ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Hortorum Cultus, 20(6) 2021, 29–44
https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2021.6.5

O R I G I N A L   P A P E R

Accepted: 4.01.2021

DISTRIBUTION, COLLECTION AND EVALUATION OF *Iris* SPECIES IN SOUTHWEST CHINA

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ABSTRACT

China is known as one of the most diverse centres of wild *Iris* resources in the world, there are 60 species, 13 varieties, and five forms distributed in southwest, northwest, and northeast China. The goal of this study was to describe the distribution, collection, and evaluation of *Iris* species collected in southwest China. Wild populations were identified and classified into 23 species, two varieties, and one form based on their morphological characteristics. We discovered some species with new distribution and characteristics. Furthermore, we also used the analytical hierarchy process (AHP) method with 16 indicator points to evaluate the collected *Iris* resources based on their ornamental value, utilization potential, and ecological adaptability. The results showed that *I. pseudacorus*, *I. delavayi*, *I. germanica*, *I. wilsonii*, *I. sibirica*, and *I. tectorum* had excellent ornamental characters and best suited for sustained exploitation. This research also provided a good theoretical guidance and an important reference value for the application of *Iris* plants in landscaping and provided suggestions for the conservation and utilization of wild *Iris* resources.

Key words: analytical hierarchy process, distribution, classification, *Iris*

INTRODUCTION

Iris, one of the largest genera in Iridaceae, has very high development potential as both an ornamental and medicinal. This genus consists of approximately 300 species worldwide that grow widely throughout the Northern Hemisphere. There are 60 species, 13 varieties, and five forms in China [Goldblatt 1990, Zhao 2005]. Great contributions on the investigation and collection of wild *Iris* have made in China during the last century [Zhao 1985], the resource and utilization of *Iris* in the parts of northwest, northeast, north, and east China have already been investigated [Yuan 1994, Shen et al. 2001, Lin et al. 2003, Huang 2003, Zhou 2003, Bu 2007, Mou et al. 2007, Yu et al. 2009]. However, limited investigations have been conducted in southwest China. Investigating wild *Iris* in southwest China was conducted from the late 1930s to early 1980s and the current status of this resource remains unclear. Moreover, only a small number of wild *Iris* species were collected. Since the environment and climate have changed a lot of China in the past century, it may influence the number and distribution of some species. Furthermore, wild flower resources not only have strong regional characteristics, high environmental adaptability, but also have high ornamental application value. Nevertheless, the ornamental characters and environmental adaptability of different wild flower plants are quite different, so it is necessary to select the species that are easy to be cultivated, have beautiful flowers and are suitable for landscaping materials. In order to further develop the development, conservation, breeding and application value of wild *Iris* resources, it is necessary to investigate the distribution

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location and quantity changes of wild *Iris* resources in southwest China and evaluate their ornamental value, environmental adaptability and application potential.

In recent years, the analytic hierarchy process (AHP), first proposed by Saaty [1980], is widely used to evaluate the value of cultivated varieties and wild species [Rong et al. 2011, Jia et al. 2014, Zheng et al. 2017]. In this study, the AHP method was employed to evaluate the ornamental value and potential for utilization of 51 typical populations in 23 species, two varieties, one form. The aims of the study are to: (1) investigate the distributions and collect the wild *Iris* species in southwest China, thus provide the specific data to better protect the germplasm resoureces; (2) use the AHP method to evaluate the ornamental value and potential utilization of *Iris*, and then put forward a good theoretical guidance for the application of wild *Iris* species in landscaping; and (3) provide suggestions for protecting and preserving *Iris* resources.

MATERIALS AND METHODS

In field investigation, a total of 51 typical populations belonging to 23 species, two varieties, and one form of *Iris* were collected from diverse habitats in southwest China from 2004 to 2019 (Tabs 1–2). We also collected some living plants, which were brought to the nursery at the College of Landscape Architecture, Sichuan Agricultural University for further breeding programs and ex situ conservation.

Sixteen important characteristics (Tab. 3) of flower colors, the extent of the flower show, inflorescence diameter, fragrance, florescence, flower quantity, plant height, plant type, foliage, resource quality, development level, regeneration capacity, stress resistance, distribution range, reproductive capacity, and survival rate from related documents were used as evaluation indicators in the AHP method [Rong et al. 2011, Jia et al. 2014, Zheng et al. 2017].

AHP evaluation

Step 1. The AHP model was constructed based on three layers in this study: objective (A) – comprehensive evaluation of *Iris* species; criteria (C) – ornamental value (C1), utilization potential (C2), and ecological adaptability (C3); alternative (P) – with 16 sub-criteria in total [ten sub-criteria (P1–P10) under C1, three sub-criteria (P11–P13) under C2, and three sub-criteria (P14–P16) under C3] (Fig. 1).

Step 2. To define the relative importance of each criterion, pairwise comparisons of all the requirements were performed. The fundamental scale for this analysis is shown in Table 4. If one criterion was preferred more than the comparison criterion, the reciprocal of the preference score was assigned. The use of reciprocals yields the property that $(a_{i,j})(a_{j,i}) = 1$, where $a_{i,j}$ is the preference score of criterion i to criterion j; $a_{j,i}$ is preference score of criterion j to criterion i; and $a_{i,j} = 1/a_{j,i}$ [Saaty 2008]. The judgment matrix and determination of consistency of the evaluation model is shown in Table 5.

Step 3. The weights of the decision elements were computed using the eigenvalue method. The consistency index (CI) is computed from the eigenvalue as CI = (λmax – n)/(n – 1). λmax denotes the maximum principal eigenvalue of the comparison matrix. The consistency indices of randomly generated reciprocal matrices from scale 1–9 are called the random indices (RI). The RI for matrices of the order are given in Table 6, with the first row of the table showing the order of the matrix (n), and the next row giving the corresponding 'RI' value. The ratio of 'CI' to 'RI' for the same order matrix is called the consistency ratio (CR), which defines the accuracy of the pairwise comparisons. As a general rule, a CR of 0.10 or less is considered acceptable. The weights of criteria and consistency check were calculated and shown in Table 5. The integrated weight was then calculated.

Step 4. The 1–5 marking standard was laid down according to ornamental value, utilization potential and ecological adaptability as shown in Table 7. The comprehensive evaluation results were shown in Table 8. The 23 species, 2 varieties, 1 form collected were then scored and their total value was evaluated, shown in Table 9. Table 10 showed the ranking of each of the species for the three indices as well as the overall ranks.

RESULTS

Distribution of *Iris* species in southwest China

The distribution range of *Iris* plants in southwest China is relatively wide. From the vertical distribution, it can be found from the elevation of 600 m

Table 1. The genus *Iris* resources collected in southwest China

Code	Species	Sources
Col	*I. collettii* Hook. f.	Kangding, Sichuan
Lac1	*I. lactea* Pall. var. *chinensis* (Fisc) Koidz	Wenchuan, Sichuan
Lac2	*I. lactea* Pall. var. *chinensis* (Fisch) Koidz	Mao County, Sichuan
Lac3	*I. lactea* Pall.	Mao County, Sichuan
Rut	*I. ruthenica* Ker-Gawl.	Kangding, Sichuan
Wil	*I. wilsonii* C.H. Wright	Kangding, Sichuan
For	*I. forrestii* Dykes	Xiaojin, Sichuan
Chr	*I. chrysographes* Dykes	Xiaojin, Sichuan
San	*I. sanguinea* Donn ex Horn.	Kangding, Sichuan
Tec1	*I. tectorum* Maxim.	Mao County, Sichuan
Tec2	*I. tectorum* Maxim.	Wenjiang, Sichuan
Tec3	*I. tectorum* Maxim.	Kangding, Sichuan
Tec4	*I. tectorum* Maxim.	Kangding, Sichuan
Tec5	*I. tectorum* Maxim.	Wenchuan, Sichuan
Tec6	*I. tectorum* Maxim.	Leshan, Sichuan
Tec7	*I. tectorum* Maxim.	Kangding, Sichuan
Tec8	*I. tectorum* Maxim.	Songpan, Sichuan
Tec9	*I. tectorum* Maxim.	Wenchuan, Sichuan
Tec10	*I. tectorum* Maxim.	Li County, Sichuan
Tec11	*I. tectorum* Maxim.	Maerkang, Sichuan
Tec12	*I. tectorum* Maxim.	Li County, Sichuan
Jap	*I. japonica* Thunb.	Dujiangyan, Sichuan
Con1	*I. confusa* Sealy	Dujiangyan, Sichuan
Con2	*I. confusa* Sealy	Weiyuan, Sichuan
Con3	*I. confusa* Sealy	Pengzhou, Sichuan
Con4	*I. confusa* Sealy	Qionglai, Sichuan
Con5	*I. confusa* Sealy	Luding, Sichuan
Con6	*I. confusa* Sealy	Neijiang, Sichuan
Con7	*I. confusa* Sealy	Yibing, Sichuan
Con8	*I. confusa* Sealy	Leshan, Sichuan
Con9	*I. confusa* Sealy	Chengdu, Sichuan
Con10	*I. confusa* Sealy	Ya'an, Sichuan
Con11	*I. confusa* Sealy	Ya'an, Sichuan
Gon1	*I. goniocarpa* Baker	Wenchuan, Sichuan
Gon2	*I. goniocarpa* Baker	Maoxian, Sichuan
Gon3	*I. goniocarpa* Baker	Zoige, Sichuan
Gon4	*I. cuniculiformis* Noltie & K.Y. Guan in Noltie	Maerkang, Sichuan
Wat1	*I. wattii* Baker	Luding, Sichuan
Wat2	*I. wattii* Baker	Chengdu, Sichuan
Pse	*I. pseudacorus* L.	Liangshan, Sichuan
Hal1	*I. halophila* Pall.	Zoige, Sichuan
Spe	*I. speculatrix* Hance.	Chongqin, Sichuan
Lep	*I. leptophylla* Lingelsheim	Wenchuan, Sichuan
Dec	*I. decora* Wall.	Luding, Sichuan
Jap	*I. japonica* f. *pallescens* P.L. Chiu et Y.T. Zhao	Leshan, Sichuan
Sic	*I. sichuanensis* Y.T. Zhao	Wenchuan, Sichuan
Son	*I. songarica* Schrenk	Hongyuan, Sichuan
Lac	*I. lactea* var. *chrysantha* Y.T. Zhao	Xiahe, Gansu
Sib	*I. sibirica* L.	Kunming, Yunnan
Ger	*I. germanica* L.	Kunming, Yunnan
Del	*I. delavayi* Mich.	Dali, Yunnan

Table 2. The geographical position of *Iris* investigation sites in southwest China

Code of population	Longitude	Latitude	Altitude	Habitat	Landform type	Soil type
Kangding KD1	30°02'	101°32'	4298 m	hillside brush	alpine area	alpine meadow soil
Kangding KD2	28°13'	102°37'	3948 m	hillside grassland	alpine area	alpine meadow soil
Kangding KD3	29°08’	102°03'	2760 m	hillside forest wasteland	mid-relief terrain	sandy soil
Kangding KD4	30°05'	101°97'	2550 m	roadside wasteland	mid-relief terrain	sandy soil
Kangding KD5	30°01'	101°14'	3657 m	hillside meadow	alpine area	brown soil and chao soil
Kangding KD6	31°22'	102°94'	4005 m	hillside shrub	alpine area	black soil
Wenchuan WC1	31°55'	103°45'	1375 m	hillside shrub	low-relief terrain	sandy soil
Wenchuan WC2	31°37'	103°34'	1413 m	hillside forest	low-relief terrain	brown soil
Wenchuan WC3	31°43'	103°60'	1346 m	the hillside wasteland	low-relief terrain	sandy soil
Wenchuan WC4	31°41'	103°62'	1395 m	hillside shrub	low-relief terrain	brown soil
Marxian MX	31°67'	103°89'	1580 m	hillside shrub	low-relief terrain	sandy soil
Xiaojin XJ	31°07'	102°74'	3277 m	forest edge grassland	alpine area	black soil
Chengdu CD	30°41'	103°49’	768 m	roadside wasteland	plain area	paddy soil
Songpan SP	32°26'	102°78'	3245 m	road slope protection	alpine area	black soil
Lixian LX1	31°82'	103°06'	2704 m	roadside grassland	mid-relief terrain	black soil
Lixian LX2	31°12'	103°18'	3211 m	hillside grassland	alpine area	black soil
Lixian LX3	31°08'	103°13'	3649 m	hillside meadow	alpine area	black soil
Maerkang MEK	31°98'	102°10'	2535 m	hillside forest	mid-relief terrain	brown soil
Dujiangyan DJY	31°00'	120°52'	2034 m	hillside forest	low-relief terrain	brown soil
Weiyuan WY	29°23'	104°46'	625 m	roadside wasteland	plain area	brown soil
Pengzhou PZ	30°62'	103°24'	1362 m	hillside forest	hilly area	brown soil
Qionglai QL	30°35'	103°47'	1300 m	bamboo forest	hilly area	dark brown soil
Moxi MX	30°08'	102°28'	2920 m	bamboo forest	mid-relief terrain	brown soil
Neijiang NJ	29°59'	105°04'	330 m	roadside wasteland	plain area	paddy soil
Yibin YB	28°30'	105°03'	987 m	bamboo forest	hilly area	brown soil
Ya'an YA1	29°53'	103°01'	700 m	hillside forest	low-relief terrain	brown soil
Ya'an YA2	29°61'	103°10'	1385 m	hillside forest	low-relief terrain	humus soil
Zoige REG	33°67'	102°99'	3969 m	grassland	alpine area	meadow soil
Luding LD	29°91'	102°05'	2850 m	hillside forest	mid-relief terrain	black soil
Dayi DL	30°77'	103°53'	2440 m	hillside forest	mid-relief terrain	drab soil
Yanyuan YY	27°42'	101°51'	2563 m	hillside brush	mid-relief terrain	sandy soil
Chongqin CQ1	28°43'	106°9'	631 m	hillside forest	low-relief terrain	sandy soil
Chongqin CQ2	29°81'	107°11'	1078 m	hillside forest	low-relief terrain	sandy soil
Chongqin CQ3	29°02'	107°11'	1419 m	hillside meadow	low-relief terrain	sandy soil
Chongqin CQ4	29°32'	108°38'	655 m	hillside meadow	low-relief terrain	sandy soil
Chongqin CQ5	29°46'	107°47'	1206 m	hillside forest	low-relief terrain	sandy soil
Mianning MN1	28°53'	102°17'	2452 m	hillside forest	mid-relief terrain	sandy soil
Mianning MN2	28°53'	102°17'	2452 m	hillside shrub	mid-relief terrain	sandy soil
Leshan LS1	29°11'	103°52'	997 m	roadside trees	hilly area	brown soil
Leshan LS2	27°42’	103°21’	922 m	hillside forest	low-relief terrain	alpine meadow soil
Leshan LS3	29°34'	103°21'	1169 m	hillside forest	low-relief terrain	alpine meadow soil
Luding LD1	29°38'	102°08'	2014 m	hillside forest	mid-relief terrain	alpine meadow soil
Luding LD2	29°36'	102°04'	1976 m	hillside forest	low-relief terrain	alpine meadow soil
Luding LD3	29°36'	102°04'	1782 m	hillside forest	low-relief terrain	alpine meadow soil
Hanyuan HY1	29°21'	102°48'	1972 m	hillside forest	low-relief terrain	paddy soil
Hanyuan HY2	29°22'	102°48'	1790 m	bamboo forest	low-relief terrain	paddy soil
Shimian SM	29°13'	102°14'	1387 m	hillside meadow	low-relief terrain	paddy soil
Li Country LX4	31°25'	103°12'	1789 m	hillside wasteland	low-relief terrain	sandy soil
Xiahe XH	92°13'	32°31'	3280 m	hillside wasteland	forest edge grassland	alpine area
Kuiming KM1,2	102°10'	24°23'	1891 m	hillside meadow	low-relief terrain	alpine meadow soil

Table 3. Evaluation standard and points of 16 evaluation indicators

Evaluation indicator	Points				
	5	4	3	2	1
Flower color	very colorful	more colorful	general colorful	not colorful	dim
The extent of the flower show	extremely easy	easy to see	generally	not easy to see	hard to see
Inflorescence diameter	>10 cm	8–10 cm	6–8 cm	4–6 cm	<4 cm
Fragrance	aroma	slightly aroma	generally	without aroma	malodour
Florescence	>30 d	20–30 d	10–20 d	5–10 d	<5 d
Flower quantity	>5	4–5	3	2	1
Plant height	>55 cm	50–55 cm	45–50 cm	30–40 cm	<30 cm
Plant type	compact	slightly compact	generally compact	incompact	very incompact
Foliage	glossy/broad/bright green/non–mealy	3 of 4	2 of 4	1 of 4	linear
Resource quantity	$n \geq 15$	$10 \leq n < 15$	$5 \leq n < 10$	$n < 5$	none
Development level	unexplored	once introduced but not succeed	generally	only for germplasm conservation	widely used for ornamental
Regeneration capacity	pole–strength	better	generally	difficult to regeneration	unrenewable
Stress resistance	cold, drought, water logging and high temperature	3 of 4	2 of 4	1 of 4	none
Distribution range	≤2000 m	2000–2500 m	2500–3500 m	3000–3500 m	≥3500
Reproductive capacity	seed /division both very easily	seed /division both easily	one propagation method very easily	two propagation methods uneasily	two propagation methods very uneasily
Survival rate	>80%	60 < survival rate < 80%	40 < survival rate < 60%	20 < survival rate < 40%	< 20%

Table 4. Explanation of the standard nine-point preference score system used for the AHP [Saaty 2008]

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

Table 5. Judgement matrix and consistency check of evaluation model

Model hierarchy	Judgement matrix										Consistency check	
A-C	A	C1	C2	C3							W	λmax = 3.003
	C1	1	3	7							0.944	CI = 0.0015
	C2	1/3	1	2							0.299	RI = 0.90
	C3	1/7	1/2	1							0.142	CR = 0.002 < 0.10
C1-P	C1	P1	P2	P3	P4	P5	P6	P7	P8	P9	W	λmax = 9.919
	P1	1	1/2	4	3	1/3	5	5	2	5	0.447	CI = 0.115
	P2	2	1	2	1/2	1/2	5	2	2	7	0.379	RI = 1.49
	P3	1/4	1/2	1	1/6	1/4	1/2	1/2	1/3	2	0.098	CR = 0.077 < 0.10
	P4	1/3	2	6	1	1/2	2	2	1	3	0.317	
	P5	3	2	4	2	1	9	3	3	7	0.646	
	P6	1/5	1/5	2	1/2	1/9	1	1/3	1/4	1	0.088	
	P7	1/5	1/2	2	1/2	1/3	3	1	1/3	7	0.184	
	P8	1/2	1/2	3	1	1/3	4	3	1	7	0.288	
	P9	1/5	1/7	1/2	1/3	1/7	1	1/7	1/7	1	0.061	
C2-P	C2	P19	P11	P12							W	λmax = 3.065
	P10	1	7	3							0.94	CI = 0.1325
	P11	1/7	1	1/5							0.11	RI = 0.90
	P12	1/3	5	1							0.332	CR = 0.036 < 0.10
C3-P	C3	P13	P14	P15	P16						W	λmax = 4.199
	P13	1	1/2	3	5						0.426	CI = 0.66
	P14	2	1	7	9						0.881	RI = 1.12
	P15	1/3	1/7	1	5						0.192	CR = 0.059 < 0.10
	P16	1/5	1/9	1/5	1						0.069	

Table 6. RI value of 1–12 grades

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49	1.52	1.54	1.56

Table 7. Climatic conditions at the locations of the natural populations of 26 *Iris* species from southwest China

Code of population	Climate type	Annual average tempera-ture (°C)	Average tempera-ture of January (°C)	Average temperature of July (°C)	Annual day light hour (h)	Relative humidity (%)	Annual precipita-tion (mm)	Annual evapora-tion (mm)	Frost--free duration (d)
1	2	3	4	5	6	7	8	9	10
Kangding KD1	subtropical monsoon	–1.1	–10.1	11.4	2651.1	91	3042.3	3179	21
Kangding KD2	cold temperate zone	0.2	–12.0	12.5	2689.2	94	3112	3067	20
Kangding KD3	plateau humid subtemperate	7	–2.2	16.2	1748.5	68	940.4	1726	177
Kangding KD4	plateau humid subtemperate	7.5	–2.0	16.4	1748	67	933.9	1883	177
Kangding KD5	plateau continent	5.5	–3.7	15.9	1793	71	1024	1789	180
Kangding KD6	cold temperate zone	1.8	–8.0	12	2090	76	1021	990	132
Wenchuan WC1	plateau humid subtemperate	13.5	2.9	20.5	1318	74	1332.1	1047.8	265
Wenchuan WC2	plateau humid subtemperate	14.3	3.2	21.1	1447.7	73	1259	1123.8	260
Wenchuan WC3	plateau humid subtemperate	14.1	2.8	20.9	1242.1	69	987.3	1022	248
Wenchuan WC4	plateau humid subtemperate	14	3	20.1	1245	69	999.2	1014.6	249
Maoxian MX	plateau monsoon	11	3.4	20.2	1549.4	54	486.3	547.2	216
Xiaojin XJ	subtropical monsoon	1.5	–8.6	14.7	2500.2	87	2765.5	2651	46
Chengdu CD	subtropical humid monsoon	16.5	5.6	25.4	1200.9	79	918.4	851.1	278
Songpan SP	subtropical monsoon	5.7	–10.1	10.3	1827.5	64	729.7	860.1	120
Lixian LX1	mountain stereo	11	–0.3	18.2	1806	60	650.9	679.1	205
Lixian LX2	plateau monsoon	4.7	–3.5	15	2196.8	80	2067.9	1780.2	167
Lixian LX3	continental plateau	9.2	0.5	17.5	2214	78	1600	890.7	220
Maerkang MEK	alpine canyon	8.6	–1.2	15.8	2020.8	62	753.7	887.9	120
Dujiangyan DJY	subtropical monsoon wetness	15.2	4.6	24	1016.9	79	1200	1178	280
Weiyuan WY	subtropical warm monsoon	17.8	7.4	27.1	1192	70	985.2	1036.8	344
Pengzhou PZ	subtropical humid	15.7	3.5	25.2	1073.6	78	1746.6	1650	276
Qionglai QL	subtropical humid monsoon	16.3	5.8	28.8	1107.9	75	1117.6	976.2	285
Moxi MX	subtropical humid	13	1	23	1350.7	73	1080	1267	279
Neijiang NJ	subtropical humid monsoon	16.8	5.8	27	1280.8	69	1009	1290	330

Table 7 cont.

1	2	3	4	5	6	7	8	9	10
Yibin YB	subtropical humid monsoon	18	6	29.8	1108	75	1418	1300	350
Ya'an YA1	subtropical humid monsoon	15.8	6.1	25.4	1305	80	1800	1548	290
Ya'an YA2	subtropical monsoon wetness	14.8	3	24	1300	81	1917	1780	288
Zoige REG	warm temperate monsoon	1.1	–10.1	10.7	2400	72	648.5	640	100
Luding LD	plateau humid subtemperate	3.52	–2.5	16	2380.8	86	2789	2207.8	89
Dayi DL	subtropical humid monsoon	4	–1.8	18	1680	79	1450.9	1400	170
Yanyuan YD	subtropical monsoon	12.1	2.4	24	2054	68	855.2	890	201
Chongqin CQ1	subtropical humid monsoon	16~18	4~8	26~30	1000~1400	78	2001	1023	210
Chongqin CQ2	subtropical humid monsoon	16~18	4~8	26~30	1000~1400	78	2001	1023	210
Chongqin CQ3	subtropical humid monsoon	16~18	4~8	26~30	1000~1400	78	2001	1023	210
Chongqin CQ4	subtropical monsoon	16~18	4~8	26~30	1000~1400	78	2001	1023	234
Chongqin CQ5	subtropical monsoon	16~18	4~8	26~30	1000~1400	78	2001	990	234
Mianning MN1	subtropical monsoon	14~17	5	29.8	2000~2400	86	1879	990	230
Mianning MN2	subtropical monsoon	14~17	5	29.8	2000~2400	86	1879	990	306
Leshan LS1	subtropical humid monsoon	17.5	5.7	28.4	957.9	73	1114.1	987.1	333
Leshan LS2	subtropical monsoon	13.1	5	29.8	1500	85	1922	990	132
Leshan LS3	subtropical monsoon	17.2	5	38.3	1500	85	1922	990	132
Luding LD1	subtropical monsoon	16.5	3.9	13	1500	85	664.4	789	279
Luding LD2	subtropical monsoon	16.5	3.9	13	1500	85	664.4	789	279
Luding LD3	subtropical monsoon	16.5	3.9	13	1500	85	664.4	789	279
Hanyuan HY1	subtropical monsoon	17.9	5.6	21	1475.8	76	741.8	789	300
Hanyuan HY2	subtropical humid monsoon	17.9	5.6	21	1475.8	79	741.8	1573	300
Shimian SM	subtropical humid monsoon	17.1	8	24.7	1245.6	81	777.4	1573	326
Li Country LX4	subtropical monsoon	6.9-11	2	23	1245.6	81	700	1573	290
Xiahe XH	temperate monsoon climate	2.6	0	16	2296	85	516	879	56
Kuiming KM1,2	subtropical plateau mountainous monsoon climate	15	8	19	2200	69	1035	880	240

Table 8. Comprehensive evaluation results of 26 *Iris* species in southwest China

C	C1									C2			C3			
	0.944									0.299			0.142			
P	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
	0.447	0.379	0.098	0.317	0.646	0.088	0.184	0.288	0.06	0.94	0.11	0.332	0.426	0.881	0.192	0.069
Total	42.20%	35.78%	9.25%	29.92%	60.98%	8.31%	17.37%	27.19%	5.66%	28.11%	3.29%	9.93%	6.05%	12.51%	2.73%	0.98%

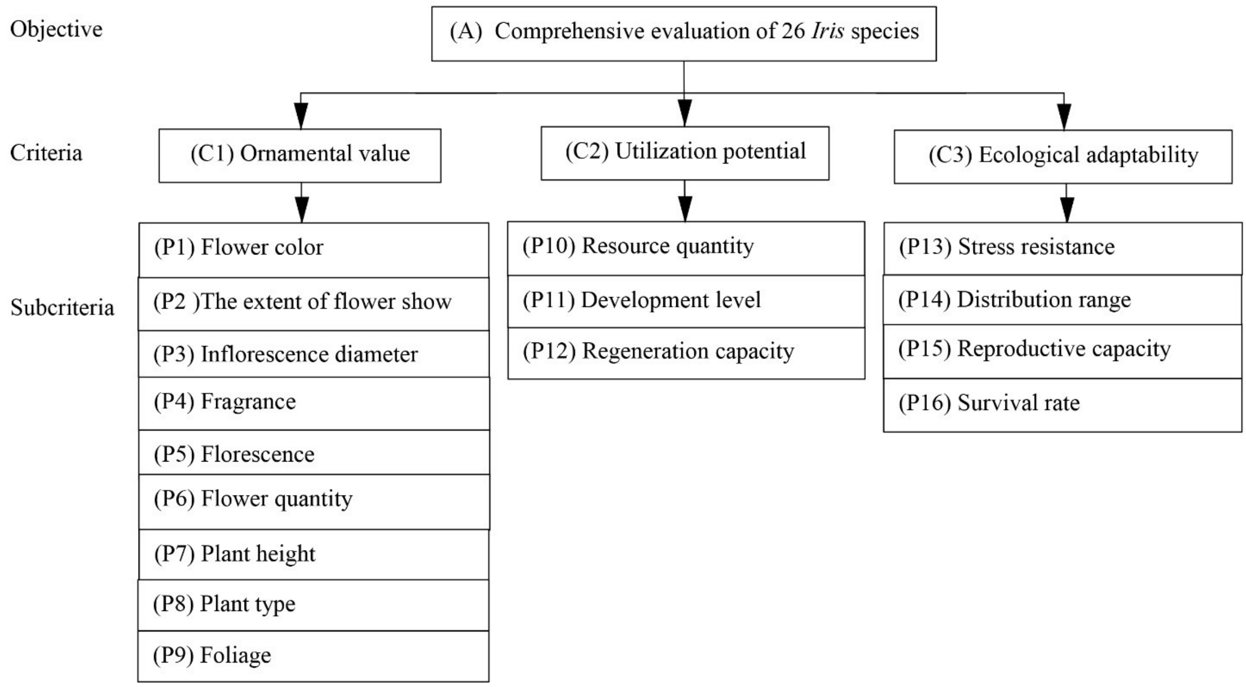

Fig. 1. Hierachies in evaluation model of *Iris*

to 4200 m. In the field, the *Iris* specimens were collected from 29 cities in western China (Tab. 1). Tables 2 and 3 show the ecological data of the 51 typical populations where 23 species, two varieties, and one form were collected.

Botanical characteristics

Based on morphological observations, *Iris* collected in this survey were clearly divided into 16 factors. Every species of *Iris* in each factor has its own unique morphological features. According to our observation in the field, in Sect. *Limniris* spach em. Rodion., the perianth color of *I. lactea* (Fig. 2–3) is pure white; the outer perianth of *I. lactea* var. *chinensis* (Fig. 4–5) is blue-violet with white stripes, and the inner perianth appeared blue-violet; the outer perianth of *I. lactea* var. *chrysantha* (Fig. 6) is pale yellow in the middle, with a pale white and dark purple texture in rim, and inner perianth is light blue-purple. The outer three petals have purple-brown stripes and spots, claw with conspicuous dark purple auricles on both side of *I. wilsonii* (Fig. 7–8) is the

Table 9. Score of 26 *Iris* species collected from southwest China

	I. pseudacorus	*I. wilsonii*	*I. wattii*	*I. tectorum*	*I. confusa*	*I. chrysographes*	*I. lactea* Pall. var. *chinensis*	*I. lactea*	*I. sanguinea*	*I. halophila*	*I. forrestii*	*I. japonica*	*I. sichuanensis*
Flower color	4	4	3	4	3	2	2	3	3	2	3	3	3
The extent of the flower show	4	4	4	4	3	4	4	4	4	4	3	4	3
Inflorescence diameter	5	3	3	4	2	4	2	2	3	2	3	2	3
Fragrance	2	2	2	2	2	2	2	2	2	4	2	2	2
Florescence	4	4	4	4	4	4	4	4	4	4	4	4	4
Flower quantity	3	2	3	2	4	2	3	3	2	2	2	4	3
Plant height	5	5	3	2	1	3	1	1	3	2	2	3	1
Plant type	4	4	4	3	4	4	4	4	3	4	4	3	3
Foliage resource	4	4	4	4	4	4	4	4	4	4	4	4	4
Quality	5	5	4	5	5	4	4	4	4	3	4	3	4
Development level	1	3	3	1	1	3	2	2	4	4	4	2	3
Regeneration capacity	4	4	4	4	4	3	4	4	3	3	3	4	4
Stress resistance	3	2	2	4	2	2	3	3	1	2	2	4	2
Distribution range	5	5	5	5	5	2	5	5	5	3	2	2	4
Reproductive capacity	4	4	4	4	4	4	4	4	4	3	4	4	4
Survival rate	4	3	4	4	4	4	4	4	4	4	3	3	4

	I. ruthenica	*I. leptophylla*	*I. collettii*	*I. goniocarpa*	*I. cuniculiformis*	*I. delavayi*	*I. decora*	*I . germanica*	*I. lactea* var. *chrysantha*	*I. songarica*	*I. sibirica*	*I. japonica* f. *pallescens*	*I. speculatrix*
Flower color	3	2	4	2	4	4	2	3	4	3	4	2	2
The extent of the flower show	3	3	3	3	3	5	2	5	4	4	4	4	3
Inflorescence diameter	2	1	1	1	4	4	2	5	2	4	4	2	2
Fragrance	2	2	2	2	2	2	2	2	2	2	2	2	2
Florescence	4	4	4	4	4	4	4	4	4	4	4	4	4
Flower quantity	1	2	2	1	1	2	2	2	3	2	2	4	2
Plant height	1	1	1	1	3	5	1	5	1	2	4	3	1
Plant type	4	3	2	3	3	4	3	4	4	2	4	3	3
Foliage resource	4	4	4	4	4	4	4	4	4	4	4	4	4
Quality	3	3	3	2	3	4	4	5	4	5	4	3	4
Development level	4	4	4	4	4	3	3	4	2	4	2	2	3
Regeneration capacity	4	3	3	3	3	4	3	3	4	3	4	4	3
Stress resistance	2	2	2	2	3	5	5	3	3	2	5	4	4
Distribution range	4	5	2	1	4	3	4	5	5	2	5	2	2
Reproductive capacity	4	4	4	4	3	4	4	3	4	2	3	4	4
Survival rate	3	4	3	2	4	5	4	4	4	3	4	3	3

Table 10. Comprehensive evaluation value and grades of 26 species of *Iris* from southwest China

Species	Score	Rank
I. pseudacorus	11.84	I
I. delavayi	11.69	I
I. germanica	11.67	I
I. wilsonii	11.57	I
I. sibirica	11.34	I
I. tectorum	10.93	I
I. lactea Pall.var. *chrysantha*	10.62	II
I. wattii	10.61	II
I. lactea Pall. var. *chinensis*	10.20	II
I. sanguinea	10.13	II
I. confusa	10.11	II
I. cuniculiformis	9.89	III
I. halophila	9.81	III
I. lactea	9.78	III
I. japonica	9.75	III
I. chrysographes	9.72	III
I. songarica	9.68	III
I. forrestii	9.55	III
I. sichuanensis	9.51	III
I. japonica f. *pallescens*	9.33	III
I. ruthenica	9.26	III
I. collettii	8.78	IV
I. speculatrix	8.67	IV
I. decora	8.64	IV
I. leptophylla	8.60	IV
I. goniocarpa	7.71	IV

significant difference between *I. wilsonii* and *I. forrestii* (Fig. 9). The flower color of *I. chrysographes* (Fig. 10) is very dark violet, the outer perianth has golden yellow stripes at base and the center is sunken in a groove, flower stem is hollow. For *I. songarica* (Fig. 11), the flower color is blue-purple, outer perianth lobes violin-shaped, claws nearly lanceolate. The most prominent characteristic of *I. sibirica* (Fig. 12) is the outer perianth lobes have brown reticulate and yellow markings, and the claws are wide and wedge-shaped, and the center is depressed and grooved. *I. delavayi* (Fig. 13–14) and *I. sanguinea* (Fig. 15–16) have solid flower stem is the distinguish character of these two species. *I. pseudacorus* (Fig. 17–18) has yellow flowers, the outer perianth lobes are wedge-shaped, with dark brown stripes, growing in the wetlands or swamps along rivers and lakes. There are 2 species and 4 varieties in Sect. *Ioniris*, we collected *I. ruthenica* (Fig. 19), the leaves are linear, with 3–5 longitudinal veins, and the seeds are

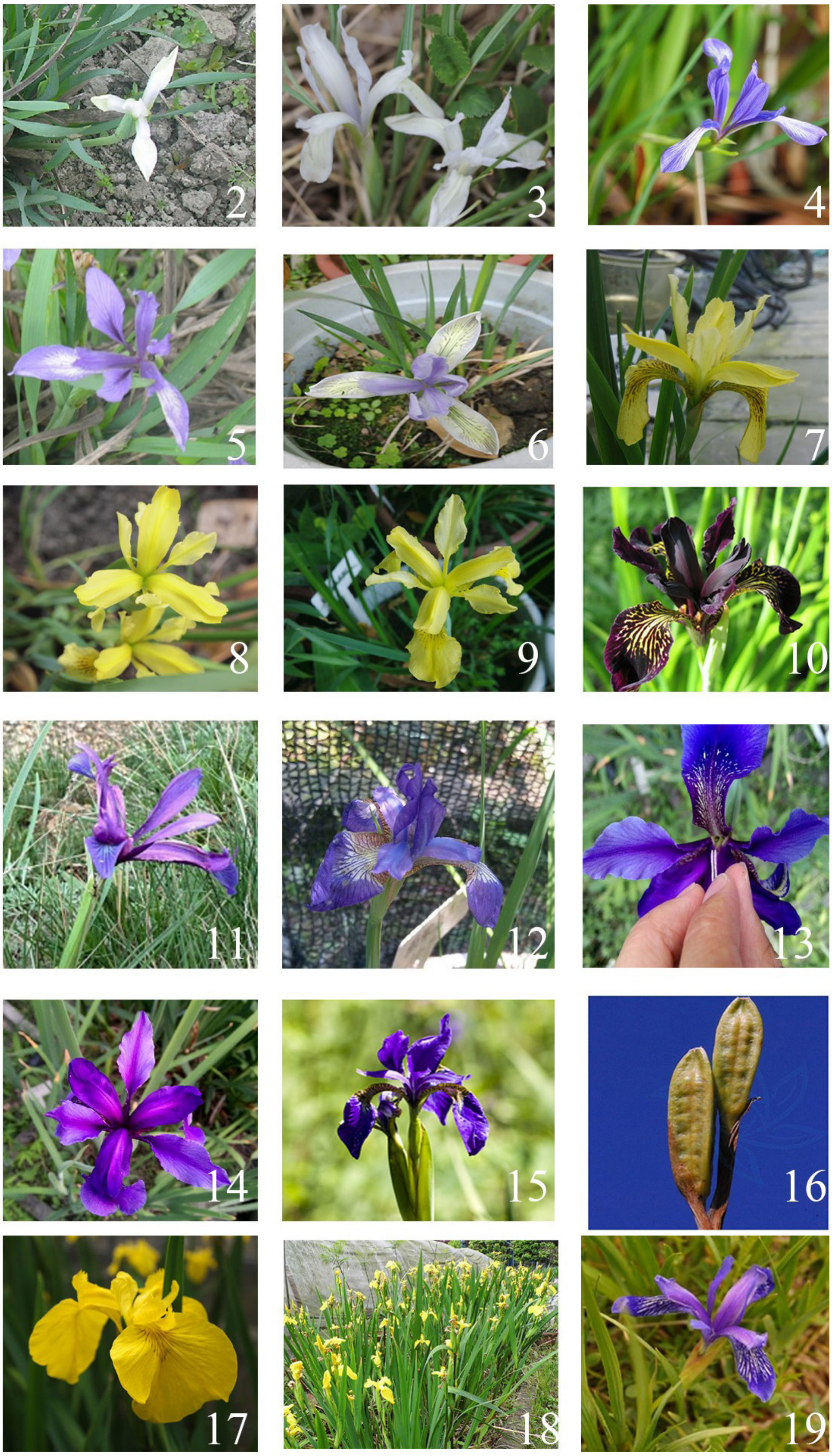
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Fig. 2–37. Flowers of *Iris* species in southwest China

2–3: *I. lactea*; 4–5: *I. lactea* var. *chinensis*; 6: I. *lactea* var. *chrysantha*; 7–8: *I. wilsonii*; 9: *I. forrestii*; 10: *I. chrysographes*; 11: *I. songarica*; 12: *I. sibirica*; 13–14: *I. delavayi*; 15–16: *I. sanguinea*; 17–18: *I. pseudacorus*; 19: *I. ruthenica*; 20: *I. halophila*; 21: *I. decora*; 22: *I. collettii*; 23: *I. speculatrix*; 24–25: *I. tectorum*; 26: *I. confusa*; 27: *I. japonica*; 28–29: *I. wattii*; 30: *I. japonica* f. *pallescens*; 31–32: *I. germanica*; 33–34: *I. sichuanensis*; 35: *I. leptophylla*; 36: *I. cuniculiformis*; 37: *I. goniocarpa* spherical or pear-shaped, with milky white appendages, and the appendages become sticky when wet.

There are one species and one variety in Subgen. *Xyridion* (Tausch) spach em. Rodion., we collected *I. halophila* (Fig. 20), they grow at grasslands, hillsides, wet salty soils. The flower is yellow, 5–6 cm in diameter, outer perianth segments fiddle-shaped.

There are only two species in sugen. *Nepalesis* (Dykes) Law., one is *I. decora* (Fig. 21), the other is *I. collettii* (Fig. 22), they both blooming at May to June, except the former has yellow beard hairy appendages and the latter has orange hairy appendages on midvein of outer perianth.

Five species and one form have been found in Subgen. *Crossiris* Spach. The outer perianth segments with a crest could be the character to distinguish the other subgen. For *I. speculatrix* (Fig. 23), crest of outer perianth segments are yellow. *I. tectorum* (Fig. 24–25) has outer perianth segments are mottled darker around conspicuous, white, irregularly toothed crest. The flower and fruit of *I. confusa* (Fig. 26) are similar with *I. japonica* (Fig. 27), and overground part is similar with *I. wattii* (Fig. 28–29). *I. confusa* is wildly distributed in China, it can be growth in open forest margins, wet grasslands with altitude from 500–3400 m. *I. japonica* and *I. japonica* f. *pallescens* (Fig. 30) are quite similar in every part except the color of flower, *I. japonica* has blue-purple or light blue flower and *I. japonica* f. *pallescens* has white flower.

We collected five species in Subgen. *Iris*. *I. germanica* (Fig. 31–32) is in sect. *Iris* with big flower in 12 cm in diam, outer perianth segments with yellow-tipped hairs. The rest four species are in sect. *Hexapogon* (Bunge) Baker em. Radion. *I. sichuanensis* (Fig. 33–34) and *I. leptophylla* (Fig. 35), the morphological characteristics, except the size of leaf, are similar to each other, the leaf of *I. sichuanensis* is bigger than that of *I. leptophylla*. *I. cuniculiformis* (Fig. 36) was a variety of *I. goniocarpa* (Fig. 37), has taller plant height, longer leaves, larger flowers than *I. goniocarpa*.

AHP evaluation

Based on the overall score of the analysis (Tab. 10), the six top-most ranking *Iris* species, *I. pseudacorus*, *I. delavayi*, *I. germanica*, *I. wilsonii*, *I. sibirica*, and *I. tectorum*, should be studied further due to the following excellent ornamental traits: strong scape and large, brightly colored flowers. Moreover, these species are distributed at lower altitudes and have better ecological adaptability, making it more likely for the introduction to be successful. At the same time, *I. collettii*, *I. speculatrix*, *I. decora*, *I. leptophylla*, and *I. goniocarpa* had the lowest score.

DISCUSSION

Morphological characteristics and distribution

I. narcissiflora, which has only been reported in Hanyuan County of Ya'an City in Sichuan Province and in 2004 was listed on the China Species Red List as a vulnerable species [Wang and Xie 2004]. We have investigated the locations described in distribution records for 15 years yet we were unable to locate the species in the field. After two major earthquakes in Sichuan, one in Wenchuan in 2008 (*Ms* 8.0) and the other in Ya'an in 2013 (*Ms* 7.0), which is the unique distribution of *I. narcissiflora*, many mountains have collapsed and some roads disappeared. Thus, we speculate that *I. narcissiflora* might be extinct. The habitat of *I. sichuanensis* has been extensively degraded as a result of these disasters; such that this species is now difficult to find in the field. In contrast, numerous populations of *I. goniocarpa* are distributed in Sichuan. With the high demand in landscaping, *I. confusa*, *I. pseudacorus*, *I. sibirica*, and *I. germanica* are presently cultivated in nurseries.

We found a new distribution of *I. lactea* Pall. var. *chrysantha* in Gansu Province, which is previously only known from Xizang Province as reported in Flora of China [Zhao 1985, 2000]. For *I. japonica* f. *pallescens*, this form is only distributed in Zhejiang province [Zhao 1985], in this investigation, we found a new distribution in Leshan, Sichuan Province. We also identified a new character in two species: *I. germanica* with purplish-blue petals and a ginger-like scent, *I. germanica* with white petals and a charming fragrance, and *I. japonica* with pale whitish-blue petals and a light, pleasant smell. Therefore, *Iris* species should be explored further for their application.

Evaluation

There is a high application value of *Iris* plants in China. For example, *I. japonica*, *I. tectorum* and

I. sibirica not only have a widely distributed, but also have a strong resistance, widely used in green belt [Yu 2009]. However, at present, the majority of *Iris* species in China are still in the state of development [Jiang 2016]. In order to select good species, it is necessary to continuously screen in the process of introduction and domestication. Previous studies on *Iris* have mainly focused on stress resistance [Han et al. 2007, Wu et al. 2007, Zhang et al. 2014, Wang et al. 2014]. For ornamental value, there are only 18 species and two varieties that have previously been evaluated and most of them are distributed in northeast China [Liu et al. 2016, Wang et al. 2012, Zheng et al. 2017]. Consider the findings of this study and those from previous research, we recommend three *Iris* species for application: *I. germanica*, *I. pseudacorus*, and *I. tectorum*. These three species have already been attracted more attention than other species in China due to their good resistance in drought, cold, and barren stress, and also have wild distribution, extensive adaptability, easy management, and large flowers. Furthermore, future studies should focus on *I. delavayi*, *I. wilsonii*, and *I. sibirica* owing to the excellent ornamental characters of long scape, large and beautiful flower make these three species have tremendous potential as cut flower and potted plants, and can be applied to landscape application.

The AHP evaluation method has been successfully applied to investigate plant resources in genus *Lilium*, *Primula*, and *Iris* [Rong et al. 2011, Jia et al. 2014, Zheng et al. 2017]. The AHP presented in our study provides more information for using *Iris* resources.

Conservation of *Iris* genetic resources

After an extensive field survey, although Sichuan is one of the distribution centers of *Iris* [Zhao 1985], we were still unable to investigate nine species, including *I. polysticta*, *I. henryi* Baker, *I. potaninii* Maxim., *I. narcissiflora* Diels, *I. kemaonensis* Wall, and so on. The distribution of these species in Sichuan is narrow and no new records have been listed in the Flora of Sichuan for over forty years. In recent years, with the development of tourism, the great impacts of earthquakes, and the rapid deterioration of the ecological environment, some species may be extinct. Therefore, it is urgent and necessary to protect and preserve wild *Iris* resources. Specifically, we propose the following: (1) To establish specialized gardens to facilitate the ex situ conservation of *Iris* resources. For example, botanical gardens in Shanghai, Hangzhou, and Wuhan already have specialized gardens to collect and protect *Iris* resources; however, in the northwest and southwest of China, *ex situ* conservation of *Iris* is limited. (2) Intensifying environmental protection to better preserve the genetic diversity of *Iris in situ*. (3) Strengthen public education to raise awareness of protecting plant resources.

CONCLUSION

In this study, 23 species, two varieties, and one form wild *Iris* from southwest China were collected and evaluated using the AHP method with 16 indicator points based on the ornamental value, utilization potential, and ecological adaptability of *Iris*. The results showed that *I. pseudacorus*, *I. delavayi*, *I. germanica*, *I. wilsonii*, *I. sibirica*, and *I. tectorum* received the highest AHP score; therefore, future studies should be conducted on these species to improve their reasonable application in horticulture.

ACKNOWLEDGEMENTS

The author would like to thank Miao Tan (Sichuan Agricultural University, China) for her help in data analysis. We would also like to express our gratitude to Prof. Yonghong Zhou (Sichuan Agricultural University, China) for careful reading of the manuscript and valuable suggestions. This work was supported by the PhD Program of Sichuan Agricultural University (grant: 63670010).

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