNA was isolated from 20–25 mg of dried leaves using DNeasy Plant Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's protocol. PCR products were electrophoresed on 1% agarose gel to visualize characteristic band patterns to differentiate between DNA fragments. To investigate molecular variations, PCR utilized internal transcribed spacer (ITS), *trnL-trnF*, *psbA-trnH*, and *rbcL* based on previous molecular phylogenetic studies of *Saussurea*

(Raab-Straube et al., 2003; Kita et al., 2004; Wang et al., 2007, 2009, 2013). In addition, we used *trnQ-5'rps16* and *psbJ-petA* because they had high potentially informative character and percentage variability values (Shaw et al., 2007). Six regions of DNA were amplified: one nuclear DNA region and five chloroplast DNA (cpDNA) regions. PCR for amplification of DNA preparations was carried out with the following components: 1 µL of template DNA, 5 µL of 10× Taq polymerase reaction buffer, 1 µL each of 10 mM dNTPs mix, 1 µL each of 10 pmol primer, 0.2 µL of 1.25 units of Diastar-Taq DNA polymerase (SolGent Co., Daejeon, Korea), and

Table 3. Characteristics of ITS and combined cpDNA datasets obtained from maximum parsimony analyses.

	ITS	Combined cpDNA
Number of taxa (including 1 outgroup)	30	30
Total length	647	3,346 (<i>trnL-trnF</i> 852, <i>rbcL</i> 503, <i>psbJ-petA</i> 795, <i>trnQ-5'rps16</i> 798, <i>psbA-trnH</i> 398)
Number of parsimony informative sites	68	25
Number of parsimony uninformative sites	57	43
Number of constant sites	522	3278
Tree length	161	77
Consistency index	0.851	0.896
Retention index	0.919	0.906

ITS, internal transcribed spacer; cpDNA, chloroplast DNA.

distilled water to make a total volume of 50 μ L. PCR cycling conditions were: template denaturation at 95°C for 1 min followed by primer annealing at 54–58°C for 1 min and primer extension at 72°C for 2 min. We repeated the above denaturation, annealing, and extension steps with 35–40 cycles.

3. Sequence alignment and phylogenetic analysis

Editing and alignment of all sequences were conducted using Geneious version 10.2.2 (Kearse et al., 2012). Gaps were treated as missing characters and all traits were equally weighted. Each data matrix (Table 3) was subjected to maximum parsimony (MP) and maximum likelihood (ML) for taxonomic analysis. ML was analyzed using PAUP* 4.0b10 (Swofford, 2001). MP analyses involved a heuristic search strategy with tree bisection reconnection branch swapping option. ML analyses were conducted using IQ-TREE software (Nguyen et al., 2015). TIM3e+G4 was selected as the fittest model of ITS. Furthermore, F81+I was selected for combined cpDNA data. To investigate statistical support of each cladogram, bootstrap values were calculated from 1,000 replicates (Felsenstein, 1985).

Results and Discussion

External morphology

According to protologue and description in the name combination of *Saussurea maximowiczii* and *S. triceps*, the

difference between the two taxa is that the latter is shorter in height than the former and lower leaves of *S. triceps* are shorter. Morphological traits such as involucre bract, florets, achene, and pappus have been used as important criteria of *Saussurea* classification in previous studies (Im, 1989, 1990, 1991). For 53 individuals used for morphometry, morphological traits were examined to determine the range of morphological variations of *S. maximowiczii* and *S. triceps* (Table 1). For some individuals that were not fully mature, there were some deficiencies in the measurement.

For quantitative traits such as height, stem diameter, and lower leaf size, *S. triceps* from the 1100-m altitude Highland population tended to be smaller than those of *S. maximowiczii* from Seonwangsan Mountain population. However, this variation is continuous between populations and within populations. Such continuity becomes clear when heights of samples collected from the 1100-m altitude Highland population and the Seonwangsan Mountain population are compared (Fig. 1). This is also true in the graphs based on specimens deposited in the herbaria (Fig. 2). The quantitative trait represented by plant height is generally a trait that has wide range of variations because it is highly affected by the environment.

In contrast, reproductive organs such as involucre bract, florets, achene, and pappus are less affected by the environment. For traits of involucre bract, florets, achene, and pappus, *S. triceps* which consists of 1100-m altitude Highland population and *S. maximowiczii*, including Seonwangsan Mountain population are mixed within narrow variation range (Table 1). Florets of *Saussurea* consist of tube and limb. The limb is divided into five lobes. The tube is divided into a narrow part at the bottom and a broad part at the top (Fig. 3). Lengths of the narrow part and the broad part are very stable traits (Im, 1989). When lengths of the broad and narrow parts of florets are plotted on a graph, *S. maximowiczii* and *S. triceps* cannot be distinguished (Figs. 4, 5).

Molecular data

Phylogenetic tree based on ITS nucleotide sequence of nuclear DNA revealed that *S. triceps* and *S. maximowiczii* formed a monophyletic group supported by MP bootstrap (BS) = 100% and ML BS = 100% (Fig. 7). This demonstrates that *S. triceps* and *S. maximowiczii* share most recent common ancestor regardless of their taxonomic position or species distinctness. However, *S. triceps*/*S. maximowiczii* clade is well segregated from other *Saussurea* taxa distributed on the Korean peninsula.

Phylogenetic tree based on five regions of cpDNA was

similar to the ITS tree in which *S. triceps* and *S. maximowiczii* formed a clade. However, two clades which were not detected in the ITS tree were observed in the cpDNA tree: Clade 1

consisted of *S. maximowiczii* from Mudeungsan Mountain and Biseulsan Mountain, with 63% of MP BS and 92% of ML BS; Clade 2 consisted of *S. maximowiczii* from Baekunsan

Fig. 1. Plants from Hwasun Seonwangsan population (A; *Saussurea maximowiczii*) and Jeju 1100-m altitude Highland population (B; *S. maximowiczii* var. *triceps*).

Fig. 2. Plants height of *Saussurea maximowiczii* (BT) and *S. maximowiczii* var. *triceps* (JJ).

Fig. 3. Floret of genus *Saussurea*.

Mountain and *S. triceps* from Jeju Island, with 61% of MP BS and 93% of ML BS (Fig. 8). A sister group relationship between *S. triceps* and *S. maximowiczii* of Baekunsan Mountain implies their geographical correlation.

These results support the possibility that *S. triceps* is an ecophene of *S. maximowiczii*. However, it cannot be ruled out that *S. triceps* may maintain a species position. The distribution of *S. triceps* is confined to Jeju Island which has quite different environmental conditions from the inland area. Populations of *S. triceps* are relatively small in size. Thus, it is easily affected by founder effect, inbreeding, and so that that may lead to wide morphological variations among subpopulations. In addition, it is isolated from *S. maximowiczii* distributed across the Korean peninsula. *S. triceps* may maintain genetic traits by cutting off genetic interactions with *S. maximowiczii*. *S.*

Fig. 4. Length of broad part of tube: *Saussurea maximowiczii* (BT) and *S. maximowiczii* var. *triceps* (JJ).

Fig. 5. Length of broad part of tube: *Saussurea maximowiczii* (BT) and *S. maximowiczii* var. *triceps* (JJ).

Fig. 6. Maximum parsimony (MP) tree and Maximum likelihood (ML) tree based on internal transcribed spacer sequences of 30 taxa including outgroup. **A.** Fifty percent majority consensus tree. Numbers below branches represent bootstrap support (BS) values (MP BS). **B.** ML tree. Numbers above branches represent bootstrap support values (ML BS).

Fig. 7. Maximum parsimony (MP) tree and Maximum likelihood (ML) tree based on combined cp sequences of 30 taxa including outgroup. **A.** Fifty percent majority consensus tree. Numbers below branches represent bootstrap support (BS) values (MP BS). **B.** ML tree. Numbers above branches represent bootstrap support values (ML BS).

triceps is likely to continue to function as an independent species through peripheral isolation during local speciation process (Levin, 1993). To more clearly confirm the origin and taxonomic position of *S. triceps*, research results such as population genetics and others are needed.

Taxonomic identity of *Saussurea triceps* - the ecophene

In high elevation of Hallasan Mountain such as Yeongsil, Eorimok, and 1,100-m altitude wetlands, many plants are assumed to be ecophenes adapted to high mountain winds and low temperatures (Fig. 8). In the case of *Aruncus aethusifolius* (H. Lév.) Nakai, there is no difference between individuals of Yeongsil, the high mountain area (Fig. 8A), and individuals of Donnaeko above sea level of 400 m. Both are about 20–30 cm tall. But in the case of *Rubus oldhamii* Miq., ordinary size of the terminal leaflet is 3–5 × 2–3 cm in its main distribution region, forest margin of mountainous area. However, it is only about 1 cm in Yeongsil population (Fig. 8B). *Ligularia fischeri*

(Ledeb.) Turcz. of Eorimok dramatically shows change in shape between individuals on the windward side (Fig. 8C) and individuals on the downwind side (Fig. 8D). Individuals on the windward side are about 25 cm high with 6–8 heads. On the other hand, individuals on the downwind (8D) only 10 m away from those of windward side (8C) are 60–70 cm high with 30–40 heads.

Saussurea triceps also tends to be similar to *Ligularia fischeri*. Among specimens deposited at JNUB, there are individuals with stem lengths of 45 cm collected at the top of Hallasan Mountain (No. JJU0001401) (Table 1). Some specimens collected at 1,100-m altitude wetland had stem lengths of 56 cm (No. JJU0013999) (Table 1). These individuals are presumed to have grown on the downwind side. Taking these morphological and molecular findings into considerations, *S. triceps* is an ecophene of *S. maximowiczii* that has adapted to the highland of Hallasan Mountain facing strong winds. Therefore, it is reasonable to recognize that *S. triceps* is a synonym of *S. maximowiczii*.

Fig. 8. Examples of ecophene adapted in highland of Hallasan Mountain, Jeju Island. **A.** *Aruncus aethusifolius* (H. Lév.) Nakai. **B.** *Rubus oldhamii* Miq. **C, D.** *Ligularia fischeri* (Ledeb.) Turcz., **C** on windward side and **D** on downwind.

Taquet's taxa reported in Jejudo Island

Among specimens collected by Taquet from Jejudo Island from 1907 to 1910, there are many new species described by H. Léveillé and E. Vaniot, such as *Allium taquetii* H. Léév. & Vaniot (1908), *Rosa taquetii* Lev. (1909), *Prunus taquetii* H. Léév. (1909), *Astilbe thunbergii* var. *taquetii* H. Léév. (1910), *Astilbe thunbergii* var. *aethusifolius* H. Léév. (1910), *Senecio taquetii* H. Léév. & Vaniot (1910), *Ophiopogon taquetii* H. Léév. (1910), *Chionanthus coreanus* H. Léév. (1910), *Matricaria coreana* H. Léév. (1910), *Salix blinii* H. Léév. (1912), *Salix hallaisanensis* H. Léév. (1912), *Ranunculus crucilobus* H. Léév. (1912), *Corydalis hallaisanensis* H. Léév. (1912), *Thalictrum punctatum* H. Léév. (1912), *Pyrus brunnea* H. Léév. (1912), *Rosa quelpaertensis* H. Léév. (1912), *Cnicus rhincoceros* H. Léév. & Vaniot (1912), *Cardamine glechomifolia* H. Léév. (1913), *Adenophora taquetii* H. Léév. (1913), *Aster hayatae* H. Léév. & Vaniot (1913), and so on. Some of these taxa underwent taxonomic treatment such as name combination or synonym while others are recognized as endemic species in Jejudo Island and Korea (NIBR, 2013).

Aruncus aethusifolius was originally reported to be a variety of *Astilbe thunbergii* (i.e., *Astilbe thunbergii* var. *aethusifolia* H. Léév., 1909). Later, it was changed to species *Aruncus aethusifolius* (H. Léév.) Nakai, 1912. Afterwards, it was downgraded to a variety (*Aruncus dioicus* var. *aethusifolia* (H. Léév.) Hara). Regardless its taxonomic position and rank (genus, species or infraspecific taxa) the taxonomic entity of *Aruncus aethusifolius* itself actually exists. In contrast, taxonomic identity of *S. triceps* is suspected since it has been treated as a synonym of other taxon frequently. To confirm or discuss taxonomic identity of taxa described based on nearly a century old collections such as *A. aethusifolius* or *S. triceps*, examination of field collected samples from type locality is necessary. Domestic researchers may play an important role in this regard because it is difficult for foreign researchers to access Korean endemic species.

Conflict of Interest

Authors declare that there is no conflict of interest.

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한라분취의 분류학적 인식

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적 요: 한라분취(*Saussurea maximowiczii* var. *triceps*)의 분류학적 실체에 대해 형태 및 분자적 접근을 했다. 줄기 길이, 잎의 크기와 같은 영양기관의 정량형질에서 한라분취가 버들분취(*S. maximowiczii* Herd.)보다 작은 경향이 있으나, 이는 연속적 변이다. 소화, 총포를 비롯한 생식기관 성질에서 한라분취와 버들분취는 구별할 수 없었다. 버들분취와 한라분취의 염기서열을 확인한 결과 이들은 단계통을 이루었다. 한라분취는 강풍에 면한 한라산 고산지대에 적응한 버들분취의 생태표현형으로 추정된다.

주요어: 한라분취, 생태형, 고지, 제주도