Pak. J. Bot., 50(2): 589-598, 2018.

INVESTIGATION OF THE WILD *LILIUM* RESOURCES NATIVE TO MIDWESTERN CHINA

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Abstract

Lilium is a genus with 110 species globally. Among them, 55 species are found only in China, making this region a significant distribution zone. The *Lilium* species native to Midwestern China, including seven Provinces: Gansu, Shaanxi, Sichuan, Hubei, Henan, Chongqing and Yunnan, have been investigated in this study for their species categorization and morphological characterization. 16 species and 3 variants were involved in the survey: *L. lancifolium*, *L. leucanthum*, *L. brownii*, *L. duchartrei*, *L. pumilum*, *L. davidii*, *L. fargesii*, *L. regale*, *L. tenuifolium*, *L. papilliferum*, *L. sargentiae*, *L. lophophorum*, *L. sulphureum*, *L. nepalense*, *L. amoenum*, *L. taliense*, *L. brownii* var. *viridulum*, *L. leucanthum* var. *centifolium* and *L. bakerianum* var. *delavayi*. Evaluation of their botanical characteristics was then conducted. All the collected germplasm of *Lilium* was investigated by using the analytic hierarchy process (AHP) established on 15 indicators regarding ornamental value, exploitation potential and ecological adaptability. The result showed that *L. sulphureum* performed the highest ornamental value. *L. regale* performed the highest exploitation potential. *L. lancifolium* performed the highest ecological adaptability. *L. regale* was found as the most suitable species for sustained utilization because of its utmost AHP value. Further, *L. sulphureum*, *L. lancifolium*, *L. sargentiae* and *L. leucanthum* exhibited outstanding features for exploitation compared to the other tested species.

Key words: AHP, Classification, Evaluation, Wild *Lilium*.

Introduction

The genus *Lilium*, a perennial bulb flower belonging to the Liliaceae (Long *et al.*, 1999; Shimizu, 1987), possessing great ornamental (Tang *et al.*, 2017), edible (Jin *et al.*, 2012) and medicinal (Tong, 2009; Man and Sher, 2011) values, is very noticeable in the horticulture field globally (Lim *et al.*, 2008). The genus *Lilium*, including approximately 110 species, is distributed from subtropical areas to the coldest parts of the northern hemisphere including Europe, Asia and North America (McRae, 1998; Liang and Tamura, 2000). China is believed as an important distribution region of *Lilium* globally, having about 55 species and 32 variants (Liang and Tamura, 2000; Du *et al.*, 2014). Such rich *Lilium* germplasm made great contribution to the development of *Asiatic hybrids*, *Longiflorum*, and *Oriental hybrids* (Lim *et al.*, 2008). Currently Southwestern China, Northeastern China, and Northwestern China are considered as main areas with *Lilium* resources in China.

Specifically, Southwestern China is an imperative and also the largest distribution region of *Lilium* species, including provinces of Guizhou, Sichuan, Chongqing, Yunnan and Tibet, with about 36 species or variants among which 27 species are found only in Yunnan province (Wang and Tang, 1980; Peng, 2002; Bao *et al.*, 2004; Wu *et al.*, 2006; Tang *et al.*, 2010; Zhou *et al.*, 2012). Another distribution area, Northeastern China, which mainly covers 3 provinces: Heilongjiang, Jilin and Liaoning, has 9 species or variants (Rong *et al.*, 2011). As for Northwestern China mainly refering to Shaanxi, Gansu and their adjacent area, about 14 species or variants have been found (Zhao *et al.*, 2000; Che *et al.*, 2008).

However, Midwestern China has not been sufficiently studied yet. This area covers seven provinces, including Gansu, Shaanxi, Sichuan, Hubei, Henan, Chongqing and Yunnan, located between latitude 24°47′ ~ 34°21′ N and longitude 111°53′ ~ 100°02′ E, with temperate and subtropical climate (Zhu *et al.*, 2010). The topography in this area is varied and complicated. Although previous studies have already been conducted to investigate genus *Lilium* fragmentarily in Midwestern China (Zhao *et al.*, 2000; Bao *et al.*, 2004; Wu *et al.*, 2006; Che *et al.*, 2008; Tang *et al.*, 2010; Zhou *et al.*, 2012), the wild *Lilium* species involved were very limited. Thus a systematic study on wild *Lilium* germplasm in this region is meaningfully necessary.

Generally *Lilium* is widely known for its great ornamental value (Shimizu *et al.*, 1987). When it comes to overall potential for landscape exploitation, however, many other factors besides beauty must be taken to determination together such as altitude distribution, habitat types and ecological adaptability. Hence, a comprehensive evaluation system for the resource assessment on this genus is indispensable indeed. To establish such a system, the analytic hierarchy process (AHP) method was applied to the work (Saaty, 1980), which is considered as one of the most effective decision-making tools especially when best alternatives are needed to be selected (Coyle, 2004). With both qualitative and quantitative criteria applied to evaluation, AHP method usually offers a more effective, feasible and reliable result than other methods do (Sarangthem *et al.*, 2013). In recent years, AHP has widely been practiced for evaluation of different cultivars (Chen *et al.*, 2004; Fen *et al.*, 2005) and wild species (Rong *et al.*, 2011; Sarangthem *et al.*, 2013; Du *et al.*, 2014; Jia *et al.*, 2014).

The present study was carried out with the objectives to investigate and highlight the wild *Lilium* resources native to Midwestern China, so as to lay a scientific foundation for conservation and exploitation.

Materials and Methods

Collection of germplasm: A total of 147 accessions of *Lilium* from diverse habitats were collected during June to August in 2011~2013, by investigating all the 55 counties of Midwestern China. Complete information of the entire wild *Lillium* germplasm including their number, sites and populations is presented in Table 1. The specific distribution is presented in the map (Fig. 1). To make this map, GPS data was used with the help of software program MapInfo Professional.

Identification: Specimens were examined at the Herbarium, Institute of Botany, Chinese Academy of Sciences (Liang and Tamura, 2000). All the botanical characters were studied systematically and categorized accordingly. The bulbs were well-kept in the germplasm nursery at College of Landscape Architecture, Northwest A&F University. All the collected germplasm was assessed with analytic hierarchy process (AHP) (Rong *et al.*, 2011; Sarangthem *et al.*, 2013), and the AHP analysis was carried out by using Yaahp v. 6. 0 software (Foreology Software Ltd. Beijing, China 2012).

Evaluation

Step 1: During blossom (2013), for each species, ten plants were selected arbitrarily for morphological characteristics data (Ronaldo *et al.*, 2012). 15 alternatives (P1-P15) were studied under three main criteria shown in Fig. 2. The characteristics below ornamental value (C1) include flower color, flower shape, flower gesture, flower diameter, fragrance, florescence, flower quantity, plant type and pedicel length. As for utilization potential (C2), 3 alternatives including stress resistance, endangered status and exploitation degree were studied. The third one is ecological adaptability (C3), below which 3 alternatives were listed too: survival rate, distribution range and reproductive capacity (Fig. 2).

Step 2: The nine-point preference scale of Saaty, (2008) was used as the fundamental scale for pairwise comparisons of all the criteria. If the criterion was preferred less than one another, the reciprocal of the preference score would be allocated. The reciprocals produce the property that is $(a_{i,j})(a_{j,i})=1$, where $a_{i,j}$ shows the preference score of criterion i to criterion and j, $a_{j,i}$ shows preference score of criterion j to criterion i, and $a_{j,i} = 1/a_{i,j}$ (Saaty, 2008).

Step 3: The eigenvalue method was used to compute the weights of the decision elements. In the pairwise assessment of more than two objects, there is a usual impending for intransitivity, and AHP is a very consistent method. The consistency ratio 'CR' (ratio of 'CI' to 'RI' for the same-order matrix) describes the correctness of comparisons. Usually, 'CR value' less than 0.10 is suitable. The first pointer of result correctness of the pairwise comparisons is 'CI' = $(\lambda max-n)/(n-1)$, where λmax shows the maximum principal eigenvalue of the comparison matrix. The consistency indices of arbitrarily produced reciprocal matrices from the scale 1-9 are termed as the random indices, RI (Saaty, 2008).

Step 4: The marking standards (1-7) were established based on the criteria (C1, C2, C3), scoring accordingly. Then the total score was calculated.

Step 5: 19 *Lilium* species were graded based on the 3 indices mentioned above.

Table 1. The species, no. of accessions and sites of the genus *Lilium* resources collected in Midwestern China from 2011 to 2013.

Species	No. of Accessions	Sites (No. of accessions)
L. lancifolium	28	Baoji (2), Xi'an (1), Ankang (6), Hanzhong (8), Shangluo (2), Guanyuan (1), Bazhong (1), Aba (1), Shiyan (2), Yichang (1), Sanmenxia (1), Chongqing (1), Dali (1)
L. leucanthum	30	Baoji (2), Ankang (8), Hanzhong (9), Shangluo (1), Guanyuan (3), Bazhong (1), Shiyan (2), Yichang (1), Gannan (2), Chongqing (1)
L. brownii	26	Baoji (2), Xi'an (1), Ankang (5), Hanzhong (7), Shangluo (4), Guanyuan (2), Shiyan (2), Yichang (1), Shennongjia (2)
L. duchartrei	5	Aba (1), Gannan (2), Ganzi(1), Ya'an(1)
L. pumilum	13	Baoji (1), Hanzhong (2), Shangluo (5), Shiyan (1), Gannan (2), Longnan(1), Sanmenxia (1)
L. davidii	13	Baoji (3), Ankang (2), Shangluo (1), Hanzhong (1), Xi'an (1), Aba (1), Ganzi (2), Lijiang (1), Kunming (1)
L. brownii var. *viridulum*	9	Baoji (1), Xi'an (1), Ankang (1), Hanzhong (2), Shiyan (1), Yichang (1), Shennongjia (2)
L. fargesii	4	Baoji (2), Ankang (2)
L. regale	1	Aba (1)
L. leucanthum var. *centifolium*	4	Shangluo (1), Hanzhong (2), Gannan (1)
L. tenuifolium	1	Baoji (1)
L. papilliferum	1	Lijiang (1)
L. sargentiae	1	Ya'an (1)
L. lophophorum	1	Ankang (1)
L. sulphureum	2	Ganzi (1), Dali (1)
L. bakerianum var. *delavayi*	1	Lijiang (1)
L. nepalense	5	Lijiang (3), Dali (2)
L. amoenum	1	Kunming (1)
L. taliense	1	Lijiang (1)
Total	147	

Fig. 1. Collection sites of *Lilium* species native to Midwestern China.

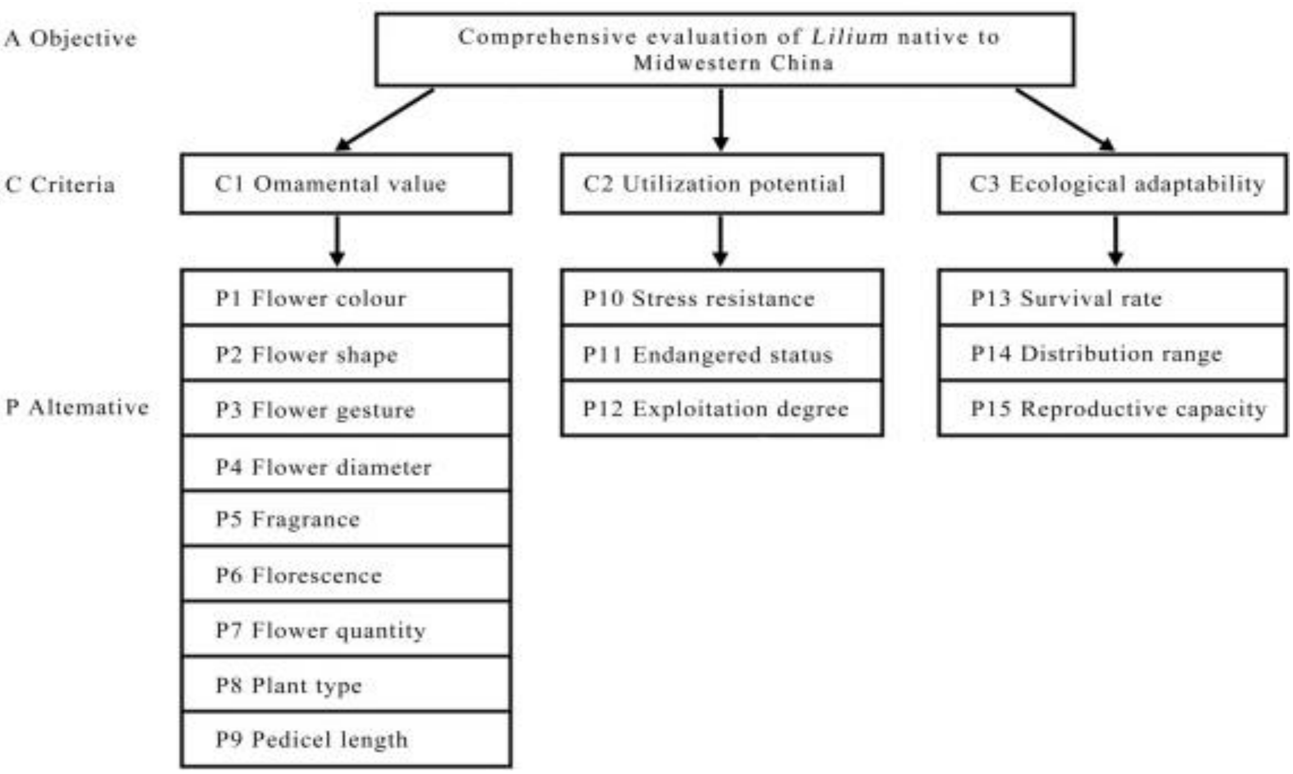

Fig. 2. Hierarchies in evaluation models of the genus *Lilium* native to Midwestern China.

Fig. 3. Flowers of *Lilium* species native to Midwestern China. a *L. lancifolium*, b *L. leucanthum*, c *L. brownie*, d *L. duchartrei*, e *L. pumilum*, f *L. davidii*, g *L. brownii var. viridulum*, h *L. fargesii*, i *L. regale*, j *L. leucanthum* var. *centifolium*, k *L. tenuifolium*, l *L. papilliferum*, m *L. sargentiae*, n *L. lophophorum*, o *L. sulphureum*, p *L. bakerianum* var. *delavayi*, q *L. nepalense*, r *L. amoenum*, s *L. taliense.*

Results

Distribution of Lilium species in Midwestern China: The accessions, *L. lancifolium*, *L. leucanthum*, *L. brownii*, *L. duchartrei*, *L. pumilum*, *L. davidii*, *L. fargesii*, *L. regale*, *L. tenuifolium*, *L. papilliferum*, *L. sargentiae*, *L. lophophorum*, *L. sulphureum*, *L. nepalense*, *L. amoenum*, *L. taliense*, *L. brownii* var. *viridulum*, *L. leucanthum* var. *centifolium* and *L. bakerianum* var. *delavayi*, were identified and classified into sixteen species and three variants based on the morphological characteristics (Fig. 3).

Main botanical characteristics: The botanical characteristics of 16 species and 3 variants have been systematically described (Table 2). Furthermore, the detailed analyses of these botanical characteristics are as follows.

Flower shape: The flowers of *L. lancifolium*, *L. duchartrei*, *L. pumilum*, *L. davidii*, *L. fargesii*, *L. tenuifolium*, *L. papilliferum*, *L. nepalense* and *L. taliense* were in the shape of turk's-cap type. The flowers of *L. leucanthum*, *L. brownii*, *L. regale*, *L. sargentiae*, *L. sulphureum*, *L. brownii* var. *viridulum* and *L. leucanthum* var. *centifolium* were in the shape of trumpet type. *L. bakerianum* var. *delavayi* and *L. amoenum* owned the campanulate flower. Only *L. lophophorum*'s flower was like sphere.

Flower color: *L. duchartrei*, *L. taliense*, *L. brownii*, *L. brownii* var. *viridulum*, *L. sulphureum L. sargentiae*, *L. leucanthum*, *L. leucanthum* var. *centifolium* and *L. regale* showed white petals. The flowers of *L. pumilum*, *L. tenuifolium*, *L. lancifolium* and *L. davidii* were orange-red. *L. nepalense* and *L. bakerianum* var. *delavayi* possessed green-yellow floral tissues, while *L. lophophorum*, *L. papilliferum*, *L. fargesii* and *L. amoenum* had different colors from one another, the flowers of which were in yellow, purple, viridis and rose red respectively.

Table 2. Botanical characteristics of the *Lilium* accessions collected from Midwestern China.

Species	Bulb	Stem	Leaf	Flower
L. lancifolium	White; big; spherical with broad, thick, lanceolate scales	148.3 cm; stiff; ribbed; dense white hairs; dark-purple bulbils in the axil	Lanceolate; white hairs; dense	Nodding; orange; purple spot; reflexed; dense white hairs
L. leucanthum	Purple or yellow; big; spherical with lanceolate scales	131.5 cm; stiff	Lanceolate; dense	Oblique upward; light fragrance; white; trumpet type
L. brownii	White; big; spherical with lanceolate scales	112.8 cm; glabrous	Lanceolate	Horizontal; sweet aroma; white; trumpet type
L. duchartrei	White; small; spherical with round scales	80.6 cm; brown; few white hairs; with rhizome	Lanceolate	Nodding; sweet aroma; white, with purple spot; reflexed
L. pumilum	White; small; conical with round; thin scales	63.8 cm; few white hairs	Narrow	Nodding; light fragrance; red; reflexed
L. davidii	White; small; conical with lanceolate scales	114.8 cm; brown; dense white hairs	Narrow; white hairs	Nodding; orange, with purple spot; white hairs
L. brownii var. *viridulum*	White; big; spherical with lanceolate scales	82 cm; glabrous	Lanceolate	Horizontal; sweet aroma; white; trumpet type
L. fargesii	White; small; conical with lanceolate; thin scales	54.6 cm; viridis; salient spot; few white hairs	Narrow; viridis	Nodding; sweet aroma; green, with brown spot; reflexed
L. regale	Black; conical with lanceolate; thick scales	103.7 cm; stiff; brown	Narrow; dense	Oblique upward; flavorful scent; white; trumpet type
L. leucanthum var. *centifolium*	Purple; big; spherical with lanceolate scales	110.5 cm; stiff; with puce spot	Narrow	Oblique upward; light fragrance; white, with purple spot; trumpet type
L. tenuifolium	White; small; conical with round; thin scales	56.3 cm; dark green; few white hairs	Liner; dark green;small; dense	Nodding; light fragrance; dark red; reflexed
L. papilliferum	Milk white; small; spherical with small, ovate scales	35.0 cm; few white hairs	Lanceolate	Nodding; yeasty smell; purple; reflexed
L. sargentiae	Purple; big; spherical with lanceolate scales	160.6 cm; stiff; ribbed; green bulbils in the axil	Long lanceolate; dense	Oblique upward; bad smell; white; trumpet type
L. lophophorum	Tawny; small; conical with lanceolate; narrow scales	37.3 cm; glabrous	Oval; basal growth	Nodding; sweet aroma; yellow, with purple spot; campanulate
L. sulphureum	Black; big; spherical with broad, thick, lanceolate scales	117.4 cm; stiff; ribbed; green bulbils in the axil	Lanceolate; dense	Oblique upward; bad smell; white; trumpet type
L. bakerianum var. *delavayi*	Tawny; spherical with lanceolate scales	76.5 cm; greyish-green	Oval	Horizontal; green-yellow, with purple spot; campanulate
L. nepalense	Tawny; spherical with lanceolate scales	80.6 cm; purple	Lanceolate	Nodding; Light fragrance; green-yellow, with purple spot; reflexed
L. amoenum	White; small; conical with lanceolate scales	35.8 cm; purple brown	Oval	Nodding; Light fragrance; rose red; campanulate
L. taliense	White; small; spherical with lanceolate scales	93.4 cm; greyish-green	Lanceolate	Nodding; Light fragrance; white, with purple spot; reflexed

Color spot: Purple spots were observed on the whole petal inner side of *L. bakerianum* var. *delavayi* and *L. nepalense*, while they appeared on the whole petal outer side when it comes to *L. leucanthum* var. *centifolium* contrarily. Occasionally, purple spots also took place on the whole petal outer side of *L. brownii*. *L. leucanthum*, *L. regale* and *L. sulphureum* had light yellow halos on the inner side of their petals. *L. duchartrei*, *L. davidii*, *L. lancifolium*, *L. fargesii*, *L. papilliferum* and *L. lophophorum* displayed purple spots on the inner side of the petals. *L. taliense* had both light yellow halos and purple spots on the inner side of the petals, and had a purple line in the central groove of the tepals. *L. pumilum*, *L. tenuifolium*, *L. sargentiae*, *L. amoenum* and *L. brownii* var. *viridulum* didn't have any spots on their flowers.

Fragrance: *L. regale*'s corolla emitted a flavorful scent. The flowers of *L. brownii*, *L. duchartrei*, *L. brownii* var. *viridulum*, *L. lophophorum* and *L. fargesii* had a sweet aroma. The flowers of *L. leucanthum*, *L. pumilum*, *L. davidii*, *L. tenuifolium*, *L. nepalense*, *L. amoenum*, *L. taliense*, *L. leucanthum* var. *centifolium* and *L. bakerianum* var. *delavayi* had a light fragrance. However, inflorescence tissues of *L. lancifolium* didn't have any aromas. *L. papilliferum* smelt yeasty. *L. sulphureum* and *L. sargentiae* had a bad smell when blooming.

Number of petals: Commonly a single lily flower has six petals, but a special *L. sulphureum* plant was found to have a double-layer flower with 12 petals in total (Fig. 4), which could be steadily inherited. This case had never been discovered in other lily individuals before.

Bulbil: Every year, from May to June, bulbils take place in the axils of 3 species such as *L. lancifolium*, *L. sargentiae* and *L. sulphureum*, and fall off automatically in autumn. This feature greatly differed from the other species.

Leaf shape: The leaf shape of *L. lancifolium*, *L. brownii*, *L. duchartrei*, *L. taliense*, *L. nepalense*, *L. papilliferum* and *L. sulphureum* was lanceolate. *L. leucanthum*, *L. leucanthum* var. *centifolium* and *L. sargentiae* had leaves in the shape of long lanceolate. *L. lophophorum*, *L. bakerianum* var. *delavayi* and *L. amoenum* owned oval leaf shape. The leaf shape of *L. regale*, *L. pumilum*, *L. davidii* and *L. fargesii* was strip. *L. brownii* var. *viridulum*'s leaf shape was oblanceolate, looking like a spoon. *L. tenuifolium* had thread-like leaves.

Leaf texture: *L. lophophorum* owned fleshy leaves. *L. nepalense* and *L. bakerianum* var. *delavayi* owned leathery leaves. The other species all possessed membranous leaves.

Fig. 4. Double flower of *L. sulphureum*.

Evaluation: Pairwise comparisons were conducted by using the nine-point preference scale (Table 3). Judgement matrix and consistency check of the evaluation model was built in Table 4. Table 5 presents RI for matrices of order 'n'. The upper and lower rows show the order of the matrix (n) and the resultant 'RI' value of the random judgement respectively. The weights of criteria and consistency check were determined (Table 4). In the end, the combined weight of each index and the overall weight were calculated (Table 6).

The marking standards (1-7) were established and mentioned in Table 7. The nineteen *Lilium* species from Midwestern China were then classified accordingly and their overall value was assessed in Table 8. The rankings of collected germplasm of *Lilium* were calculated based on the 3 indices (Table 9).

Rank I: *L. regale*, *L. sulphureum*, *L. lancifolium*, *L. sargentiae* and *L. leucanthum* had high scores from 4.974 to 5.711, which indicated that they have excellent potentials for future development. All the five species in this class had great ornamental value. The highest score went to *L. regale* for its great resistance. In addition, extraordinary ecological adaptability was in possession of *L. lancifolium.*

Rank II: This class including *L. leucanthum* var. *centifolium*, *L. fargesii*, *L. davidii*, *L. tenuifolium*, *L. brownii* and *L. brownii* var. *viridulum*, had scores ranging from 4.294 to 4.769. *L. fargesii* owned green flowers, which is very rare among all the species. *L. leucanthum* var. *centifolium*, *L. brownii* and *L. brownii* var. *viridulum* had large trumpet-shaped flowers. In addition, *L. davidii* had a strong ecological adaptability.

Rank III: *L. pumilum, L. amoenum, L. lophophorum and L. bakerianum* var. *delavayi* were the subjects, in this class, scoring from 3.703 to 3.940. Among the 4, *L. amoenum*, with beautiful rose-red flowers, considered as an endangered species in Midwestern China, has been extremely rare and valuable these days.

Rank IV: *L. nepalense*, *L. taliense, L. duchartrei* and *L. papilliferum* receiving scores with a range of 2.612 to 3.302, were all evaluated as Class IV. With a narrow distribution range, these 4 species had small populations, poor ornamental value, insufficient utilization potential and inadequate ecological adaptability according to their relatively low scores. Though they didn't show great potentials for cultivation, the urgency of protecting them shouldn't be doubted as they are becoming rare due to an increasing decline.

Discussion

Distribution of *Lilium* genetic resources: Based on the geographical distribution of Midwestern China, the analysis showed clearly that *L. leucanthum* had the widest distribution range, usually inhabiting in shrubs, on cliffs or on hillsides. This species was only found in Southwestern China (Long *et al.*, 1999; Liang & Tamura, 2000; Du *et al.*, 2014). *L. lancifolium* with high adaptability, living in a variety of habitats such as shrub, rock seam, forest edge and riverside, was known as one of the most widespread species in China (Long *et al.*, 1999; Liang & Tamura, 2000; Du *et al.*, 2014), followed by *L. leucanthum*. *L. brownii* rank the third widespread species in China (Long *et al.*, 1999; Liang & Tamura, 2000; Du *et al.*, 2014). Other species, on the other hand, were not largely distributed, such as *L. regale*, *L. tenuifolium*, *L. sargentiae*, *L. lophophorum*, *L. papilliferum*, *L. amoenum*, *L. bakerianum* var. *delavayi* and *L. taliense*, which were restricted to small populations. Some species were even in danger, such as *L. amoenum*, *L. papilliferum* and *L. fargesii* (Wang and Xie, 2004). These 3 rare and endangered species, *L. amoenum*, *L. papilliferum* and *L. fargesii* (Wang and Xie, 2004) were also collected in this study.

Table 3. Explanation of the standard nine-point preference scoring system used for the AHP.

Preference score	Explanation of numerical preference score
1	Two attributes preferred equally
3	Judgement slightly favors one over the other
5	Judgement strongly favors one over the other
7	Judgement very strongly favors one over the other
9	Extreme preference of one attribute over the other
2, 4, 6, 8	Intermediate values, when compromise is needed
Reciprocal factors	When we compare i with j get bij, so when compare j with i must be bji=1/bij

Table 4. Judgment matrix and consistency check of evaluation model.

Model hierarchy	Judgment matrix											Consistency check
A-C	A	C1	C2	C3	W							λmax=3.004
	C1	1	3	5	0.648							CI=0.002
	C2	1/3	1	2	0.230							RI=0.580
	C3	1/5	1/2	1	0.122							CR=0.003＜0.1
C1–P	C1	P1	P2	P3	P4	P5	P6	P7	P8	P9	W	λmax=9.060
	P1	1	2	2	2	3	3	5	7	9	0.260	CI=0.007
	P2	1/2	1	1	1	2	2	3	5	7	0.155	RI=1.450
	P3	1/2	1	1	1	2	2	3	5	7	0.155	CR=0.005＜0.1
	P4	1/2	1	1	1	2	2	3	5	7	0.155	
	P5	1/3	1/2	1/2	1/2	1	1	2	3	4	0.085	
	P6	1/3	1/2	1/2	1/2	1	1	2	3	4	0.085	
	P7	1/5	1/3	1/3	1/3	1/2	1/2	1	2	3	0.052	
	P8	1/7	1/5	1/5	1/5	1/3	1/3	1/2	1	2	0.032	
	P9	1/9	1/7	1/7	1/7	1/4	1/4	1/3	1/2	1	0.021	
C2–P	C2	P10	P11	P12	W							λmax=3.000
	P10	1	3	9	0.692							CI=0.000
	P11	1/3	1	3	0.231							RI=0.580
	P12	1/9	1/3	1	0.077							CR=0.000＜0.1
C3–P	C3	P13	P14	P15	W							λmax=3.004
	P13	1	3	5	0.648							CI=0.002
	P14	1/3	1	2	0.230							RI=0.580
	P15	1/5	1/2	1	0.122							CR=0.003＜0.1

Table 5. RI value versus ‘n’.

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 6. Hierarchy P weight and integrated weight of 15 criteria.

Hierarchy C weight	Hierarchy P weight	Integrated weight
C1 0.648	P1 0.260	0.169
	P2 0.155	0.100
	P3 0.155	0.100
	P4 0.155	0.100
	P5 0.085	0.055
	P6 0.085	0.055
	P7 0.052	0.034
	P8 0.032	0.021
	P9 0.021	0.014
C2 0.230	P10 0.692	0.159
	P11 0.231	0.053
	P12 0.077	0.018
C3 0.122	P13 0.648	0.159
	P14 0.230	0.053
	P15 0.122	0.018
Total 1.000	3.000	1.000

Exploitation of *Lilium* genetic resources: Based on the comprehensive investigation of wild *Lilium* species from Midwestern China, one species *L. regale* showed the highest value for its pure trumpet-shaped flowers (Long *et al.*, 1999; Liang and Tamura 2000), strong resistance to virus (Van de Kasteele, 1974), and significant ecological adaptability (Sun *et al.*, 2016). Moreover, its long florescence and high percentage of fertile fruit made it a good parent for lily hybridization (Long *et al.*, 1999). *L. nepalense* showed the lowest value because of its small size and lower adaptability (its site was very restricted at high altitudes) , but it possessed leathery leaves and yellowish green flowers with distinct purple points (Liang & Tamura, 2000), proving that *L. nepalense* could be a great resource for cultivation of new flower colors (Long *et al.*, 1999).

L. pumilum, *L. amoenum*, *L. lophophorum*, *L. bakerianum* var. *delavayi*, *L. taliense*, *L. duchartrei* and *L. papilliferum* scored lower than the others because of their small height and feeble potency, which, however, did not necessarily mean these species were worthless. These species have great economic and decorative potential worth (Rong *et al.*, 2011; Du *et al.*, 2014), leading to a great need to preserve these species on priority basis. For instance, *L. lophophorum* had yellowish green flowers, in the shape of sphere, showing good breeding potential. *L. papilliferum* had good wet endurance, and obvious purple flowers (Peng, 2002; Wu *et al.*, 2006), which gave this species an advantage to breed colorful offsprings with resistance to humidty. *L. pumilum* had strong propagation abilities. *L. duchartrei* and *L. taliense* had white flowers and reflexed petals with distinct purple points. *L. amoenum* and *L. bakerianum* var. *delavayi* owning campanulate flowers with rose-red and greenish yellow colors respectively (Peng, 2002; Wu *et al.*, 2006), could be exploited for new ornamental breeds.

L. davidii, *L. fargesii*, *L. tenuifolium*, *L. lancifolium* and the species with trumpet-shaped flowers showed greater values. *L. davidii*, besides its great characteristics like orange flowers, strong propagation ability, and high stress resistance, was also widely used as a food ingredient (Long *et al.*, 1999; Munafo and Gianfagna, 2015). Although *L. fargesii* was small sized, it had rare green flowers (Du *et al.*, 2014), making it a good option for cultivating colorful flowered breeds. *L. tenuifolium* with erect red-colored flowers, was quite similar to *L. pumilum* in terms of their bulbs, stems, and flowers (Che *et al.*, 2008). Other sililarities of these 2 species were found as strong stem, adaptability, and viral resistance with a single difference of the leaf width. The only difference lied in the width of the leaf. *L. lancifolium* showed great value for its strong propagation ability and adaptability. *L. sulphureum*, *L. sargentiae*, *L. leucanthum*, *L. brownii*, *L. leucanthum* var. *centifolium* and *L. brownii* var. *viridulum*, shared similar features in terms of flowers, plants height, petals size, color, sweet aroma, stress resistance and adaptability.

Conservation of *Lilium* genetic resources: According to this study, we found that *Lilium* resources are in gradual deline especially for rare species like *L. amoenum*, *L. papilliferum* and *L. fargesii*. A widely believed fact is that, the worsening environment in wild *Lilium*'s habitats is a major reason for the germplasms' decrease, caused by natural forces and, however, mainly human activities (Long *et al.*, 1999). Despite of the urgency, only a few studies concerning investigation of *Lilium* resources in China have been conducted. These studies have proved a poor utilization efficiency of *Lilium* resources, with a rate of less than 50% (Du *et al.*, 2014). Yet no preservation organizations have been found in China (Rong *et al.*, 2011).

Therefore, it is high time to protect and preserve the *Lilium* resources in China. Methods to this severe problem are suggested as follows: (1) Relevant laws and policies should be established to protect natural habitats of *Lilium* particularly with priority to those rare species, and to regulate human behaviors (Van de Kasteele, 1974; Stanilova *et al.*, 1994). (2) Specialized departments and foundations need to be developed whose main responsibility is to protect the resources *ex situ* (Jin *et al.*, 2014) as what the Lily Species Preservation dedicates for. (3) Introducing and breeding new varieties of the genus becomes more essential than ever, which needs to be accelerated as much as possible. However, *Lilium* lives at low altitudes areas with high temperatures in summer, due to which this alpine is extremely hard to be introduced as a garden plant. Thus more studies on heat resistance and transgenic experiments should be conducted even though several published reports related to this field are already available for the future progress (Liu and Yang, 2011). (4) Another efficient approach for *Lilium* germplasms preservation and reproduction is to establish an in vitro tissue culture system. (5) Seeds acquirement, as the best and safest way to collect lily species, plays an important role in protecting *Lilium* resources (McRae, 1998), relying on a comprehensive understanding of their natural geographic distribution.

Table 7. Evaluation standard and points of 15 evaluation indicators.

Evaluation indicator	Point			
	7	5	3	1
Flower color	Purple, green, Rose-red	Yellow-green	Orange, red	white
F1ower shape	Funnel-shaped	Belled	Spherical	Reflexed
Flower gesture	Half-upwards	Outwards	Half-downwards	Downward
Flower diameter	＞10 cm	7-10 cm	5-7 cm	＜5cm
Fragrance	Aroma	Slightly aroma	Without aroma	Malodour
Florescence	＞20 day	15-20 day	10-15 day	＜10day
Flower quantity	＞5	3-5	1-3	≤1
Plant type	Vertical	Slightly vertical	Slanting	Lodging
Pedicel length	＞8 cm	6-8 cm	4-6 cm	＜4 cm
Stress resistance	Cold, heat, drought, water logging resistance	Three of four	Two of four	One of four
Endangered status	Critically endangered	Endangered	Vulnerable	Low-risk
Exploitation degree	Unexplored	Only for food and medicine	Rarely used for ornament and breeding	Widely used for ornamental and breeding
Survival rate	Survival rate＞90%	90≥Survival rate＞70%	70≥Survival rate＞50%	Survival rate≤50%
Distribution range	Distribution city＞16	16≥Distribution city＞8	10≥Distribution city＞1	Distribution city=1
Reproductive capacity	Sowing blastochoty, and cutting very easily	Two propagation method very easily	One propagation methods very easily	No propagation method very easily

Table 8. Points of different index for 19 *Lilium* species collected from Midwestern China.

Species	C1 Ornamental value criteria									C2 Utilization potential criteria			C3 Ecological adaptability criteria		
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
L. lancifolium	3.0	1.0	2.3	5.0	3.0	7.0	7.0	7.0	5.0	7.0	1.0	5.2	7.0	7.0	5.0
L. leucanthum	1.0	7.0	6.6	7.0	5.1	1.0	5.0	7.0	5.0	4.2	1.0	3.4	5.0	7.0	4.1
L. brownii	1.0	7.0	5.4	7.0	6.7	1.0	3.0	7.0	5.0	3.0	1.0	3.0	3.0	7.0	4.5
L. duchartrei	1.0	1.0	1.0	2.5	7.0	3.0	3.0	5.8	7.0	4.9	1.0	4.0	3.0	3.0	1.8
L. pumilum	3.0	1.0	1.6	1.8	4.8	3.0	5.0	4.1	3.0	6.8	1.0	1.0	5.0	5.0	3.0
L. davidii	3.0	1.0	2.2	3.0	3.0	7.0	7.0	2.8	7.0	6.4	1.0	1.0	7.0	5.0	3.0
L. brownii var. *viridulum*	1.0	7.0	4.8	7.0	7.0	1.0	3.0	7.0	1.0	3.0	3.0	4.6	3.0	5.0	4.5
L. fargesii	7.0	1.0	1.5	1.0	7.0	1.0	3.0	5.0	3.0	3.5	7.0	7.0	7.0	3.0	2.8
L. regale	1.0	7.0	6.7	7.0	7.0	3.0	3.0	7.0	7.0	7.0	3.0	2.6	7.0	1.0	5.0
L. leucanthum var. *centifolium*	1.0	7.0	6.5	7.0	5.3	1.0	3.0	7.0	5.0	3.8	3.0	5.5	5.0	3.0	3.8
L. tenuifolium	3.0	1.0	4.1	1.0	4.3	5.0	5.0	3.6	3.0	6.9	3.0	3.0	7.0	1.0	3.0
L. papilliferum	7.0	1.0	1.2	3.0	1.0	1.0	1.0	3.0	3.0	2.7	5.0	7.0	3.0	1.0	1.0
L. sargentiae	1.0	7.0	5.9	7.0	1.0	3.0	7.0	7.0	3.0	5.3	1.0	5.2	7.0	1.0	6.5
L. lophophorum	5.0	3.0	3.0	3.0	6.7	1.0	3.0	7.0	7.0	3.3	5.0	7.0	1.0	1.0	3.7
L. sulphureum	3.8	7.0	6.4	7.0	1.0	5.0	5.0	7.0	7.0	6.9	1.0	1.0	5.0	3.0	6.3
L. bakerianum var. *delavayi*	5.0	5.0	3.6	5.0	3.2	1.0	1.0	2.9	3.0	1.0	5.0	7.0	3.0	1.0	2.8
L. nepalense	5.0	1.0	1.5	1.0	5.3	3.0	3.0	1.5	3.0	1.0	3.0	5.0	1.0	3.0	3.3
L. amoenum	7.0	5.0	1.0	3.0	5.6	1.0	1.0	1.3	7.0	3.3	7.0	7.0	1.0	1.0	1.5
L. taliense	4.6	1.0	1.4	1.0	4.8	1.0	3.0	2.7	5.0	4.6	1.0	4.5	1.0	1.0	2.0

Table 9. Score and rank of 19 *Lilium* species native to Midwestern China.

Species	Ornamental value		Utilization potential		Ecological adaptability		Overall	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
L. lancifolium	2.342	II	1.260	I	1.574	I	5.176	I
L. leucanthum	2.952	I	0.782	III	1.240	II	4.974	I
L. brownii	2.852	II	0.584	IV	0.929	III	4.365	II
L. duchartrei	1.491	IV	0.904	III	0.668	IV	3.063	IV
L. pumilum	1.674	IV	1.152	II	1.114	III	3.940	III
L. davidii	2.072	III	1.089	II	1.432	I	4.593	II
L. brownii var. *viridulum*	2.752	II	0.719	III	0.823	III	4.294	II
L. fargesii	2.222	II	1.054	II	1.322	II	4.598	II
L. regale	3.136	I	1.319	I	1.256	II	5.711	I
L. leucanthum var. *centifolium*	2.885	II	0.862	III	1.022	III	4.769	II
L. tenuifolium	1.916	III	1.310	I	1.220	II	4.446	II
L. papilliferum	1.952	III	0.820	III	0.548	IV	3.320	IV
L. sargentiae	2.806	II	0.989	II	1.283	II	5.078	I
L. lophophorum	2.516	II	0.916	III	0.279	IV	3.711	III
L. sulphureum	3.427	I	1.168	II	1.067	III	5.662	I
L. bakerianum var. *delavayi*	2.573	II	0.550	IV	0.580	IV	3.703	III
L. nepalense	1.827	III	0.408	IV	0.377	IV	2.612	IV
L. amoenum	2.605	II	1.022	II	0.239	IV	3.866	III
L. taliense	1.665	IV	0.865	III	0.248	IV	2.778	IV

Conclusions

Our study of *Lillium* in Midwestern China involved 16 species and 3 varieties. Based on their morphological diversity features, significant variations take place among the samples. Some differences were also found within the same species (like flower color), which might be evidence to support a new discovery of natural varieties. The AHP method gives an idea of efficiently utilizing wild *Lilium* resources with sustainability. Both the distinctive magnificence of each species and their potential values for upcoming crossing should be considered. Searching novel genes from wild *Lilium* species to extend their genetic base is also a vital objective for exploitation of *Lilium* germplasm. Besides, we must spare no efforts to protect rare and endemic species such as *L. fargesii* and *L. papilliferum* as they are already in great danger. This research signifies work on partial flora but pulls consideration to the rich bio-resources that could form a groundwork for additional systematic interventions. Hence, more studies related to *Lilium* survival should be addressed in the future to cement this evaluation, regarding molecular, ecological and biochemical fields.

Acknowledgments

This study was funded by the project from National High-tech R&D Program (863 Program) (Project No. 2011AA1008). The authors thanks Si Guo-chen for his assistance in directing the research work. Further, we also appreciate Che Fei, Jin Lei, Guo Yu-long and Yan Lin-mao (College of Forestry, Northwest A&F University, China) for their kind help with our investigation of the germplasm. The staff of Forest Department of Shaanxi Province, China are also acknowledged for their great miscellaneous help.

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(Received for publication 21 March 2017)