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Application of Flower Borders in Hefei City

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Abstract The application value of 70 kinds of flowers in Hefei City was evaluated by analytic hierarchy process (AHP). From the three aspects of adaptability, ornamental value and economic traits, 12 indicators were summarized to establish a comprehensive evaluation system. The results show that the application of grade-I plants ($J \geqslant 3.664\ 2$) in flower borders is the most suitable, and they include 19 species of plants such as *Osmanthus fragrans* var. *thunbergii*, accounting for 27.14%. The application of grade-II plants ($3.231\ 9 \leqslant J \leqslant 3.664\ 1$) in flower borders is suitable, and 36 species of plants such as *Jacobaea maritima* are included, with the proportion of 51.42%. The application of grade-III plants ($2.793\ 5 \leqslant J \leqslant 3.231\ 8$) in flower borders is relatively suitable, and they contain 8 species of plants such as *Acer palmatum* 'Atropurpureum' (Van Houtte) Schwerim, accounting for 11.42%. Grade-IV plants ($J \leqslant 2.793\ 4$) can be applied in flower borders under special circumstances, and include 6 species of plants such as *Muehlenbeckia complexa* Meisn., accounting for 8.57%. The results can provide reference for the selection of flower border plants in Hefei. The locations and types of 40 flower borders were summarized to provide a basis for the development direction and future planning of flower borders in Hefei.

Keywords Analytic hierarchy process (AHP), Flower border, Application value, Comprehensive evaluation
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A flower border is a natural patch planting form that simulates the staggered growth state of various wild flowers in the natural forest margin zone, and it is mainly composed of perennial ball perennial flowers[1]. With the continuous development of society, people's living standards continue to improve, and people have higher requirements for their living environment, pursuing a higher quality of life. The pleasure of urban residents is positively correlated with the visual difference of flower border landscape. Therefore, the construction of flower border landscape can provide residents with better plant healing places and achieve better spiritual healing effects[2]. Many cities began to apply flower borders in urban construction and planning to meet the physiological needs of people close to nature. In order to better combine flower borders with the city and avoid the appearance of low-quality or overly simple flower borders, 40 flower borders in 8 districts of Hefei were investigated, and analytic hierarchy process (AHP) was used to comprehensively analyze and evaluate flower border plants from the aspects of adaptability, ornamental value and economy. Moreover, the positions, advantages and disadvantages of 40 flower borders were analyzed to provide scientific basis for the construction and improvement of flower borders in Hefei.

1 Construction of the evaluation model system

1.1 Comprehensive evaluation model

40 flower borders in Hefei City were surveyed, from which 80 kinds of flower border plants commonly used were selected as the research object, and analytic hierarchy process (AHP) was used to construct a comprehensive evaluation model of the landscape value of flower border plants in Hefei. It is composed of target layer A, criterion layer C, indicator layer P and scheme layer D. According to the suggestions of experts and teachers, criterion layer C was divided into three levels: adaptability, ornamental value and economy, and 12 corresponding indicators were determined to constitute the indicator layer. Based on the above layers, the comprehensive evaluation system of flower border plants in Hefei was constructed (Table 1)[3].

1.2 Establishment of weight of evaluation factors

In the analytic hierarchy process, landscape value was scored based on various literature sources with the help of several experienced landscape architecture expert teachers and scholars. 1-9 ratio scale method was used to construct a pairwise comparison judgment matrix. In decision analysis and multi-attribute decision making, using pairwise comparison to construct a judgment matrix is an important means to determine the weight of each factor. In order to ensure the validity and reliability of the judgment matrix, its consistency test is particularly critical. It is generally considered that the consistency of the judgment matrix is acceptable when λ_{max} is slightly greater than n and the other characteristic roots are close to zero. λ_{max} is the maximum characteristic root of the judgment matrix, and it can be calculated directly by using the eig function in Matlab software, namely $\lambda_{max}=\frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i}$. The formula can be converted to $A_\omega=\lambda_{max}\omega$.

1.3 Consistency test

In the analytic hierarchy process, CI is used as a scale to judge the the consistency indicator of matrix deviation. $CI=(\lambda_{max}-n)/(n-1)$. In the formula, λ_{max} is the maximum eigenvalue of the judgment matrix; n is the number of indicators; CI is the consistency indicator of matrix deviation. In the consistency test, the ratio CR between CI and the average random consistency indicator RI of the judgment matrix is taken as the random consistency ratio[4], namely $CR=CI/RI$. All four matrices have satisfactory consistency if their CR is less than 0.100 (Table 2).

1.4 Total sorting weight

The relative importance sorting weight of layer P to layer A was calculated, and then the

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consistency test was also carried out. Finally, the total sorting weight of 12 evaluation factors[5] was obtained (Table 3). The sorting value of the relative importance of all factors at the same level to the highest level is called the total hierarchical sorting. After the weighted value of each specific evaluation indicator (P) relative to the subordinate trait (C) was calculated, it was weighted and combined with the weight of the trait (C), and then the weight of each evaluation indicator (P) relative to the total comprehensive evaluation value (B) can be calculated to obtain the total sorting. In the formula $B=\sum_{i=1}^{n} X_i Y_i$, X_i stands for the weight of an evaluation factor, and Y_i represents the score of the factor[5].

2 Evaluation and discussion

2.1 Scoring criteria

According to the 12 indicators, a 5-point scoring standard was developed to correspond to the importance of each indicator, and it was divided into three grades: 5 points, 3 points and 1 point (Table 4).

2.2 Calculation results and grade classification

According to the results of the comprehensive evaluation, plants were divided into four grades according to the scores. The flower border plants with the comprehensive score of 3.664 2−4.069 9 belong to grade I, including 19 species (accounting for 27.14%); the flower border plants with the comprehensive score of 3.231 9−3.662 1 are at grade II, containing 36 species (accounting for 51.42%). There are 8 species of flower border plants with the comprehensive score of 2.793 5−3.231 8 (grade III), accounting for 11.42%. The flower border plants with the comprehensive score of lower than 2.793 4 belong to grade IV, containing 6

Table 1 Comprehensive evaluation model of landscape value hierarchy of flower border plants

Target layer A	Criterion layer C	Indicator layer P	Scheme layer D
Comprehensive evaluation of flower border plants A	Adaptability (C_1)	Cold resistance (P_1), heat resistance (P_2), waterlogging resistance (P_3), and drought resistance (P_4)	70 plants to be evaluated
	Ornamental value (C_2)	Plant type (P_5), flower viewing (P_6), fruit viewing (P_7), leaf viewing (P_8), and flower quantity (P_9)	
	Economy (C_3)	Replacement frequency (P_{10}), maintenance difficulty (P_{11}), and price and source (P_{12})	

Table 2 Judgment matrices and consistency test

Model layer		Judgment matrix machine scale					W	Consistency test
A−C		C_1	C_2	C_3				
C_1	C_1 Adaptability	1.000 0	0.333 3	2.000 0			0.251 9	λ_{max}=3.053 90
C_2	C_2 Ornamental value	3.000 0	1.000 0	3.000 0			0.588 9	*CI*=0.030
C_3	C_3 Economy	0.500 0	0.333 3	1.000 0			0.159 3	*CR*=0.052
C_1−P		P_1	P_2	P_3	P_4			
	P_1 Cold resistance	1.000 0	2.000 0	0.333 3	1.000 0		0.215 1	
	P_2 Heat resistance	0.500 0	1.000 0	0.333 3	0.500 0		0.117 9	λ_{max}=4.081 51
	P_3 Waterlogging resistance	3.000 0	3.000 0	1.000 0	3.000 0		0.488 9	*CI*=0.030
	P_4 Drought resistance	0.666 7	2.000 0	0.333 3	0.666 7		0.178 1	*CR*=0.030 5
C_2−P		P_5	P_6	P_7	P_8	P_9		
	P_5 Plant type	1.000 0	5.000 0	3.000 0	6.000 0	7.000 0	0.515 7	
	P_6 Flower viewing	0.200 0	1.000 0	1.000 0	5.000 0	0.500 0	0.137 0	λ_{max}=5.405 21
	P_7 Fruit viewing	0.333 3	1.000 0	1.000 0	3.000 0	0.500 0	0.129 2	*CI*=0.030
	P_8 Leaf viewing	0.166 7	0.200 0	0.333 3	1.000 0	0.333 3	0.049 8	*CR*=0.090 4
	P_9 Flower quantity	0.142 9	2.000 0	2.000 0	3.000 0	1.000 0	0.168 3	
C_3−P		P10	P11	P12				
	P_{10} Replacement frequency	1.000 0	2.000 0	0.500 0			0.263 4	λ_{max}=3.350 90
	P_{11} Maintenance difficulty	0.500 0	1.000 0	0.142 9			0.109 9	*CI*=0.020
	P_{12} Price and source	2.000 0	7.000 0	1.000 0			0.626 7	*CR*=0.034

Table 3 Total sorting weight

Target layer	Criterion layer	W	Indicator layer	W	Total sorting weight
A	C_1	0.251 9	P_1	0.215 1	0.054 2
			P_2	0.117 9	0.029 7
			P_3	0.488 9	0.123 1
			P_4	0.178 1	0.044 9
	C_2	0.588 9	P_5	0.515 7	0.303 7
			P_6	0.137 0	0.080 7
			P_7	0.129 2	0.076 1
			P_8	0.049 8	0.029 3
			P_9	0.168 3	0.099 1
	C_3	0.159 3	P_{10}	0.263 4	0.041 9
			P_{11}	0.109 9	0.017 5
			P_{12}	0.626 7	0.099 8

Table 4 Scoring criteria of flower border plants in Hefei

Evaluation indicator	Score		
	5	3	1
P1 Cold resistance	Extremely strong resistance to freezing damage	Strong resistance to freezing damage	The ability to resist freezing damage is poor, and it is easy to suffer freezing damage
P2 Heat resistance	Very resistant to waterlogging, and surviving in a damp environment for a long time	Resistant to waterlogging, and surviving in a damp environment for a short time	Not resistant to waterlogging
P3 Waterlogging resistance	Rarely needing watering	Needing watering due to long-term drought	Needing frequent watering
P4 Drought resistance	Strong heat resistance	Recovering after sun exposure	Not resistant to heat
P5 Plant type	Flowers are beautiful and have a fragrance	Flowers are beautiful	Flowers are small and have no fragrance
P6 Flower viewing	Compact and graceful	Relatively compact	Loose, and having a poor effect
P7 Fruit viewing	Fruits are strange and large	Fruits are large and ordinary in shape	Fruits are few and small
P8 Leaf viewing	Denser flowers	Plain flowers	Sparser flowers
P9 Flower quantity	Colorful leaves with bright colors	Emerald green, and green	Grayish green
P10 Replacement frequency	Perennial plants that require nearly no replacement	Perennial plants that need to be replaced every several years	Annual and biennial plants that need to be replaced annually
P11 Maintenance difficulty	Seedlings are cheap and easy to obtain	Seedling prices are average	Seedlings are expensive
P12 Price and source	Plants grow well and do not require much maintenance	Plants grow well and need to be maintained	Plants grow generally and need careful care

Table 5 Scoring results of flower border plant indicators

No.	Plant name	Comprehensive score	Grade	No.	Plant name	Comprehensive score	Grade
1	*Hypochaeris ciliata* (Thunb.) Makino	4.069 9	Ⅰ	36	*Celosia cristata* L.	3.538 4	Ⅱ
2	*Lavandula angustifolia* Mill.	3.926 4	Ⅰ	37	*Rhododendron indicum* (L.) Sweet	3.535 5	Ⅱ
3	*Pittosporum tenuifolium*	3.865 3	Ⅰ	38	*Rhododendron simsii* Planch.	3.535 5	Ⅱ
4	*Echinacea purpurea*	3.828 7	Ⅰ	39	*Sedum lineare* 'Aurea'	3.529 8	Ⅱ
5	*Plumbago auriculata* Lam.	3.811 5	Ⅰ	40	*Nandina domestica* Thunb.	3.513 8	Ⅱ
6	*Verbena bonariensis* L.	3.803 3	Ⅰ	41	*Digitalis purpurea* L.	3.493 6	Ⅱ
7	*Muhlenbergia capillaris*	3.803 3	Ⅰ	42	*Dahlia pinnata* Cav.	3.473 0	Ⅱ
8	*Dianthus chinensis* L.	3.766 4	Ⅰ	43	*Miscanthus sinensis*	3.450 9	Ⅱ
9	*Osmanthus fragrans* var. *thunbergii*	3.764 0	Ⅰ	44	*Tagetes erecta* L.	3.449 4	Ⅱ
10	*Loropetalum chinense* var. *rubrum* Yieh	3.764 0	Ⅰ	45	*Cuphea hookeriana* Walp.	3.445 5	Ⅱ
11	*Salvia farinacea* Benth.	3.761 4	Ⅰ	46	*Jacobaea maritima*	3.436 8	Ⅱ
12	*Yucca gloriosa*	3.751 9	Ⅰ	47	*Viola* × *wittrockiana* Gams	3.428 7	Ⅱ
13	*Rosmarinus officinalis* L.	3.734 4	Ⅰ	48	*Farfugium japonicum* (L. f.) Kitam.	3.360 5	Ⅱ
14	*Canna* × *generalis* L.H. Bailey	3.699 9	Ⅰ	49	*Vinca major* L.	3.337 7	Ⅱ
15	*Fatsia japonica* (Thunb.) Decne. & Planch.	3.699 1	Ⅰ	50	*Serissa japonica* (Thunb.) Thunb.	3.315 6	Ⅱ
16	*Hydrangea paniculata* Siebold	3.694 4	Ⅰ	51	*Ilex crenata* Thunb.	3.281 3	Ⅱ
17	*Ipomoea nil* (L.) Roth	3.690 7	Ⅰ	52	*Agastache foeniculum*	3.266 5	Ⅱ
18	*Buddleja davidii* Franch.	3.680 2	Ⅰ	53	*Lantana montevidensis*	3.260 4	Ⅱ
19	*Hibiscus mutabilis* L.	3.664 2	Ⅰ	54	*Syringa reticulata* subsp. *pekinensis* (Ruprecht) P. S. Green & M. C. Chang	3.252 4	Ⅱ
20	*Rosa chinensis* Jacq.	3.657 3	Ⅱ	55	*Ligustrum japonicum* Thunb.	3.243 9	Ⅱ
21	*Canna* × *generalis* L.H. Bailey	3.639 9	Ⅱ	56	*Hosta ventricosa* (Salisb.) Stearn	3.231 9	Ⅱ
22	*Iris tectorum* Maxim.	3.635 3	Ⅱ	57	*Begonia grandis* Dryand.	3.154 1	Ⅲ
23	*Salvia splendens* Ker Gawl.	3.628 4	Ⅱ	58	*Tulbaghia violacea*	3.148 0	Ⅲ
24	*Pelargonium hortorum* Bailey	3.625 3	Ⅱ	59	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.	3.105 6	Ⅲ
25	*Trachelospermum asiaticum* (Siebold & Zucc.) Nakai	3.623 7	Ⅱ	60	*Acer palmatum* '*Atropurpureum*' (Van Houtte) Schwerim	3.010 1	Ⅲ
26	*Farfugium japonicum* (L. f.) Kitam.	3.619 3	Ⅱ	61	*Acorus calamus* L.	2.952 9	Ⅲ
27	*Tagetes patula* L.	3.619 1	Ⅱ	62	*Chasmanthium latifolium* (Michx.) H. O. Yates	2.941 0	Ⅲ
28	*Gomphrena globosa* L.	3.619 1	Ⅱ	63	*Acorus gramineus* Soland.	2.817 3	Ⅲ
29	*Torenia fournieri* Linden. ex Fourn.	3.613 8	Ⅱ	64	*Buxus sempervirens* L.	2.793 5	Ⅲ
30	*Salvia leucantha*	3.603 6	Ⅱ	65	*Cycas revoluta* Thunb.	2.635 1	Ⅳ
31	*Hosta plantaginea* (Lam.) Aschers.	3.596 6	Ⅱ	66	*Brassica oleracea* var. *acephala* DC.	2.607 9	Ⅳ
32	*Lantana camara* L.	3.584 1	Ⅱ	67	*Ligustrum* × *vicaryi* Rehder	2.606 5	Ⅳ
33	*Nandina domestica* Thunb.	3.583 9	Ⅱ	68	*Hedera canariensis* Willd.	2.580 5	Ⅳ
34	*Leucanthemum maximum* (Ramood) DC.	3.560 8	Ⅱ	69	*Acorus gramineus* 'Ogan'	2.438 5	Ⅳ
35	Liriope platyphylla F. T. Wang & Tang	3.557 8	Ⅱ	72	*Muehlenbeckia complexa* Meisn.	2.351 9	Ⅳ

species (accounting for 8.57%).

3 Distribution and types of flower borders in Hefei

A total of 40 flower borders were surveyed, and they are distributed in eight administrative areas in Hefei. According to the survey, flower borders in Hefei are mainly street green space and roads, accounting for 40% and 22.5% respectively, followed by campus green space, residential green space and isolation belt green space. It can be seen that flower borders are mostly used in green space along streets and on both sides of roads, reflecting that green space is more used in administrative green space at the emerging stage, and there is less campus green space, residential green space and isolation belt green space. The flower borders are concentrated mainly in Yaohai District and Baohe District, while the number is small in other administrative areas. Among the 40 flower borders surveyed, 10 flower borders are located in Yaohai District, and 9 flower borders are located in Baohe District, while the number is very small in areas far away from the city center.

4 Conclusions and discussion

4.1 Conclusions

In this study, 40 flower borders in 8 administrative areas of Hefei City were investigated from the aspects of plants and application of flower borders. By using AHP, the comprehensive evaluation system of flower border plants in Hefei was established to evaluate their landscape value from three aspects: ornamental value, adaptability and economy, and then 12 indicators such as cold resistance, waterlogging resistance, drought resistance, flower viewing, plant type, fruit viewing and flower quantity were refined. Among them, drought resistance (P_3), flower viewing (P_5), leaf viewing (P_9) and maintenance difficulty (P_{12}) have the highest weight and are also the most important. In the design of flower borders, these four indicators should be given priority to in the selection of plants. The comprehensive scores of these 70 plants were calculated and divided into four grades, which provided scientific basis for the selection of flower border plants in Hefei in the future. Besides, the application types, locations, number and distribution of various types of flower borders along roads, park green space and street green space in Hefei were summarized to provide scientific basis for the main location of flower border development in the future.

4.2 Discussion

According to the scoring results of plants, the number of plants at grade I is slightly less than that of plants at grade II, and that of grade-III and grade-IV plants is relatively small. It can be seen that the application of flower border plants in Hefei is generally good, but there is still a certain room for improvement. Although many grade-II plants have greater advantages in some aspects and score higher, these plants also have obvious shortcomings, which will pull down their score. For example, *C.*×*generalis* L.H. Bailey has a good flower viewing effect, but it is afraid of waterlogging and gale, and the environmental effect is poor in winter, so the score is low. Grade-III and grade-IV plants have many disadvantages, but some have unique advantages in one aspect. In the design of flower borders, grade-I plants can be selected, and grade-II plants can be selected according to the environment and field conditions, while the close relatives and hybrids of grade-IV and grade-IV plants can be selected according to their own advantages. According to the analysis of the location classification of flower borders in Hefei, it is found that most of the flower borders exists in street green space, and only a small part is used as residential green space and school green space. Flower borders are still mostly used in urban administrative greening, and have not been fully integrated into people's lives. At present, flower borders are relatively concentrated, and few flower borders are slightly away from the urban area. There is a lack of government support and investment. The government should strengthen the construction of flower borders in various places, not restrict the construction of flower borders to urban administrative roads, create people-oriented flower borders[6], and integrate flower borders into people's lives.

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