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Exploitation of Diversity for Morphological Traits in *Lilium tsingtauense* under Different Habitats

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Abstract

In this study naturally growing morphological variation of *Lilium tsingtauense* (Korean wheel lily), from southern Chung San Island to northern Mount Seorak, was investigated in 16 habitats around the country. Morphological analysis revealed that this species had its own unique characteristics in different habitats. Flowers with luster are in actinomorphic form, with shades of orange, each plant having an average of 2.4 flowers that blossom upward. The shape of flower petals was from oval to oblong. The width of the petals, which determines the shape of the flower, significantly varied among regions. Flower petals showed purple spots and its occurrence greatly varied among plants from almost none to 300 spots per flower. In addition, when the number of spots increased, the flower color was more vivid. Leaves were typically one-tiered verticillate and most of the leaves were long, oval and some were lanceolate. Young leaves showed definitive patterns that faded during growth. Starting from the verticillate leaves, stems below the leaves were smooth, although 81% of all stems, above the verticillate leaves, showed rough micro-protrusions. Bulb shapes were long and vertically elliptical. The ramentum was light yellow in color and the base was darker, with the color fading toward the upper region of the plant. The shape of the ramentum was long, with a pointy end, and its adhesiveness was weak. This study offers basic fundamental information for the effective exploitation and recognition of *L. tsingtauense* resources as a potential cut flower and potting plant in floral trade worldwide.

Keywords: blossoming time, bulb colour, habitat, Korea, Martagon lilies, verticillate leaves

Introduction

Lilies are categorized into seven sections: Martagon, Pseudolirium, Liriotypus, Archelirion, Sinomartagon, Leucolirion, and Daurolirion on the basis of their morphological and physiological characteristics (Comber, 1949). Approximately 100 lily species are distributed across the globe, with the majority occurring in the northern hemisphere. However, one species, *Lilium zairii* has been previously reported to naturally grow in the southern hemisphere (Edward, 1998; Kucharska, 2001). Korea offers diverse climatic conditions that support *Lilium* production and thereby, considered as a major distribution center of *Lilium* germplasm (Lucidos *et al*., 2013). It has been reported that 11 species, consisting of 7 species from Sinomartagon section, 1 species from Daurolirion section, and 3 species from Martagon section, naturally grow in Korea (Lee, 2003). Among these, the lily with whorled leaves in section Martagon has been considered to be the most primeval type of lily, as indicated by phylogenetic systematics (Lighty, 1968). Five species from Martagon section are distributed around the world but 3 species viz. *Lilium hansonii*, *L. distichum*, and *L. tsingtauense* have natural habitat in Korea (Kim, 2008; Lee, 1980). *L. martagon* is widely distributed in Europe, Northern China, including Central Asia, and Russia, including various mutants. *L. medeoloides* is distributed up to Kamchatka Peninsula, following the Japanese Islands, while no distribution in South Korea has been reported (Lee *et al.*, 2011). However, *L. tsingtauense* is distributed in the Korean Peninsula and the Shandong Peninsula, *L. distichum* occurs within a relatively narrow range from the Korean Peninsula to Manchuria and Vladivostok in Russia. *L. hansonii* occurs in Ullenungdo in Korea, which is unique in the world (Fox, 2006).

These distributions, thus suggest that South Korea is the center of the Martagon section lilies. Korean wheel lilies (*L. tsingtauense*) are distributed only in the Korean Peninsula and the Shantung Peninsula, with their specific classification systems, are not investigated due to extensive morphological variation (Fox 2006). According to Lighty (1968), lilies that present whorled leaves and naturally thrive across the Korean Peninsula have been identified as *L. distichum* and *L. miquelianum,* whereas lilies with whorled leaves in Jeju-do were not reported as *L. tsingtauense*, which is distinguishable from the land lilies (Lim, 2013). On the other hand, in another plant

classification, the *malnari* in the Korean Peninsula has been identified as *L. distichum,* whereas the *haneulmalnari* has been classified as *L. tsingtauense* (Lee, 2003, 2007; Kim, 2008). *L. miquelianum* has been used interchangeably as a synonym for *L. tsingtauense* (Lee, 2003). According to Lighty (1968), *L. distichum* is mainly characterized by the presence of a node on a scale, which could be easily separated. However, this species is commonly mistaken as *L. tsingtauense*, based on the common feature of its flowers facing upward and thus resulting in a lower propensity for the plant to lean backward. In addition, because *L. miquelianum* is characterized by square-shaped floral leaves and may or may not have a node on a scale, it is usually referred to as *L. tsingtauense*; however, the direction of flowering of *L. miquelianum* suggests that it carries the features of *L. distichum*. Furthermore, *L. tsingtauense* flowers in the upward direction, and the flower petals are not bent backwards; *L. tsingtauense* is exclusively found in Jeju-do. For its morphological features to coincide with those of *L. tsingtauense*, the range of distribution *L. tsingtauense* has to be revisited. Because the *L. haneulmalnari* in the Korean Peninsula has been identified as *L. tsingtauense*, which is similar to *L. miquelianum*, *L. tsingtauense* described by Lighty (1968) as growing in Jeju-do might be a different species from that growing on land or may have been incorrectly identified. Lily species' identification has also been controversial since Lighty (1968) described *L. malnari, L. haneulmalnari,* and *L. miquelianum* as having different morphological features.

The present research was performed to comparatively analyze characteristics and modifications of the Korean wheel lilies (*L. tsingtauense*) naturally growing in each region of South Korea to test the hypothesis that habitat influences the variation in morphological traits. This will provide baseline data for the establishment of an accurate morphological taxonomy of Korean wheel lilies.

Materials and methods

This study performed a sample survey of 5 entities of each Korean wheel lily's, naturally growing in 16 regions from southern Chung-San Island to northern Mount Seorak, from 2009 to 2011 during blossoming time. During the experimental time extensive survey of the habitats was carried out to collect data regarding morphological characteristics of petals, stems, and bulbs.

Flower characteristics examined in this study included fragrance, spikes, blossoming direction, inflorescence, flower width, length and width of flower petals, length and width of calyx, luster, density of spots on flower, color and size of spots, filament color, anther color, pistil color, and stigma color. For leaves, verticillate leaves, shapes, leaf length and width, leaf color, number of verticillate leaves, number of bracts, and number of alternate leaves above and below the verticillate leaves were examined. Plant height was measured from the soil surface to the beginning of the pedicel. The diameter of stems (above and below the verticillate leaves), protrusion from the surface (above and below the verticillate leaves), color, and pedicel color were also analyzed. For bulbs, circumference, diameter, length, width, form, length and width of ramentum, form of ramentum, ramentum nodes, and color of ramentum were examined.

Data was analyzed statistically using ANOVA techniques and means were compared. The Royal Horticultural Society (RHS) colour chart (2001) was used for classifying the colour of every specimen that was examined.

Results

Characteristics of flowers

The flower forms of Korean wheel lilies naturally growing in each region are shown in Tab. 1. The average number of flowers in Korean wheel lilies was 2.4. Umbel type of inflorescence was observed when there were two flowers, whereas, raceme and umbel formation was observed for 3 flowers, and 4 or more flowers were associated with a raceme. All lilies exhibited an upward direction of flowering. The average diameter of the flower was 6.7 cm, Mount Mindung habitat had the largest flower size (7.9 cm), whereas, lilies growing in Mt. Jiri showed the smallest flower size (5.6 cm). Flower colors were RHS #28A and RHS #28B, in shades of orange color (Fig 1). Fragrance was not observed in all surveyed regions, but part of the samples found in Mount Gyebang and Mount Odae produced an indistinct fragrance. The average length of the petals was 3.7 cm and the average length of calyx was 3.9 cm. The average width of the petals was 1.2 cm, and it was slightly wider than the

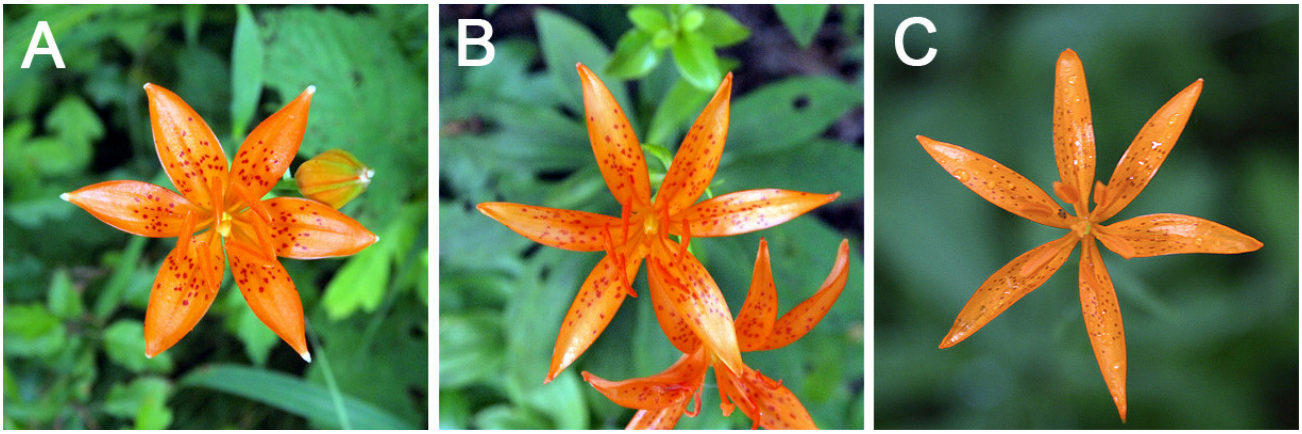

Fig. 1. Variation of flower morphology in *L. tsingtauense* found in different habitats. Flowers from A: short-wide type, B: normal type, and C: narrow type

Tab. 1. Flowering seasonality, flower and inflorescence characteristics of *L. tsingtauense* by region in Korea (n=20)

Habitat	Anthesis	Fragrance[z]	No. of flowers	Facing	Inflorescence	Size (cm)	Color
Geoje Island	10 July	N	1.6±0.3	upward	umbel, single	6.7±0.2[Z]	28A
Mt. Biseul	13 July	N	1.3±0.3	upward	umbel, single	6.3±0.1	28B
Mt. Cheongyang	13 July	N	1.9±0.3	upward	umbel, single	7.1±0.2	28B
Mt. Chaejeong	10 July	N	2.5±0.5	upward	raceme, umbel	7.0±0.5	28B
Mt. Deogyu	10 July	N	2.3±0.3	upward	raceme, umbel	5.7±0.4	28A
Mt. Gariwang	18 July	N	4.3±1.5	upward	raceme, umbel	7.0±1.0	28A
Mt. Gaya	12 July	N	1.4±0.2	upward	umbel, single	6.2±0.2	28A
Mt. Gyebang	20 July	N	2.0±0.4	upward	umbel, single	6.9±0.6	28B
Mt. Hambaek	19 July	N	2.0±0.3	upward	umbel, single	7.3±0.4	28B
Mt. Jiri	12 July	N	2.3±0.3	upward	raceme, umbel	5.6±0.3	28B
Mt. Mindung	17 July	N	3.7±1.2	upward	raceme, umbel	7.9±0.4	28B
Mt. Naejang	10 July	N	2.1±0.3	upward	umbel, single	6.0±0.5	28A
Mt. Odae	16 July	N	2.7±0.5	upward	raceme, umbel	6.9±0.1	28A
Mt. Seorak	16 July	N	2.5±0.4	upward	raceme, umbel	7.1±0.3	28A
Mt. Sobaek	14 July	N	2.3±0.3	upward	raceme, umbel	7.3±0.2	28A
Mt. Songni	13 July	N	4.7±1.6	upward	raceme, umbel	6.7±0.2	28A
Average	-	-	2.5±0.5	-	-	6.7±0.4	-

[Z]Mean ± standard error.

Tab. 2. Floral morphological characteristics of *L. tsingtauense* by region in Korea (n=20)

Habitat	Petal			Sepal			Spot			Anther	Filament	Style	Stigma
	Length (cm)	Width (cm)	Index (L/W)	Length (cm)	Width (cm)	Index (L/W)	No. of Spot	Color	Size (mm)				
Geoje Island	3.5±0.2[Z]	1.1±0.2	3.2±0.2	4.0±0.2	0.9±0.1	4.4±0.2	91.0±13.0	N79C	0.7±0.1	24A	24A	24A	24A
Mt. Biseul	3.4±0.3	1.2±0.1	2.8±0.3	3.9±0.2	1.0±0.1	3.9±0.2	153.0±27.7	N79C	0.7±0.1	28A	24A	24A	24A
Mt. Cheongyang	4.0±0.3	1.2±0.1	3.2±0.3	4.0±0.3	0.9±0.1	4.3±0.3	39.6±11.1	N79C	0.7±0.1	24A	24A	24A	24A
Mt. Chaejeong	3.9±0.3	1.2±0.2	3.4±0.3	4.0±0.2	1.0±0.1	4.3±0.2	99.8±41.5	N79C	0.6±0.1	28B	28A	24A	24A
Mt. Deogyu	3.2±0.3	1.2±0.2	2.7±0.3	3.3±0.3	0.9±0.2	3.7±0.4	354.7±35.0	N79C	0.7±0.1	24A	24A	28A	24A
Mt. Gariwang	3.9±0.3	1.3±0.2	3.1±0.3	3.8±0.3	1.0±0.1	4.0±0.3	148.7±64.2	N79C	0.6±0.1	28A	28A	24A	24A
Mt. Gaya	3.5±0.2	1.0±0.1	3.5±0.2	3.8±0.3	0.8±0.1	4.8±0.3	29.3±9.0	N79C	0.3±0.2	24A	24A	24A	24A
Mt. Gyebang	3.6±0.2	1.3±0.1	2.8±0.2	3.8±0.3	1.0±0.2	3.8±0.3	87.5±25.5	N79C	0.4±0.1	28A	24A	24A	28A
Mt. Hambaek	4.0±0.2	1.3±0.1	3.1±0.2	4.3±0.2	1.0±0.1	4.3±0.2	81.4±10.5	N79C	0.7±0.1	28A	24A	28B	24A
Mt. Jiri	3.1±0.2	1.0±0.1	2.7±0.2	3.3±0.2	0.9±0.1	3.9±0.2	166.0±13.4	N79C	0.7±0.1	28A	24A	24A	24A
Mt. Mindung	4.5±0.2	1.4±0.1	3.3±0.2	4.8±0.2	1.1±0.2	4.3±0.3	277.3±36.6	N79C	0.8±0.1	28A	28B	24A	24A
Mt. Naejang	3.5±0.4	1.0±0.1	3.5±0.4	3.2±0.7	0.9±0.3	3.6±0.5	102.0±18.0	N79C	0.6±0.2	28A	24A	24A	28B
Mt. Odae	3.9±0.3	1.1±0.2	3.4±0.3	4.3±0.3	0.9±0.1	4.8±0.3	105.5±62.5	N79C	0.7±0.1	28A	28B	28A	28B
Mt. Seorak	4.1±0.2	1.2±0.1	3.5±0.2	4.2±0.2	1.0±0.2	4.4±0.3	89.8±9.4	N79C	0.7±0.1	28A	24A	24A	24A
Mt. Sobaek	3.7±0.2	1.3±0.1	3.0±0.2	4.1±0.2	1.0±0.1	4.3±0.2	69.7±6.4	N79C	0.7±0.1	24A	24A	28B	24A
Mt. Songni	3.8±0.1	1.1±0.1	3.4±0.1	3.9±0.2	0.9±0.1	4.4±0.2	162.0±25.4	N79C	0.7±0.1	28B	24A	24A	24A
Average	3.7±0.2	1.2±0.1	3.2±0.2	3.9±0.2	1.0±0.1	4.2±0.2	128.6±23.7	-	0.6±0.1				

[Z]Mean ± standard error.

average calyx width of 1.0 cm (Tab. 2). Regarding the ratio of petal length and width, the widest petals were those from Mount Deogyu and Mount Jiri, with a ratio of 2.7; the narrowest petals were from Mt. Gaya, Mt. Naejang and Mt. Seorak, with a ratio of 3.5, and were oval to oblong. In terms of length and width ratio of calyx, Mount Naejang showed the widest ratio (3.6) and Mount Gaya and Mount Odae showed the narrowest ratio (4.8). However, petal and calyx length and width ratio varied significantly within a habitat, as well as among regions (Fig. 1).

The average number of spots on each flower was 128.6; the smallest count was 29.3 spots at Mount Gaya and the highest count was 354.7 spots at Mount Deogyu. Even in a same habitat, it was confirmed that samples with more spots had flowers with more vivid color (Fig. 2). Spot color on the flower was RHS #N79C, in shades of purple. The average diameter of the flower spot was 0.7 mm, but for Mount Gaya, the average was small, at 0.3 mm. Anther, filament, pistil, and stigma were orange range colors similar to the color of the petals (RHS #28A, RHS #28B, and RHS #24A respectively).

Characteristics of leaves

Morphological characteristics of leaves are presented in Tab. 3. Most of the verticillate leaves are in one tier, rare entities with two tiers of verticillate leaves were found in Mount Songni and Mount Odae. The average number of verticillate leaves was 9.9. Leaf shape ratio was recorded as 3.9, and most of them were ellipsoid, but some leaves were lanceolate (Fig. 3). However, the leaf shape ratio at Mount Deogyu was observed as 2.8, which was rounder than that of the other regions, like in Chung San Island was 5.6, which was narrow and long. Similar to flower petals, entities showed modifications according to the habitat and variations among regions. Edges of the leaves existed in two forms, wrinkled and smooth (Fig. 4). Most of the verticillate leaves in Korean wheel lilies showed patterns, which were striking in young leaves and later faded as they grew. Bracts possessed 1.5-9.0 leaves. The average number of alternate leaves was 3.4 which were more than that in verticillate leaves. Leaf colors were generally green, identified as RHS #137A and RHS #144A.

Characteristics of stem

Morphological characteristics of stems of Korean wheel lilies based on habitat are shown in Tab. 4. The average height of Korean wheel lilies is 65.4 cm, with the shortest at 53.6 cm (Mount Gaya) and the tallest at 89.4 cm (Mount Songni). Height ratio of plant height and height to verticillate leaves is between 0.5 and 0.7. The verticillate leaves are located at the center of the plant or either located slightly higher than the center.

The diameter below verticillate leaves was 3.5 mm and diameter above the verticillate leaves was 2.0 mm. The

Tab. 3. Characteristics of leaf of *L. tsingtauense* by region in Korea (n=20)

Habitat	Whorled leaves					No. of Bracts	No. leaf		Color
	No. of layer	No.	Length	Width	Index		Upper	Lower	
Geoje Island	1	9.0±0.7[Z]	10.0±1.0	2.7±0.2	3.7±0.2	5.0±0.9	2.0±0.4	2.0±0.0	137A
Mt. Biseul	1	8.5±0.3	8.3±0.3	2.6±0.2	3.2±0.4	2.3±0.5	1.3±0.3	2.3±0.3	144A
Mt. Cheongyang	1	10.4±0.5	11.3±0.4	2.7±0.1	4.1±0.2	3.7±0.4	3.0±0.3	2.4±0.2	144A
Mt. Chaejeong	1	9.8±0.3	10.1±0.5	3.0±0.2	3.3±0.3	4.8±0.9	3.8±1.1	2.3±0.3	144A
Mt. Deogyu	1	7.7±0.3	10.3±1.1	3.7±0.3	2.8±0.2	3.3±0.3	2.7±0.3	2.7±3.3	137A
Mt. Gariwang	1	12.3±1.7	11.5±0.3	3.7±0.6	3.1±0.5	9.0±2.7	4.7±0.9	4.0±0.6	144A
Mt. Gaya	1	10.4±0.4	10.2±1.0	2.2±0.2	4.6±0.3	2.8±0.6	3.6±0.5	2.2±0.2	144A
Mt. Gyebang	1	8.5±0.5	12.6±1.0	3.0±0.0	4.2±0.3	4.0±0.0	4.5±0.5	1.5±0.5	144A
Mt. Hambaek	1	9.0±0.6	9.9±0.3	3.0±0.2	3.3±0.2	3.4±0.6	2.4±0.2	2.2±0.2	137A
Mt. Jiri	1	10.0±0.7	10.9±0.8	2.9±0.3	3.8±0.4	4.1±0.5	3.3±0.6	2.3±0.2	144A
Mt. Mindung	1	11.3±2.4	13.4±1.4	3.3±0.2	4.1±0.7	8.8±2.9	4.0±0.6	3.3±0.3	144A
Mt. Naejang	1	10.5±0.5	11.1±1.1	2.5±0.1	4.4±0.3	3.5±0.5	3.5±1.5	2.0±0.0	144A
Mt. Odae	1	10.3±0.7	10.9±0.7	2.9±0.2	3.8±0.4	5.0±1.0	3.0±0.4	2.0±0.0	144A
Mt. Seorak	1	9.2±1.0	11.4±0.4	3.3±0.2	3.5±0.3	4.2±0.9	4.2±0.4	3.2±0.4	137A
Mt. Sobaek	1	10.3±0.6	10.7±0.2	2.9±0.2	3.7±0.3	4.7±0.6	3.2±0.3	2.3±0.3	137A
Mt. Songni	1	11.3±1.4	10.6±1.0	3.2±0.3	3.3±0.3	8.7±3.0	4.4±0.4	2.7±0.4	144A
Average	1	9.9±0.8	10.8±0.7	3.0±0.2	3.7±0.3	4.8±1.0	3.4±0.5	2.5±0.5	-

[Z]Mean ± standard error.

Tab. 4. Characteristics of stem of *L. tsingtauense* by region in Korea (n=20)

Habitat	Plant height	Thickness (mm)		Surface		Stem root	Color[Y]	Pedicel color
		Upper	Lower	Upper	Bottom			
Geoje Island	57.5±5.2[Z]	1.4±0.2	3.4±0.4	Rough	Smooth	Y	144A	144A
Mt. Biseul	57.1±4.8	1.9±0.1	3.1±0.1	Rough	Smooth	Y	144A	144A
Mt. Cheongyang	54.6±3.7	1.7±0.2	3.4±0.2	Rough	Smooth	N	144A	144A
Mt. Chaejeong	77.0±7.3	2.6±0.2	4.2±0.3	Rough	Smooth	Y	144A	144A
Mt. Deogyu	54.3±4.1	1.8±0.1	3.2±0.3	Rough	Smooth	Y	144A	144A
Mt. Gariwang	87.3±7.0	3.4±0.3	5.3±0.5	Rough	Smooth	Y	144A	144A
Mt. Gaya	53.6±4.3	1.8±0.1	3.4±0.2	Rough	Smooth	Y	144A	144A
Mt. Gyebang	60.5±6.5	2.5±0.3	4.7±0.4	Smooth	Smooth	Y	144A	144A
Mt. Hambaek	56.0±2.3	2.3±0.1	3.7±0.2	Rough	Smooth	Y	144A	144A
Mt. Jiri	55.6±6.4	2.0±0.3	3.7±0.5	Rough	Smooth	Y	144A	144A
Mt. Mindung	79.7±9.4	3.3±0.4	5.3±0.6	Rough	Smooth	Y	144A	144A
Mt. Naejang	62.0±2.0	2.3±0.2	4.0±0.6	Rough	Smooth	Y	144A	144A
Mt. Odae	61.9±3.2	2.8±0.2	4.2±0.3	Smooth	Smooth	Y	144A	144A
Mt. Seorak	80.8±6.2	3.0±0.2	4.5±0.4	Smooth	Smooth	Y	144A	144A
Mt. Sobaek	59.3±4.2	2.2±0.2	3.9±0.3	Rough	Smooth	Y	144A	144A
Mt. Songni	89.4±9.7	2.4±0.4	3.8±0.6	Rough	Smooth	Y	144A	144A
Average	65.4±5.4	2.3±0.2	4.0±0.4	-	-	-	144A	144A

[Z]Mean ± standard error; [Y]Stem color indicated by RHS color chart number.

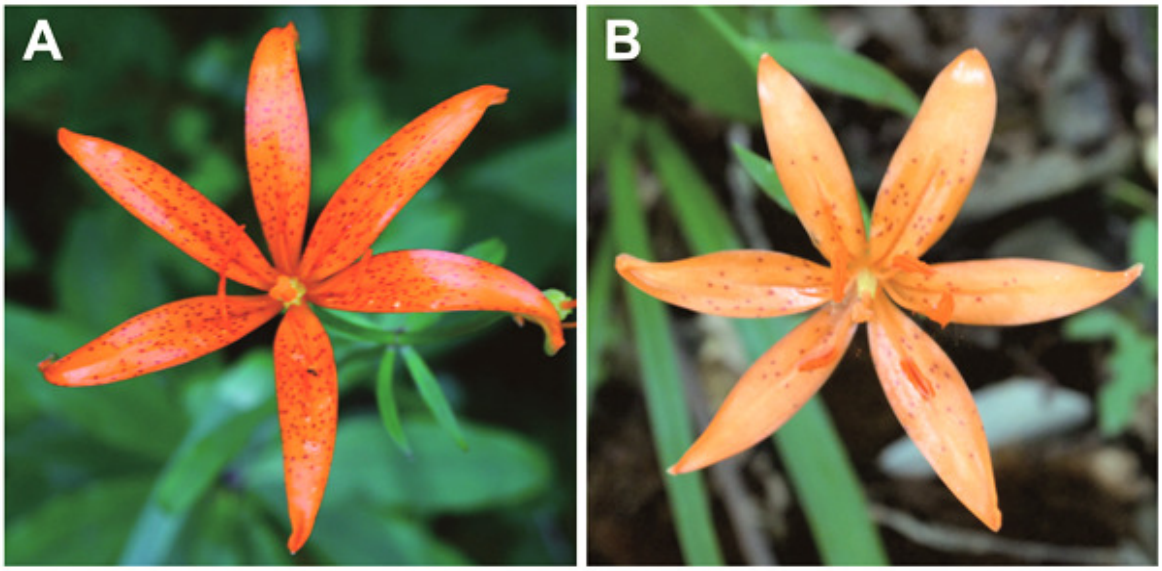

Fig. 2. Variation of flower color and spots in *L. tsingtauense*: A) orange color with many spots; B) few spots with light orange flower (mutant type)

Tab. 5. Characteristics of bulbs of *L. tsingtauense* in different habitats of Korea (n=12)

Habitat	Bulb size				Scale							Color[Y]
	Circumference (cm)	Height (cm)	Width (cm)	Index (H/W)	Length (cm)	Width (cm)	Index (L/W)	No. total scale	Jointed	Normal	Ratio jointed	
Geoje Island	6.2±0.3[Z]	2.8±0.2	1.8±0.3	1.6±0.2	1.8±0.3	0.5±0.1	3.6±0.3	49.5±5.5	22.0±2.5	33.0±3.0	40.0	15D
Mt. Biseul	6.4±0.3	2.4±0.1	2.2±0.2	1.1±0.1	2.0±0.1	0.6±0.1	3.5±0.1	35.6±2.3	17.0±1.5	21.5±2.0	44.5	15D
Mt. Cheongyang	6.6±0.2	2.7±0.2	2.0±0.2	1.3±0.1	2.2±0.2	0.6±0.1	3.5±0.2	43.3±1.2	17.8±0.6	25.5±1.7	41.2	15D
Mt. Chaejeong	7.6±1.1	2.6±0.2	2.7±0.5	1.0±0.1	2.1±0.2	0.7±0.1	3.2±0.1	51.0±3.0	23.5±13.5	27.5±10.5	44.7	15D
Mt. Deogyu	7.5±0.4	2.5±0.1	2.3±0.1	1.1±0.1	2.2±0.1	0.7±0.1	3.3±0.1	42.3±4.6	8.3±2.3	34.0±4.5	19.9	15D
Mt. Gariwang	7.0±0.4	3.2±0.1	2.9±0.2	1.1±0.1	2.9±0.2	0.8±0.1	3.6±0.2	49.0±6.0	18.0±5.0	31.0±1.0	36.0	15D
Mt. Gaya	7.4±0.4	2.8±0.1	2.4±0.2	1.2±0.1	2.2±0.2	1.0±0.1	2.2±0.2	66.0±7.6	27.3±6.9	38.8±9.8	43.0	15D
Mt. Gyebang	6.7±0.7	2.8±0.1	2.1±0.1	1.3±0.1	2.6±0.3	1.0±0.1	2.6±0.2	30.5±0.5	4.0±0.0	26.5±0.5	13.1	15D
Mt. Hambaek	5.2±0.9	2.2±0.2	1.8±0.1	1.2±0.1	2.3±0.2	0.9±0.2	2.6±0.2	27.0±5.7	2.7±2.2	27.0±4.4	9.1	15D
Mt. Jiri	7.5±1.1	2.5±0.2	2.3±0.3	1.1±0.1	2.0±0.1	0.8±0.1	2.6±0.3	40.0±3.8	16.7±5.1	23.3±3.4	39.4	15D
Mt. Mindung	10.0±0.8	3.0±0.1	2.9±0.1	1.0±0.0	3.6±0.3	1.2±0.1	3.0±0.1	55.5±12.5	20.0±0.0	23.0±0.0	46.5	15D
Mt. Naejang	6.0±0.5	2.4±0.2	1.8±0.2	1.4±0.0	2.8±0.1	0.9±0.1	2.8±0.2	54.0±3.4	28.0±4.4	26.0±6.2	51.9	15D
Mt. Odae	8.6±0.5	2.7±0.1	2.6±0.1	1.0±0.1	2.2±0.1	0.8±0.1	2.6±0.1	43.7±1.2	1.0±1.0	42.0±2.0	2.3	15D
Mt. Seorak	8.1±0.7	2.8±0.2	2.5±0.3	1.1±0.1	2.3±0.1	0.8±0.1	3.0±0.3	48.2±12.4	28.2±6.3	29.6±8.3	48.4	15D
Mt. Sobaek	7.7±0.2	2.6±0.1	2.4±0.1	1.1±0.1	1.9±0.2	0.7±0.0	2.8±0.3	43.8±2.5	19.0±5.6	24.8±5.0	42.3	15D
Mt. Songni	8.0±0.5	3.3±0.2	2.6±0.2	1.3±0.1	2.9±0.2	1.0±0.1	2.9±0.3	41.0±6.4	12.0±4.1	29.0±5.0	25.0	15D
Average	7.3±0.6	2.7±0.2	2.3±0.2	1.2±0.1	2.4±0.2	0.8±0.1	3.0±0.2	45.0±4.9	16.4±3.7	28.9±4.2	34.2	15D

[Z] Mean ± standard error.
[Y] Color indicated by RHS color chart number.

Fig. 3. Leaf morphology and mosaic of individuals of *L. tsingtauense* found in Korea. A: mosaic type, B: without mosaic

diameter of the stem did not gradually decrease going upwards and instead, the upper portion of the stem leveling from the verticillate leaves showed a drastic thinning. Several plants with protrusions on stems above the verticillate leaves and protrusions were found in 81% of habitats examined (Fig. 4). Stem color was RHS #144A, in shade of green; some entities showed shades of purple at the soil surface or pedicel. Observing that the stem or pedicel showing shades of purple were found in areas with extended light exposure, it is assumed that anthocyanin was produced. Rhizomes were observed in most habitats, but almost no rhizomes were observed in Mount Cheongyang and those detected was extremely marginal.

Characteristics of bulbs

The morphological characteristics of bulbs are shown in Tab. 5. The average circumference of bulb was 7.3 cm and width was 2.3 cm. The height and width ratio of the bulb was approximately 1.2 having shape of long oval. The ramentum was light yellow all around; the base was dark in color, with the color becoming lighter towards the upper regions (Fig. 5). The form of the ramentum was long with a pointy end and cohesiveness was weak. In all habitats, nodes were present in the ramentum (Fig. 5). Nodes were found at a frequency of 2.5% at Mount Odae and 57.4% at Chung San Island, but the average ratio of nodes in ramentum was 37%, which did not exceed 50%.

Discussion

Habitat has strong effects on the morphological characteristics of *Lilium* that suggests that habitats contribute differently to ecological diversification. Geographical variation in morphological characteristics reveals phenotype modifications to environmental conditions and evolutionary pattern of plant population and species and specifies the local regional deviations in environmental conditions (Ellison *et al*., 2004; Du *et al*. 2014). Specifically, in this study, we hypothesized that environmental gradients and ecological conditions in the Korean Peninsula resulted in correlated variations to plant morphological characters.

In this study, we demonstrated variations pattern in Korean wheel lilies morphology in different geographic locations. A characteristic change in lily inflorescence depending on the number of flowers was observed that are quite similar to the reports of Jeong and Kim (1991) as they mentioned that most of the naturally occurring lilies, including Korean wheel lilies, have an unpleasant smell. However, most of the samples in this current study did not emit any fragrance, thus, showing discrepancies from the results shown by Jeong and Kim (1991). As observed in Korean wheel lilies, petal width and number of flower spots varied within and among regions. However, the shape of the petals was oval to oblong or actinomorphic, flower color was

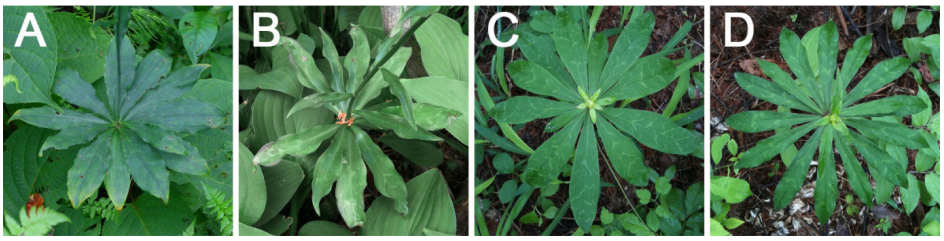

Fig. 4. Whorled-leaf variation of *L. tsingtauense* found in Korea; A) wide Corrugated; B) narrow corrugated; C) wide plane; D) narrow plane

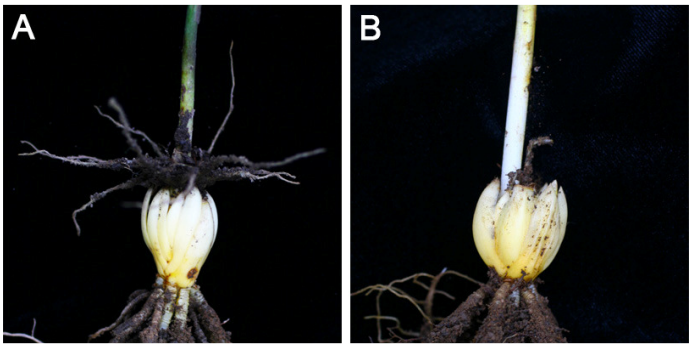

Fig. 5 Photograph of stem roots showing individual plant developed A: with stem roots, B: without stem roots

orange with luster on the petals having flower's direction upwards.

These features are considered as distinct characteristics of Korean wheel lilies (Lim, 2013). Anderson and co-worker also observed genetic differences in Easter lily 'Nellie White' growing in different locations and reported that the absence of meiotic sieve (Muller's ratchet) can be one of reasons for these mutational differences (Anderson *et al*., 2010).

In a previous study, shapes of 11 naturally growing species in South Korea were investigated and reported that the length and width ratio of the Korean wheel lily petals were within the range of 3.0-3.4 and were oval (Kim and Lee, 1990). However, the present study showed that the ratio was higher than 3.6 and the petals were oblong. These discrepancies may be attributable to the fact that Kim and Lee (1992) observed Korean wheel lilies in a few regions, whereas the current study examined lilies in a larger number of regions. The petal and calyx length and width ratio were 3.2 and 4.2, confirming that petals are much wider, as previously reported by Kim and Lee (1990). The ecological conditions including climatic gradients can be the key factor contributing to such variations, and differences in the morphological characteristics (Thompson, 1991; Hodgins and Barrett, 2008). Also, the spontaneous production unreduced gametes can also cause the variations in plants which need to be further exploit for their efficient utilization in breeding (Younis *et al*., 2014). Jeong and Kim (1991) previously reported that few entities of Korean wheel lilies with 2-3 tiers of verticillate leaves were found in Goesan and Mount Bulgap in Yeonggwang. The place where Korean wheel lilies with 2-3 tiers of verticillate leaves were found was photo environment satisfactory with the co-existence of herbaceous vegetation rather than an arbor. Therefore, it is assumed that Korean wheel lilies are capable of about 2-3 tiers of verticillate leaves when favorable conditions of temperature, humidity, and soil conditions, are present and under sufficient photo environment to give nutritive condition to the plant body. According to the inspection results of morphological characteristics of leaves, Korean wheel lilies showed one tier of verticillate leaves, as previously described (Kim and Lee, 1990; Jeong *et al*., 2002). However, the shapes of the leaves were diverse, similar to that of flower petals and this may be attributable to the fact that Korean wheel lilies are the most primitive lilies (Kim and Lee, 1990) and they continue to evolve. Morphological features such as leaf shape are controlled genetically, but local environmental conditions can affect greatly their development (Schlichting and Pigliucci, 1998).

The occurrence of verticillate leaves at the upper portion of the plant may be an ecological adaptation to receive maximum sunlight because Korean wheel lilies habitats are shady due to shielding of light from deciduous trees, shrubs, and other trees (Jeong *et al*., 1991; Lim, 2013). According to Jeong and Kim (1991), rhizomes were found in all lilies when forms of lilies were observed all around the country and there are cases where rhizomes were not found in Kochang lily. According to the current study, Korean wheel lilies growing in Mount Cheongyang did not have rhizomes and it appears to be that further research with Kochang lilies is needed to determine whether this is influenced ecological changes due to habitation or evolution.

Protrusions on stems of Korean wheel lilies have not been reported until now and this report is the first to report on this morphological characteristic. It appears that it can be used as a main index to classify Korean wheel lilies. However, further detailed research on its occurrence in Kochang lilies of the Martagon section and Hanson lilies is warranted, as well as its significance to taxonomic classifications and evolution.

The ramentum node ratios not only varied within each habitat, but also within the same region and ramentum inside and outside of the bulb. Therefore, it appears that moisture, temperature, and other environmental condition or

plant age, nutritive state, and other factors affect the formation of the ramentum and further detailed research is thus necessary. Jeong and Kim (1991) reported that Kochang lilies and Korean wheel lilies showed major differences from other naturally growing lilies, especially in terms of the ramentum nodes. Lee (1990) considered that the Korean wheel lilies are the most primitive among naturally growing lilies in Korea and Korean wheel lilies evolved into the Hanson lilies. Ramentum nodes might play a role in the evolution of lilies.

This research showed that clear morphological classification standards for Korean wheel lilies are difficult to establish due to extreme variations among regions or within the same habitat. However, it is assumed that common morphological characteristics of Korean wheel lilies include actinomorphic flowers, blossoming in the upward direction, luster on petals, patterns on young leaves, protrusions on stem above verticillate leaves, bulb form and color, and ramentum nodes.

Conclusion

The association between distribution pattern and geographic conditions may provide baseline evidence to evaluate the effect of climate change on vegetation (Samfira *et al*., 2010; Jugrana, *et al*., 2013). It is much needed to develop strategies for the protection and conservation of lily germplasm through evaluating *Lilium* resources for its efficient utilization and exploitation. It is also essential to increase clonal integrity within important floriculture plants to ensure minimum genetic differences.

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