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Comprehensive Evaluation of Flower Border Application Value of New and Superior Plants in Hefei Area

MENG Yi, ZHAO Zhiyan*, LIANG Tingwu, LU Zhaoliang
(Anhui Xinhua University, Hefei, Anhui 230088, China)

Abstract An analytic hierarchy process (AHP) was employed to assess the applicability of 18 new and superior varieties of flowers in Hefei City flower border applications. A total of 12 indicators were selected from three distinct aspects of adaptability, ornamental characteristics and use traits, in order to establish a comprehensive evaluation model. The results demonstrate that grade I (J ⩾ 2.685) exhibits excellent application value, encompassing six species of plants, such as *Hydrangea macrophylla* 'Endless Summer'; grade II (2.684 ⩽ J ⩽ 2.420) is also of notable application value, encompassing five species of plants, such as *Callistemon rigidus*; grade III (2.419 ⩽ J ⩽ 2.615) is of average application value, including five species of plants, such as *Crocosmia crocosmiflora*; grade IV (J ⩽ 2.16) is of relatively poor application value. The evaluation results may be utilized as a theoretical reference for the promotion of new and superior varieties in the flower border of Hefei.

Keywords Analytic hierarchy process (AHP), New and superior variety, Application value, Comprehensive evaluation
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New and superior varieties of plants are those that have been artificially cultivated or exploited for the discovery of wild plants. They are distinguished by novelty, specificity, consistency, and stability, and are appropriately named. They also possess good ornamental characteristics and resistance to adversity, and thus occupy a certain position in the urban flower garden[1]. Hefei City is situated within a subtropical monsoon humid climate zone. It is reasonable to posit that the origin climate of new and superior varieties is likely to differ in some respects from that of Hefei. It is necessary to conduct surveys, statistical analysis, and research to determine whether new and superior varieties introduced to the Hefei area continue to exhibit good growth and ornamental characteristics. The pertinent data indicates that the research on flower border plants in Hefei is primarily focused on specific living style or plants within a given family. However, the research on new and superior varieties lacks a quantitative evaluation.

This study employs the new and superior varieties of Hefei flower borders as the subject of investigation, with the objective of quantitatively evaluating the plants in question. The survey encompassed a number of flower borders, including Forest Miracle, Four Seasons Flower Sea Entrance Flower Border, Hefei Botanical Garden, and others. From this pool of candidates, 18 representative new and superior varieties were selected. The analytic hierarchy process (AHP) was employed to develop an evaluation system for new and superior varieties in three key areas: adaptability, ornamental characteristics, and use traits. This system was utilized to identify varieties with or without excellent application value. The new and superior plants of high and low landscape value should be promoted, and those with potential for domestication should be identified. This will provide a theoretical basis for the creation of long-lasting and conservation-oriented flower boards in Hefei, thereby injecting fresh blood into the construction of ecological civilization in Hefei.

1 Construction of evaluation model system

1.1 Evaluation system

The rationality of the selection of the evaluation indicator system directly affects the accuracy of evaluation results. Therefore, the selection of indicators must be scientifically rigorous, following the principles of completeness, independence, representativeness, feasibility, and so on. In light of the existing literature on the research of new and superior flower border plants, as well as the research on new and superior flower border plants in Hefei, the AHP was selected as the optimal choice. After exhaustive consideration of the recommendations put forth by experts and educators, three overarching guideline layers were established to encompass adaptability, ornamental characteristics, and use traits. These were further delineated into 12 indicator layers, each corresponding to a specific guideline layer. This framework was utilized to evaluate the suitability of new and superior flower border plants[2-3] (Table 1).

1.2 Establishment of evaluation factor weights

1.2.1 Construction of judgment matrix. In accordance with the established fourth-order AHP evaluation matrix, landscape professionals with relevant expertise and previous literature were invited to carry out landscape value scoring. The scoring was conducted using the 1–9 ratio scale method (Table 2), which compares the mutual scoring of each index layer and guideline layer. The comparison of the two factors allows for the identification of the most important, equally important, or slightly important factors. This process culminates in the formation of the judgment matrix[4].

1.2.2 Determination of evaluation factor weight. Let $\lambda_{\max}$ be the maximum eigenvalue of the judgment matrix A, and let the corresponding normalized eigenvector be used as the relative weight W. The power method is used to find both $\lambda_{\max}$ and W, and the formula for this is as follows:

$$W=\tilde{w}^{(k+1)}/\sum_{i=1}^{n}\tilde{w}^{(k+1)},\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{\tilde{w}_i^{(k+1)}}{w_i^{(k)}}$$

where k=0, 1, 2, …, n.

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* Corresponding author.

1.3 Consistency test

It is not possible to guarantee complete consistency in the judgment matrix, which is composed of two-by-two comparisons between factors. This is due to the inherent complexity of objective things and the diversity of human understanding. The index utilized to assess the deviation from consistency of judgment matrix is *CI*. $CI = (\lambda_{max} - n)/(n - 1)$[5], and *n* represents the order of the judgment matrix. The ratio *CR* of *CI* to the average stochastic consistency index *RI* of the judgment matrix is the judgment matrix consistency index, $CR= CI/RI$. The corresponding average stochastic consistency index (*RI*) is found by calculating the average of the first to tenth order *RI* values. The resulting values are 0, 0, 0.58, 0.90, 1.12, 1.24, 1.32, 1.41, 1.45, and 1.49. If the consistency ratio (*CR*) is less than 0.10, the matrix is deemed to exhibit satisfactory consistency. In contrast, if the *CR* exceeds this threshold, it is recommended that the matrix should be adjusted.

1.4 Calculation of hierarchical overall ranking

The hierarchical overall ranking is the sum of the relative importance of all factors at that level. This value is calculated by first determining the weighted value of each evaluation indicator (P) in relation to the trait to which it belongs (C), and then integrating this value with the weighted value of the trait (C). Finally, the weighted value of each evaluation indicator factor (P) in relation to the total comprehensive evaluation value (B) is calculated, and the total ranking is obtained. $B = \sum_{i=1}^{n} X_i Y_i$, where X_i represents the weight of an evaluation factor; Y_i represents the score of the factor (Table 3).

2 Evaluation and discussion

2.1 Scoring standards

The scoring criteria for each specific index were developed following extensive consultation with experts, based on comprehensive observation of the ornamental characteristics of new and superior flower border plants in Hefei. Additionally, investigations were conducted to assess the adaptability and use traits of these

Table 1 Landscape evaluation system of new and superior varieties in Hefei City

Target layer (A)	Constraint layer (C)	Index layer (P)	Solution layer (D)
Comprehensive evaluation of landscape application of new and superior flower border plants (A)	Adaptability (C1)	Cold tolerance (P1), drought tolerance (P2), heat tolerance (P3), disease and pest resistance (P4)	20 new and superior plants to be evaluated
	Ornamental characteristics (C2)	Flower color (P5), leaf color (P6), flower type (P7), flower quantity (P8), plant type (P9)	
	Use trait (C3)	Reproduction coefficient (P10), maintenance frequency (P11), mulching effect (P12)	

Table 2 Judgment matrix and consistency test

Model layer		Judgment matrix					Relative weight (*W*)	Consistency test
		C1	C2	C3				
A–C	C1	1.00	0.50	3.00			0.333 8	λ_{max}=3.053
	C2	2.00	1.00	3.00			0.524 7	*CI*=0.027
	C3	0.33	0.33	1.00			0.141 6	*CR*=0.052<0.10
C1–P		P1	P2	P3	P4			
	P1	1.00	3.00	0.50	3.00		0.309 2	λ_{max}=4.122
	P2	0.33	1.00	0.33	0.50		0.105 6	*CI*=0.041
	P3	2.00	3.00	1.00	3.00		0.435 1	*CR*=0.046<0.10
	P4	0.33	2.00	0.33	1.00		0.150 1	
C2–P		P5	P6	P7	P8	P9		
	P5	1.00	7.00	5.00	7.00	2.00	0.498 9	
	P6	0.14	1.00	1.00	5.00	0.50	0.129 4	
	P7	0.20	1.00	1.00	3.00	0.50	0.114 1	λ_{max}=5.253
	P8	0.14	0.20	0.33	1.00	0.33	0.051 0	*CI*=0.063
	P9	0.50	2.00	2.00	3.00	1.00	0.206 7	*CR*=0.057<0.10
C3–P		P10	P11	P12				
	P10	1.00	3.00	0.20			0.193 2	λ_{max}=3.066
	P11	0.33	1.00	0.14			0.083 3	*CI*=0.033
	P12	5.00	7.00	1.00			0.725 6	*CR*=0.063<0.10

Table 3 Ranking of the total weights of the criteria layer (P) to the target layer (A)

Target layer	Criterion layer	*W*	Datum layer	*W*	Overall ranking weight
B	C1	0.333 8	P1	0.333 8	0.111 4
			P2	0.524 7	0.175 1
			P3	0.141 6	0.047 2
			P4	0.150 1	0.050 1
	C2	0.524 7	P5	0.498 9	0.261 7
			P6	0.129 4	0.067 9
			P7	0.114 1	0.059 9
			P8	0.051 0	0.026 8
			P9	0.206 7	0.108 4
	C3	0.141 6	P10	0.193 2	0.027 3
			P11	0.083 3	0.011 8
			P12	0.723 5	0.102 4

Table 4 Scoring standard of each specific evaluation index

Evaluation index	Score		
	3	2	1
P1	High frost resistance, no frost damage	No frost damage in average years	Prone to frost damage
P2	Rarely needs watering	Prolonged drought needs watering	Needs frequent watering
P3	High heat resistance	Can return to normal after sunburn	Heat-intolerant
P4	The plants grow healthily with virtually no diseases or pests	Diseases and pests occur occasionally on the plant	Diseases and pests occur frequently that affect plant growth
P5	Bright and beautiful	Ordinary	Flowerless or lusterless and darker
P6	Colored leaves, flowering leaves, brilliant colors	Bright green, emerald green, green	Grayish green
P7	Peculiar, larger	Ordinary	No flowers or small and of no ornamental value
P8	Denser flowers	Ordinary flowers	Sparser flowers
P9	Compact, beautiful	More compact, with average results	Loose, ineffective groups
P10	Plant reproduction is easier	Plant reproduction is within the typical range	Plant reproduction is challenging
P11	Extensive management, no management required	Only needs to be managed before closure	Ongoing management required
P12	Ground coverage of 90%	Ground coverage of 70%	Ground coverage of 50%

plants[6]. A three-point scale was also developed based on the common landscape application values and the distinctive characteristics of various varieties. This scale was divided into three grades of 3, 2, and 1 points (Table 4).

2.2 Calculation results and grade classification

The results of the field study and the photographs taken were used to score the new and superior flower border varieties against the standard. The weighted average of each plant was calculated based on the weighted values derived from Table 5 and recorded as a composite score. The difference was divided into 4 grades by dividing the difference by four. Grade I (2.93–2.685), grade II (2.654–2.420), grade III (2.439–2.230), and grade IV (2.229–1.910) were the resulting grades. The statistics yielded the plant score table of new and superior flower border plants in Hefei (Table 5).

Table 5 Scoring of new and superior plants

No.	Latin name	Family name	Overall rating	Evaluation grade
1	*Hydrangea macrophylla*	Hydrangeaceae	2.93	I
2	*Vitex agnus-castus*	Labiatae	2.86	I
3	*Agapanthus africanus*	Amaryllidaceae	2.76	I
4	*Cuphea hookeriana*	Lythraceae	2.71	I
5	*Hosta ventricosa*	Asparagaceae	2.69	I
6	*Santolina chamaecyparissus*	Asteraceae	2.69	I
7	*Callistemon rigidus*	Myrtaceae	2.68	II
8	*Lantana camara*	Verbenaceae	2.63	II
9	*Trachelospermum asitaticum*	Apocynaceae	2.57	II
10	*Heuchera sanguinea*	Saxifragaceae	2.46	II
11	*Rosmarinus officinalis*	Labiatae	2.43	II
12	*Crocosmia crocosmiflora*	Iridaceae	2.39	III
13	*Monarda didyma*	Labiatae	2.36	III
14	*Gaura lindheimeri*	Onagraceae	2.33	III
15	*Tulbaghia violacea*	Amaryllidaceae	2.32	III
16	*Pyracantha fortuneana*	Rosaceae	2.23	III
17	*Nandina domestica*	Berberidaceae	2.09	IV
18	*Jacobaea maritima*	Asteraceae	1.91	IV

2.3 Analysis and discussion

The evaluation results indicate that the new and superior varieties are generally well-used in flower borders. However, there are still some shortcomings. For instance, *Jacobaea maritima* exhibits favorable foliage characteristics, yet its sparse flowering renders it inferior. Similarly, *Nandina domestica* 'Firepower' displays comparable deficiencies, with commendable foliage characteristics, yet it fails to flower or produce fruit, resulting in a diminished overall score. *Gaura lindheimeri* boasts all the ornamental characteristics, yet it lacks resistance to lodging, rendering it less ornamental. Some of the new and superior varieties in grades III and IV exhibit deficiencies in one or more aspects, yet retain the potential for application. It is possible to consider distant hybridization of varieties with expected excellent characteristics to expand the trait segregation of progeny and create new superior germplasm resources[7]. Genetic engineering can also be employed to improve varieties in terms of flower color, plant type, and stress resistance[8].

The comprehensive score indicates that the six new superior varieties, led by *Hydrangea macrophylla* 'Endless Summer', exhibit excellent adaptability, ornamental characteristics, and use traits. These varieties may be prioritized in the creation of long-lasting flower borders. Some plants that fall into the grade II category have a relatively high overall score, but this does not imply that they are without flaws. For instance, *Heuchera micrantha*, a hardy perennial herb, will decompose and melt after being exposed to direct sunlight for a period of time during the summer season, and then disappear into the flower border, which is not conducive to the construction of a conservation-oriented flower border.

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of aquatic plants, it is often necessary to establish a virtuous aquatic ecological circulation system(Fig.10). Releasing certain local aquatic animals into areas with severe water pollution can impede algae growth and decelerate the decomposition of aquatic plants. The decayed material can then be utilized to nourish aquatic plants, achieving a harmonious balance that purifies water and prevents non-point source pollution.

4 Conclusions and discussion

Using remote sensing technology, we obtained the spatial distribution of the source-sink landscape in the Huanghou basin based on the theory of source-sink landscape. We then analyzed the trend of non-point source pollution risk in the basin. Extensive forested lands and grasslands are found in the middle and lower reaches of the Huanghou basin. They play a crucial role in protecting downstream water bodies as a typical sink landscape that absorbs and intercepts pollutants in water bodies. However, the upper reaches of the basin, which are located in residential and agricultural areas to the west and southwest, are the primary source landscape areas and are at a higher risk for non-point source pollution.

To manage non-point source pollution in the basin, the management idea of "increasing sinks and reducing sources" is adopted. Ecological restoration measures are taken to achieve this goal through a two-pronged approach at both the macro and micro levels. The work to control karst rocky desertification should continue at a macro level. The rocky desertification area in the basin should gradually transform into grassland and forested land, while increasing the overall area of the sink landscape. At the micro level, ecological restoration measures such as slope planting, riparian vegetation restoration, increasing plant richness, and aquatic plant restoration can effectively control non-point source pollution.

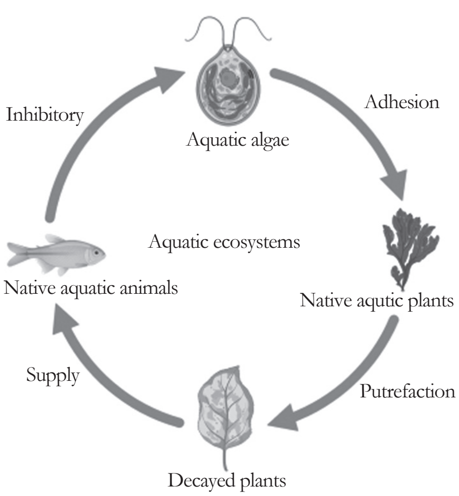

Fig.10 Good water ecosystem circulation mechanism

Currently, with the robust advancement of the source-sink landscape theory in the field of landscape ecology, research on assessing non-point source pollution in the basin based on this theory has become relatively comprehensive. However, research on preventing and treating non-point source pollution in the basin during later stages remains relatively inadequate and requires further study.

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