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Ornamental Evaluation of 30 *Viola* Germplasm Resources Based on AHP-TOPSIS

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Abstract: Ornamental evaluation is the important foundation for cross breeding. The Analytic Hierarchy Process (AHP) was used to evaluate the ornament of 30 *Viola* cultivars. The AHP model for *Viola* ornamental evaluation which consisted of the following three level: Target level, criterion level and index level. The target level is the comprehensive ornamental evaluation of *Viola*. The criterion level consisted of the three factors: Flower, leaf and plant shape. The index level includes branch number, plant width, plant height, flower color, the number of flower, florescence, blotch, the diameter of flower, leaf area, leaf length and leaf width. In the criterion level, flower with more weight; In the index of flower, flower diameter had maximum weight, next came flower number .The result showed The AHP method can provide scientific basis for *Viola* ornamental evaluation. About 30 *Viola* cultivars could be classified via AHP method into three grades. The CYS-H3, X1.11, X1.19, HSY4-1 possessed the highest ornamental value for prior utilization in *Viola* breeding.

Key words: *Viola*, analytic hierarchy process, ornamental evaluation

INTRODUCTION

Viola verecunda is perennial herb that belongs to genius *Viola*, which often used as annual and biennial cultivation. It originate from Europe, It is colorful, rich in color, early blooming, long florescence and well-known as early spring flowers (Chen *et al*., 1998). China began to introduce *Viola* in the 1920's, *Viola verecunda* increasingly used in recent years (Yang, 2002). With the introduction of *Viola* breed resource increased continuously, science evaluation is a fundamental job for the rational utilization (Dai, 2007). *Viola* ornamental evaluation included some target characters. These characters have a subjective and objective index, requires the combination of qualitative analysis with quantitative analysis in decision-making. Analytic hierarchy process is a qualitative and quantitative, systematic and hierarchical analysis method, with simple, flexible, practical characteristics (Yu and Fu, 2004). It is widely used in landscape evaluation (Li, 2005), tree species selection (Liu, 2007), forage varieties screening (Zhang *et al*., 2010b), horticultural plant quality appraisal (Liu *et al*., 2006) but it has not been reported in the appreciation of the *Viola* evaluation. The study used 30 *Viola* materials as the test materials, ornamental hierarchy analytic structure model of *Viola* tricolor is established on the basis of ornamental characteristics investigation, via the comprehensive evaluation, the applicability of Analytic Hierarchy Process (AHP) was discussed in the ornamental evaluation of *Viola* materials. This study also provides references for the rational utilization of *Viola* germplasm resources.

MATERIALS AND METHODS

Material: About 30 *Viola* germplasm resources were used as test materials, which consisted of materials collected from the United States, the Netherlands, Shanghai city, Jiuquan city (Gansu province) and the cultivars of germplasm materials which were bred in our laboratory in recent years. Firstly, the 30 test materials were sown in nutrient pot on October 4, 2012. Then the seedlings were cultured in the greenhouse. Lastly, the 30 test materials with 6-7 leafs were transplanted in the field on March 27, 2013 at a planting space of 0.3×0.3 m. Randomized block design with three replications was used, 20 test materials were planted in an experimental plot.

Construction of AHP model: The ornamental plant resources evaluation index, interdependence effect among index and AHP hierarchy jurisdiction relations were referenced, a comprehensive chart of the *Viola* ornamental evaluation (AHP model) was established (Fig. 1).

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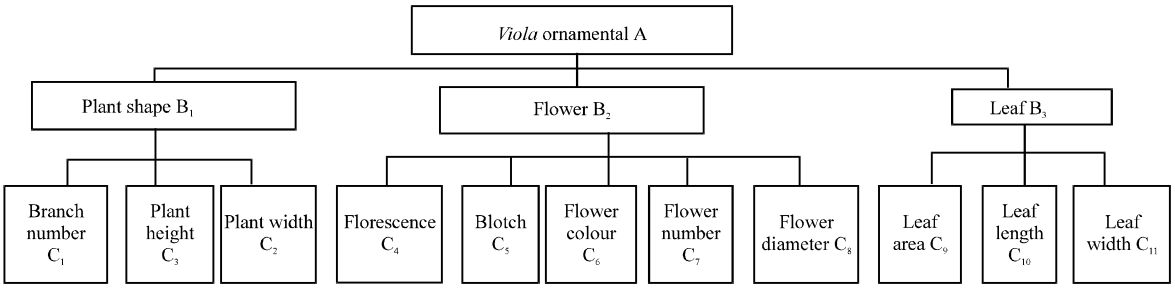

Fig. 1: AHP model of *Viola* ornamental assessment system

Table 1: Standard significance of 1-9 scales

Standard value	Definition illustration
1	Two indexs are of equal importance
3	Former is slightly more important than the latter
5	Former was more important than the latter
7	Former is more important than the latter strongly
9	Former is extreme important than the latter

Table 2: Evaluation standard of different quantity factors

Score	Flower color	Blotch	Florescene (d)
9	Golden yellow, orange, purple	Brown spot	>80
7	Rose red, purple	Black (purple) spot	80~71
5	Blue, blue purple, yellow	Yellow spot	70~60
3	Black, purple black	White spot	59~40
1	Milky white	No spot	<40

Judgment matrix and consistency check: According to the theory of Analytic Hierarchy Process (Zhao and Xu, 1986) and the garden expert's qualitative evaluation of importance on the ornamental traits in 30 *Viola* materials, the 1-9 proportional scaling method (Table 1) was used to established judgment matrix, calculated the matrix maximum eigen value: λ_{max}, consistency index CI is calculated according to the equation:

$$CI = \frac{\lambda_{max} - N}{N - 1}$$

where, N is total number in the matrix and CR is calculated according to the equation:

$$CR = \frac{\left(\frac{\lambda_{max} - N}{N - 1}\right)}{RI}$$

where, RI is read from the consistency table. The weight coefficient of each index traits (w_i) is calculated by the square root method (Lin, 1998).

Measurement project: The 10 *Viola* materials with strong growth at full-bloom stage in every experimental plot were chose to investigate plant height, plant width, branch number, florescence, blotch, flower color, flower number, flower diameter, leaf length, leaf width and the leaf area was calculated (Wang and Bao, 2007):

$$\text{Leaf area} = \frac{\left(\frac{1}{4}\right)\pi}{\text{Leaf length} \times \text{width}}$$

Data processing: According to the relevant references (Liu, 2007) and the advice of garden experts who came from Henan institute of science and technology, color, blotch and florescence evaluation standards were established (Table 2), 30 *Viola* materials were analyzed according to the equation:

$$X_{ij(standard)} = \frac{X_{ij(original)}}{\sum X_{ij(original)}} \times 100$$

where, each character index was normalized, in the equation, $X_{ij(original)}$ was a comprehensive evaluation score, $X_{ij(original)}$. For quantitative indicators is the average of all investigated scores, the comprehensive score of each index is calculated according to the equation:

$$y_i = \sum w_j d_{ij}$$

where, y_i is the comprehensive score of the i-th system in the equation and w_j is the weight coefficient that corresponding to d_{ij} (the evaluation index) (Liu *et al*., 2006).

RESULTS

Comprehensive evaluation system of A H P model: As for the plants which mainly used in flower beds or in the flower border or herb flowers that used as potted flower, the mainly ornamental requirement is flower (such as flower color, blotch, flower size, flower number, florescence), the second is the plant shape which associated with plant height, plant width, branch number,

the third is the cover effect to the ground which associated with the leaf size. A comprehensive chart of the *Viola* ornamental evaluation (AHP model) was established. The Fig. 1 showed that the model is divided into three levels: the first is target level: (1) A comprehensive evaluation to *Viola* ornamental; the second is criterion level: (2) which is marked as B = (B1, B2, B3) = (plant shape, flower, leaf), these is the three aspects of affecting the *Viola* ornamental; the third is index level: (3) which is marked as: C = (C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11) = (branch number, plant width, plant height, florescence, blotch, flower color, flower number, flower diameter, leaf area, leaf length, leaf width). The model can satisfy the basic requirements of the comprehensive evaluation of *Viola* ornamental.

Judgment matrix and weight coefficient: Table 3 was the judgment matrix of each criterion level under target level of *Viola* ornamental. Table 4-6 was the judgment matrix of each characteristic index that under criterion level. Table 3-6 showed that CR were less than 0.1 in each judgment matrix, the consistency check was passed, this showed the established judgment matrix is reasonable.

Judging from the from the weight coefficient W_i, W_2 of flowers (B_2) was the maximum among plant shape, flower and leaf, followed by the W_1 of the plant (B_1). This showed that the flower was the most important index of resource evaluation, but the plant shape was one of the important index which influence the whole ornamental value of *Viola*. The weight coefficient of branch number (C_1 = 0.6491) was larger in the plant shape. The weight coefficient of flower diameter (C_8 = 0.4679) was the largest in the flower factor, The weight coefficient of leaf area (C_9 = 0.5954) reaches 0.5954 in the leaf factor. As was shown from the weight coefficients of comprehensive evaluation in each index characteristic (Table 7), flower diameter was the largest, followed by branch number, again was the flower number.

Table 3: Matrix based on *Viola* ornament

A	B_1	B_2	B_3	W_i
B1	1	1/4	4	0.301
B2	2	1	5	0.5695
B3	1/4	1/5	1	0.0974
λ_{max} = 3.0246,	CI = 0.0123	RI = 0.5769	CR = 0.0213	

Table 4: Matrix based on plant shape B_1

B_1	C_1	C_2	C_3	W_i
C1	1	3	7	0.6491
C2	1/3	1	5	0.271
C3	1/7	1/5	1	0.0719
λ_{max} = 3.0649	CI = 0.0324	RI = 0.5769	CR = 0.0562	

Table 5: Matrix based on flower character B_2

B_2	C_4	C_5	C_6	C_7	C_8	W_i
C4	1	1/4	1/6	1/7	1/8	0.0314
C5	4	1	1/3	1/5	1/7	0.069
C6	6	3	1	1/3	1/5	0.1374
C7	7	5	3	1	1/2	0. 2926
C8	8	7	5	2	1	0.4697
λ_{max} = 5.2938	CI = 0.0735	RI = 1.109	CR = 0.0656			

Table 6: Matrix based on leaf character B_3

B_3	C_9	C_{10}	C_{11}	W_i
C9	1	2	5	0.5954
C10	1/2	1	2	0.2764
C11	1/5	1/2	1	0.1283
λ_{max} = 3.0055	CI = 0.0028	RI = 0.5769	CR = 0.0048	

Table 7: Index weight coefficient of *Viola* ornamental assessment

Item	Plant shape (W_{B1} = 0.3031)	Flower (W_{B2} = 0.5695)	Leaf (W_{B3} = 0.0974)	Weight coefficient
Branch number	0.6491			0.2162
Plant width	0.279			0.0929
Plant height	0.0719			0.024
Florescence		0.0314		0.0179
Blotch		0.069		0.0393
Flower color		0.1374		0.0783
Flower number		0.2926		0.1666
Flower diameter		0.4769		0.2665
Leaf area			0.5954	0.058
Leaf length			0.2762	0.0269
Leaf width			0.1283	0.0125

Table 8: Ornamental character of 30 *Viola* cultivars

Cultivars	Flower diameter	Flower number	Flower color	Blotch
X1.01	4.71	30.50	Golden yellow	Nothing
X1.02	5.02	29.00	Red	Black spot
X1.03	4.36	40.60	Orange	Nothing
X1.04	4.45	36.50	Milky white	Nothing
X1.07	6.25	44.00	Purple	Black spot
X1.08	5.91	40.80	White	Nothing
X1.09	3.75	37.50	Blue	Brown spot
X1.10	4.75	39.50	Golden yellow	Black spot
X1.11	5.61	44.00	Black	Nothing
X1.14	5.69	26.60	Deep purple	Nothing
X1.18	5.32	46.70	White	Purple spot
X1.19	4.97	52.60	Red and yellow	Black spot
EXX	5.45	50.00	Blue	Black spot
ERX	6.05	36.00	Pure yellow	Nothing
XSYO-2	6.01	26.30	Pure white	Nothing
ZMY2-1	6.21	30.80	Purple	Brown spot
HSY4-1	2.85	16.30	Golden yellow	Nothing
CYS-H3	5.86	57.00	Yellow	Brown spot
HWP51	6.25	25.00	White, purple	Brown spot
HED	5.44	45.60	Purple black	Nothing
HEL-1	5.36	55.00	Yellow	Purple spot
HEL-2	6.46	40.00	Purple yellow double color	Nothing
HEL-3	6.30	29.75	Purple	White spot
10WP-1	5.86	38.40	White and purple gradient	Nothing
10YP-1	5.94	27.00	Yellow	Brown spot
CC -YS1	5.36	30.60	Purplish red	Nothing
CC -YS2	6.30	31.00	Rose red	Yellow spot
CC -YS3	6.50	12.50	Rose red	Black spot
AA-1	5.07	49.60	Pure yellow	Purple stripes
AA-2	6.47	23.60	Golden yellow	Nothing

Table 9: Comprehensive scores of each *Viola*

Cultivar	Comprehensive scores	Grouping	Cultivar	Comprehensive scores	Grouping
CYS-H3	47.81	I	CC -YS2	35.19	II
X1.11	47.75	I	X1.01	34.30	II
X1.19	44.44	I	X1.1	34.28	II
HSY4-1	40.18	I	XSYO-2	30.93	II
HWP51	39.41	II	X1.09	30.88	II
X1.03	39.35	II	X1.02	30.68	II
X1.07	39.00	II	HEL-3	30.67	II
X1.18	38.75	II	X1.14	30.39	II
X1.08	38.46	II	ZMY2-1	30.21	II
X1.04	37.46	II	HEL-2	32.29	II
CC -YS1	37.03	II	10WP-1	32.15	II
CC -YS2	37.02	II	HED	31.25	II
HEL-1	36.85	II	AA-1	27.78	III
ERX	36.44	II	AA-2	27.06	III
EXX	36.36	II	10YP-1	23.78	III

order standard I>40.0, II = 30.0-40.0, III<30.0

Comprehensive evaluation for ornamental of *Viola* cultivars: Data of ornamental characteristic in every tested *Viola* cultivars were shown in Table 8. The comprehensive score for the ornamental of each *Viola* material was obtained according to the investigated data, the score of each cultivars and the weight of each index in AHP analysis (Table 9), the results indicated that the higher the score, the better the ornamental value of materials.

Table 9 showed that the comprehensive score of tested *Viola* materials was 23.78~47.81. 30 *Viola* material were divided into 3 levels according to the scores. The first level was >40 points, these consisted of CYS-H3, X1.11, X1.19, HSY4-1; the total score of the second level was 30~40 points, these included HWP51, X1.03, X1.07, X1.18, X1.08, X1.04, CC-Ys1, CC-Ys3, HEL-1, ERX, CC-Ys2, X1.01, X1.10, XSYO-2, X1.09, X1.02, HEL-3, X1.14, ZMY2-1, HEL-2, 10WP-1, HED, EXX, which had medium ornamental value; the total score of the third level is <30 points, these included AA-1, AA-2, 10YP-1, which had low ornamental value.

DISCUSSSION

The AHP model established for the comprehensive evaluation of the *Viola* ornamental in this study, included target level, criterion level and index level, the index level contained 11 characteristic index that closely related to *Viola* ornamental value, This study indicated that the AHP method could be adapted for ornamental evaluation of *Viola*, the AHP model was more comprehensive and systematic. The consistency check was passed in four *Viola* judgment matrix established in this study obtained. the rationality of each factor weight coefficient showed that flowers was the largest weight in three factors of the criterion level, followed by the plant shape, then again leaf. the results were consistent with the practical need that *Viola* is mainly used as cover plant or potted flower, Normally, this type of plant was pluriflorous, larger flower, long florescence and compact plant type etc (Zhang *et al*., 2010a). The weight coefficient of all indexs in the index level, flower diameter is the largest, this is consistent with the habit that *Viola* varieties are divided into big flower, medium flower, small flower type according to flower size (Chen *et al*., 1998). Therefore, the AHP model of *Viola* ornamental evaluation and judgment matrix established in this article is complete, reasonable and practical, this indicated the AHP model could be used for the resource evaluation of *Viola* cultivars and the selection of breeding materials.

The results of the ornamental evaluation of 30 *Viola* germplasm resources showed that CYS-H3, X1.11, X1.19, HSY4-1 in 30 *Viola* materials have a higher ornamental value, these should be given the priority option to utilize; and AA-1, AA-2, 10YP-1 has a low ornamental value, these could be conserved as germplasm resources; the ornamental value of other materials are moderate, these could be chose to use in combination with their characteristics according to the breeding goal.

CONCLUSION

The results from this study have confirmed that the AHP model for ornamental evaluation of *Viola* germplasm resources is a more appropriate and feasible approach to evaluate the *Viola* germplasm resources In addition, the results showed CYS-H3, X1.11, X1.19, HSY4-1 in 30 *Viola* materials possessed the higher ornamental value for prior utilization. The approach proposed in this study can easily be used to evaluate other herbaceous flowers.

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