Middle-East Journal of Scientific Research 8 (1): 216-221, 2011
ISSN 1990-9233

A Research on the Comprehensive Evaluation Method in *Paeonia*

[1]X.M.Sun, [1]H.D.Gao, [2]W.Q.Zhou, [1]H.G. Yang, [1]M.M. Zhang and [2]D.Wang

[1]Forestry College, Shenyang Agricultural University, Shenyang, China
[2]Shenyang Botanical Garden, Shenyang, China

Abstract: The paper adopted the Analytic Hierarchical Process to build the comprehensive evaluation model of *Paeonia* cultivars, establish matrixes of judgement, examine the consistency and calculate the inportance weights which were modified by the entropy technology. 102 *Paeonia* cultivars in Shenyang have been appraised comprehensively on the basis of the standards of appraisal and four grades were ranked. The research offered have recommendations to the utilization of *Paeonia* cultivars in landscape in Shenyang, it will be a useful for selecting the parents in the breeding and an effective example of the flower evaluation.

Key words: AHP · Entropy technology · *Paeonia* cultivars · Comprehensive evaluation

INTRODUCTION

Paeonia suffruticosa and *Paeonia lactiflora* respectively belong to *Sect. Moutan* and *Sect. Paeonia* of *Paeonia Paeoniaceae*, they are known as the "flower of two away" reputation. At present, they have been widely applied in landscape. Zhongyuan area and the northwest region of China were main productions of China's *Paeonia* plants, but the varieties which were suitable for growth in the northeast region of China haven't seen detailed reports [1]. For landscaping speaking, it has the very vital significance for exploring *Paeonia* cultivars which can adapt to cold temperatures in winter in Shenyang area and have the high ornamental value. The comprehensive evaluation to *Paeonia* cultivars can provide some advice for the utilization of *Paeonia* cultivars in landscape in Shenyang and it was useful for selecting the parents in the breeding.

Analytic Hierarchical Process(abbreviated AHP) was a decision method proposed by an American operation professor named T.L.Satty in the 1970s [2]. AHP was an effective method of the flower varieties selection [3]. However, there were some drawbacks if only using it to the evaluation, which made evaluation results not accurate enough [4]. So this paper adopted the method that AHP and entropy technology combined to appraise *Paeonia* cultivars.

MATERIALS AND METHODS

Plant Materials: 102 *Paeonia* cultivars (including 30 *Paeonia suffruticosa* cultivars and 72 *Paeonia lactiflora* cultivars) were investigated in Shenyang Botanical Garden. They were the plants of the same age (6 years) in the same site conditions and 10 strains of each cultivar were investigated.

Research Methods

Build Index System of Hierarchy Evaluation: We screened out 12 evaluation indexes according to the characteristics of *Paeonia* cultivars, which were the factors to evaluate the ornamental values and growth conditions of *Paeonia* cultivars. In accordance with the nature of each index, the evaluation indexes could be classified to the shape quality traits 'the quantitative traits' the flowering characters and the growth characters, thus they constituted an analysis structure model of multi-level (Fig. 1 indicated). The model could be divided into three layers:Target layer(A)was the comprehensive evaluation of *Paeonia* cultivars, that was the comprehensive evaluation value; Criterion strata (B) was the main criteria to determine the comprehensive evaluation value, that was the main traits of the evaluation; Index layer (C) belonged to Target layer, including all the evaluation indexes.

Corresponding Authors: X.M.Sun, Forestry College, Shenyang Agricultural University, Shenyang, China.

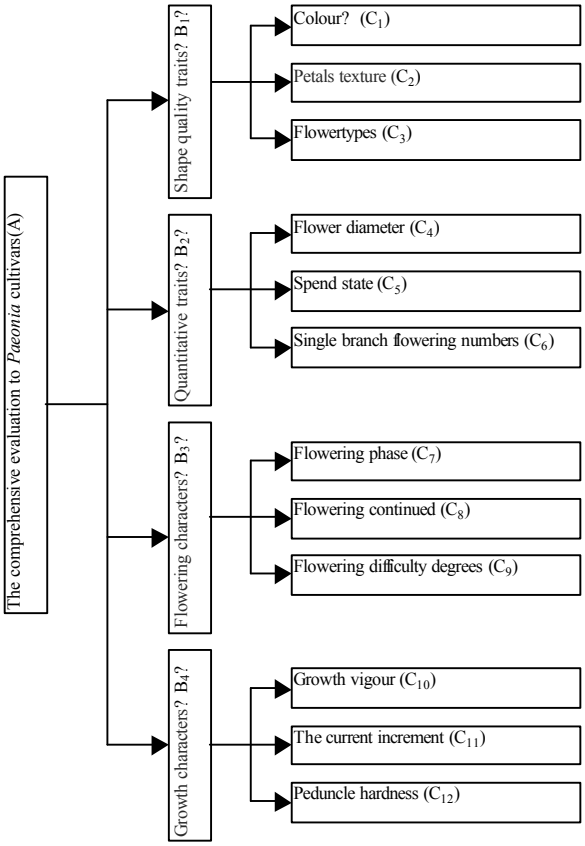

Fig. 1: The level model of the comprehensive evaluation to *Paeonia* cultivars

Indexes Weights

Ascertain the Weights of Evaluation Factors with AHP: According to the evaluation procedure of AHP, the relative importance of all the factors between two of each layer were compared after getting the analysis structure model above, thus the judgment matrixes were formed.

Tab.1 indicated the evaluation rules [5] of judging the relative importance of two indexes.

This paper adopted a evaluation method named "Expert consultation",we provided the consulting questionnaires to the experts and scholars who engaged in flower research (Note: We have provided 40 consulting questionnaires, recovered 36 valid questionnaires from them, the valid percentage was 90%), they judged the relative importance between each factor of each layer according to the overall goal. We constructed the judgment matrix of each layer ($A\text{-}B_i$ $B_1\text{-}C_i$ $B_2\text{-}C_i$ $B_3\text{-}C_i$ $B_4\text{-}C_i$) according to the consulting questionnaires and Tab.1. After that, we could use the arithmetic average method to calculate the maximum eigenvalues and the corresponding feature vectors of each judgment matrix, thereby got the weights. Considered the length of the article, the judgment matrixes and the weights were omitted (The weights which were modified by the entropy technology would be listed in Tab.3). After establishing the judgment matrixes, we must examine the consistency of them.According to AHP, "CI"was the index to measure the deviation degree of the consistency.

$CI = (\lambda \text{ max}-1)/(n-1)$ ("λ max" was the maximum eigenvalue, "n"was the order number of the judgment matrix).

It was known that the order number was bigger, the consistency of the judgment matrix was poorer. Therefore, the average random consistency index (RI) was introduced to rectify the consistency test index. "RI" was relation to the order number of the judgment matrix, which could be checked from "The table of the average randomn consistency index" [2].

Table 1: The scale of indexes

Scale	Evaluation rules
1	It shows that two factors have the same importance through comparing
3	It shows that a factor is slightly more important than another factor through comparing
5	It shows that a factor is obviously more important than another factor through comparing
7	It shows that a factor is strongly more important than another factor through comparing
9	It shows that a factor is extremely more important than another factor through comparing
2□4□6□8	They show the median of the two adjacent judgment above
The countdown of the foregoing numbers	If i and j compared to get verdict a, while i and j compared to get verdict l/a.

Table 2: The maximum eigenvalues and the consistency indexes of each judgment matrix

Index level	λmax	*CI*	CR
$A\text{-}B_i$	4.171	0.057	0.063(n=4, RI=0.90)
$B_1\text{-}C_i$	3.065	0.033	0.056(n=3, RI=0.58)
$B_2\text{-}C_i$	3.065	0.033	0.056(n=3, RI=0.58)
$B_3\text{-}C_i$	3.065	0.033	0.056(n=3, RI=0.58)
$B_4\text{-}C_i$	3.080	0.040	0.069(n=3, RI=0.58)

The index judging the consistency of the matrixe (CR) was expressed as the following:

$$CR = CI/RI$$

When "CR" was less than 0.10, it was thought that the consistency of the judgment matrix could be accepted and vice versa.

We could calculate the maximum eigenvalues and the consistency indexes (listed in Tab.2) via the information of the judgment matrixes of each layer and the formula above.

From Tab.2 knowable, all the matrixes throughed the consistency examination. To examine the consistency of the hierarchy total sort, we could figured out the value of "CR"was 0.0626(< 0. 10), so it also throughed the consistency examination. Therefore, the reliability of the results was satisfactory.

Modify The Index Weights by the Entropy Technology: Entropy was originally a thermodynamic concept. It was first introduced to the information theory by C.E.Shannon and it was a measure of the system disorder degree. The increase of the information means the reduction of the entropy, thus the entropy could be used to measure the size of the information [6]. The following method was how to modify the index weights by the entropy technology [7]:

$R = (r_{ij})_{n\times n}$ (the judgment matrixes constructed) were normalized according to the formula "$\bar{r}_{ij} = r_{ij} / \sum_{k=1}^{n} r_{kj}$" to get $\bar{R} = (\bar{r}_{ij})_{n\times n}$ (standard matrixes), then the entropy of the "i" index (E_i) was output:

$$E_i = -K\sum_{j=1}^{m} f_{ij} \ln f_{ij}$$

Among them, $f_{ij} = r_{ij} / \sum_{j=1}^{n} r_{ij}$, K = 1/lnn and assume, when f_{ij} = 0, $f_{ij}\ln f_{ij} = 0$.

The formula for the entropy weight of evaluation indexes (ω_i) was:

$$\omega_i = (1 - E_i)/(m - \sum_{i=1}^{m} E_i)$$

Among them, "m" was the number of the indexes. Then the synthesis weights of the "i" index was:

$$\mu_i = \lambda_i \omega_i / \sum_{i=1}^{m} \lambda_i \omega_i$$

Among them, "λ" was the index weight calculated by AHP.

Using the method above, the weight coefficients of each index were modified, the concrete results were listed in Tab.3.

The Rating Criteria and the Calculation of the Comprehensive Evaluation Value: In order to conduct an scientific classification to apply mathematic methods to *Paeonia* cultivars, the indexes need to be quantified, namely the corresponding score was attached to the evaluation indexes. The scoring criteria of the evaluation indexes was formulated by the survey to the characteristics of *Paeonia* cultivars, combining with the characteristics of landscape application and consulting the textbook *P. suffruticosa and P. lactiflora in China*. The scoring criteria was expressed in Tab.4.

Table 3: The inportance weights which were modified by the entropy technology

Index level	*Index code*	*E*	*ω*	*μ*	*W(Relative to A)*
A-B_i	B_1	0.8709	0.1330	0.4637	0.4637
	B_2	0.7366	0.2713	0.2950	0.2950
	B_3	0.6538	0.3566	0.1825	0.1825
	B_4	0.7678	0.2392	0.0587	0.0587
B_1-C_i	C_1	0.7828	0.2248	0.4988	0.2313
	C_2	0.6749	0.3365	0.0828	0.0384
	C_3	0.5762	0.4387	0.4185	0.1941
B_2-C_i	C_4	0.7828	0.2248	0.4988	0.1471
	C_5	0.5762	0.4387	0.4185	0.1235
	C_6	0.6749	0.3365	0.0828	0.0244
B_3-C_i	C_7	0.7518	0.3228	0.0926	0.0169
	C_8	0.6617	0.4399	0.2930	0.0535
	C_9	0.8175	0.2373	0.6145	0.1121
B_4-C_i	C_{10}	0.7194	0.2312	0.5151	0.0302
	C_{11}	0.4821	0.4268	0.4210	0.0247
	C_{12}	0.5850	0.3420	0.0640	0.0038

Note: "W" in the table were relative weights composed, which were relative to index layer A.

Table 4: The standard of appraisal defining *Paeonia* cultivars in Shenyang

		Score				
Evaluation index		1'	2'	3'	4'	5'
Color		powder blue, pink violet	purple, pink	powder with red, purple with red	red, bright red	yellow,white, multi-color
Petals texture		paper, rough	paper, smooth	silk pledges	waxy	velvet burnish
Flowertype		Single form, Anemone form	Chrysanthemum form, Rose form	Aureate stamens form□Gold ring form	Crown form, Globular form	Crown proli-feration form
Flower diameter	*P. suffruticosa*	less than 12cm	12-14cm	15-17cm	18-20cm	more than 20cm
	P. lactiflora	less than 8 cm	8-10cm	11-13cm	14-16cm	more than 16cm
Flower posture		completely hidden under the leaves	partly hidden under the leaves	side hangs	inclining to one side	upright
Single branch flowering numbers		one	two	three	four	five
Flowering phase		normal	5d sooner or later than normal	7d sooner or later than normal	10d sooner or later than normal	blossom in the other season in addition to Spring
Flowering continued		less than 5d	5-7d	8-10d	11-13d	more than 13d
Flowering difficulty degrees		not easy	have big□off-year, not easily flower forcing	have big□off-year, but not obvious	no big□off-year, flower forcing more easily	no big□off year, flower forcing more easily
Growth vigour		weak	slightly weaker	slightly stronger	strong	very strong
The annual increment	*P. suffruticosa*	less than 10cm	10-20cm	21-30cm	31-40cm	more than 40cm
	P. lactiflora	less than 60cm	60-70cm	71-80cm	81-90cm	more than 90cm
Peduncle hardness	flagging	flagging slightly	basically not flagging		straighter, harder	straight, hard

Note:The annual increment of *P. suffruticosa* cultivars was different from *P. lactiflora* cultivars. The annual increment of *P.suffruticosa* cultivars means the current branch,while the annual increment of *P.lactiflora* cultivars means the plant height

According to the index rating criteria, the indexes of the cultivars investigated were assigned to the corresponding score and combined the weight coefficients of evaluation indexes, we could calculate the comprehensive evaluation value. If the score data standardisation matrix of the evaluation index system could be expressed as $R_{m\times n}$ ("m" was the number of the indexes, "n" was the number of the evaluation samples.) and each index for the comprehensive weight vectors could be expressed as $U=(\mu_i)_m$, then the calculation formula for the comprehensive evaluation score matrix of *Paeonia* cultivars was:

$$G = U \times R = (g_1, g_2, ..., g_n)$$

Among them, g_i was the comprehensive evaluation score.

RESULTS

The grading criteria could be developed according to the distribution of the comprehensive evaluation value of *Paeonia* cultivars and the related literatures. an specific criteria was as follows: If the comprehensive evaluation value was greater than 3.8, then it could be classified as "□"; the comprehensive evaluation value who was between 3.2 and 3.8 could be classified as "□"; the comprehensive evaluation value who was between 2.6 and 3.2 could be classified as "□"; the comprehensive evaluation value who was less than 2.6 could be classified as "□".

The comprehensive evaluation score of *Paeonia* cultivars were calculated by the research methods above, then the grades were ranked (Tab.5 and Tab.6 indicated).

Table 5: The grades of *P. suffruticosa* cultivars

Cultivar	*Comprehensive evaluation value*	*Rank*	*Cultivar*	*Comprehensive evaluation value*	*Rank*
1‘Xiang Yu’	4.4213	□	16‘Luo Yang Hong’	3.0897	□
2‘Cao Zhou Hong’	4.1841	□	17‘Hai Huang’	3.0887	□
3‘Fen Zhong Guan’	4.0564	□	18‘Cai Hui’	3.0839	□
4‘Ying Luo Bao Zhu’	3.9983	□	19‘Hong Tu’	3.0581	□
5‘Zhao Fen’	3.8745	□	20‘Bai Yuan Hong Xia’	3.0263	□
6‘Yan Long Zi Zhu Pan’	3.8326	□	21‘Tai Yang’	2.8762	□
7‘Dao Jin’	3.8180	□	22‘Hei Hai Sa Jin’	2.8566	□
8‘Zhu Guang Mo Run’	3.7593	□	23‘Lan Tian Yu’	2.8524	□
9‘Jin Li’	3.5907	□	24‘Hei Hua Kui’	2.8486	□
10‘Tong Yun’	3.4928	□	25‘Chun Hong Jiao Yan’	2.8217	□
11‘Fang Ji’	3.4922	□	26‘Jin Pao Hong’	2.6578	□
12‘Wu Jin Yao Hui’	3.4228	□	27‘Xu Gang’	2.5821	□
13‘Chu Wu’	3.3470	□	28‘Zi Ban Fen’	2.5072	□
14‘Feng Dan Bai’	3.3305	□	29‘Ba Qian Dai Chun’	2.4639	□
15‘Cong Zhong Xiao’	3.3220	□	30‘Jin Gui Piao Xiang’	2.2984	□

Tab.6 The grades of *P. lactiflora* cultivars

Cultivar	*Comprehensive evaluation value*	*Rank*	*Cultivar*	*Comprehensive evaluation value*	*Rank*
1‘Yang Fei Chu Yu’	4.2382	□	37‘Zi Hong Lou’	3.0491	□
2‘Tao Hua Mian’	4.1875	□	38‘Hong Zhu Ying Yu’	3.0468	□
3‘Du Hua Kui’	3.8900	□	39‘Zi Pao Xi Jin’	3.0421	□
4‘Jin Zan Ci Yu’	3.8619	□	40‘Fen Yin Zhen’	3.0370	□
5‘Tao Hua Shi’	3.7953	□	41‘Bing Qing’	3.0340	□
6‘Hong Feng1’	3.7915	□	42‘Zhao Yang Zi Feng’	3.0262	□
7‘Hong Ling Ci Jin’	3.6968	□	43‘Ping Ding Hong’	3.0247	□
8‘Hong Ma Nao’	3.6772	□	44‘Zi Tan Sheng Yan’	3.0192	□
9‘Qiao Ling’	3.6657	□	45‘Fu Gui Hong’	2.9915	□
10‘Mei Gui Hong’	3.6444	□	46‘Lan Ju’	2.9882	□
11¡®Zi Feng Yu¡¯	3.6338	□	47‘Lan Tian Piao Xiang’	2.9793	□
12‘Hong Cui Lou’	3.5968	□	48‘Ling Long Hong Qiu’	2.9791	□
13‘Lu Fen’	3.5602	□	49‘Bian Di Hong’	2.9669	□
14‘Wan Shou Hong’,	3.4579	□	50‘Fen Zhen Zhu’	2.9482	□
15‘Lan Tian Bi Yu’	3.4149	□	51‘Hong Feng 2’	2.9382	□
16‘Hong Tuo Gui’	3.4047	□	52‘Hong Xiu Qiu’	2.9361	□
17‘Mo Zi Ling’	3.4042	□	53‘Shao Nu Zhuang’	2.9340	□
18‘Zhong Sheng Fen’	3.3948	□	54‘Niao Long Ji Sheng’	2.8991	□
19‘Hong Yan Ying Ri’	3.3937	□	55‘Man Tang Hong’	2.8934	□
20‘Zhu Sha Pan’	3.3710	□	56‘Tao Hua Fei Xue’	2.8718	□
21‘Zhao Yuan Fen’	3.3504	□	57‘Chong Qing Hong’	2.8708	□
22‘Zi Yu Lou’	3.3408	□	58‘Hong Guan Fang’	2.8628	□
23‘Ci Bai’	3.3367	□	59‘Lu He Hong’	2.8515	□
24‘Chao Yang Hong’	3.3057	□	60‘Yin Xu’	2.7681	□
25‘Tao Hua Zheng Chun’	3.2962	□	61‘Chen Hong’	2.7102	□
26‘Sha Jin Guan Ding’	3.2577	□	62‘Yan Zhi Dian Yu’	2.6894	□
27‘Lian Tai’	3.2208	□	63‘Shan Hua Lan Man’	2.6600	□
28‘Zhu Sha Dian Yu’	3.2176	□	64‘Sheng Tao Hua’	2.6440	□
29‘Fen Mian Tao Hua’	3.1777	□	65‘Yan Hong’	2.6298	□
30‘Qi Cai Qiu’	3.1690	□	66‘Wu Long Tan’	2.5859	□
31‘Da Fu Gui’	3.1617	□	67‘Yin Zhen Xiu Hong Pao’	2.5836	□
32‘Hong Hua Lan Man’	3.1464	□	68‘Fen Yu Nu’	2.5327	□
33‘Qing Kong Wan Li’	3.1357	□	69‘Zi Fu Rong’	2.5139	□
34‘Cao Zhou Hong’	3.1163	□	70‘Hong Cha Hua’	2.4185	□
35‘Zi Lian Wang Yue’	3.0542	□	71‘Hong Yu Xia’	2.2749	□
36‘Chi Fen’	3.0505	□	72‘Fen Cui Lou’	2.2369	□

The results of the comprehensive evaluation showed that 7 *P. suffruticosa* cultivars and 4 *P. lactiflora* cultivars were in grade "□". The colors of these *Paeonia* cultivars were very pure, the flowertypes of them were basically the high-level pattern of more petal rounds (such as Crown form, Crown-proliferation form), the flower diameters were relatively long and the growth potential were very strong. They were the firstchoice to the application of *Paeonia* cultivars in landscape in Shenyang and they were the better parents in the breeding of *Paeonia* cultivars.

- *P. suffruticosa* cultivars and 24 *P.lactiflora* cultivars were in grade "□". The appreciation and adaptability of these cultivars were strong. They were worth being used in the landscape application and the breeding of *Paeonia* cultivars.
- *P. suffruticosa* cultivars and 37 *P. lactiflora* cultivars were in grade "□". The integrated performance of these cultivars were general, they could basically adapt to the weather conditions in Shenyang district, they could be given an appropriate consideration to the landscape application in order to increase the diversity of species with implant.
- *P. suffruticosa* cultivars and 7 *P. lactiflora* cultivars were in grade "□". In these cultivars, the colors were not gorgeous enough, the petal rounds were less,the integrated performance were unsatisfactory and the beautification effect was not strong in landscape.

DISCUSSION

This paper adopted the method that AHP and entropy technology combined to appraise *Paeonia* cultivars, the results shown were almost unanimous with the views of specialists and the facts. The evaluation method of this paper was intuitive and simple, which avoided the inconsistencies influence of the subjective and the objective, then we got the scientific evaluation results by it. The evaluation system played the function for simulating "the comments of the experts".

It often only adopted AHP to evaluate the flowers and the other plants in previous studies. But when we used "Expert consultation" by this mothod, it could lead to the inaccurate of the scale and the loss of part information because of generating cycles easily. The weight information could increase greatly after being modified by the entropy technology and the results could be more accurate. This paper adopted the method that AHP and entropy technology combined to offset these defects.

It was known that the evaluation indexes were more, the objectivity and the accuracy of the results would be stronger in the research. The evaluation indexes of this paper mainly take the indexes about flowers, but we can increase indexes appropriately according to the research targets in related research in the future, for example, the indexes of stress resistance and disease resistance can be increased when we do the evaluation research for the purpose of introducing plants.

REFERENCES

1. Wang X.R., D.H. Wang and H. Yue, 2007. The application of *Paeonia* cultivars in North Garden. Acta. North Gardening, 5: 153-154. (in Chinese)
2. Satty, T.L., 1980. Analytic Hierarchical Process. Mcgraw Hill, Inc.
3. Tang, D.Q., S.P. Zhang and B.N. Gao, 1998. A comprehens-ive appraised by using AHP about the utilization of cultivars of sweet Osmanthus. J. Jiangsu Forestry Science & Technol., 25(1): 11-12. (in Chinese)
4. Fang, C.L. and H.Y. Mao, 1999. A system of indicators for regional development planning. Acta. Geographica Sinica, 54(5): 400-419. (in Chinese).
5. Xiong, L., Q. Liang and G.H. Wang, 2005. Method research on selection and valuation of numeric scale in analytic hierarchy process.Systems Engineering Theory & Practice, 25(3): 72-79. (in Chinese).
6. Qiu, W.H., 2002. The management decision and entropy application. Beijing: Publishing House of machinery industry. (in Chinese).
7. Wu, X.G., L. Ding, J. Ding and Z. Zhou, 2005. An evaluation of regional tourism development in Jiangsu province. J. Nanjing University (Natural Sciences), 41(5): 569-576. (in Chinese).
8. Zhou, G.P., 2007. The evaluation of economie develo-pment based on the method of entropy and AHP [Ph.M.Dissertation]. Dalian:Dalian Univers-ity of Technology. (in Chinese).