Economic Value Evaluation of Fine Individual Plants of *Ribes rubrum* Linn. Based on AHP

Yu CHEN, Yulan GUO*, Kewu LIU

Forest By-product and Speciality Institute in Heilongjiang Province, Mudanjiang 157011, China

Abstract In this experiment, the biological characteristics, the number of spikes per plant, the average number of panicles, the average spike length, and the average yield per plant of the wild *Ribes rubrum* Linn. were observed and determined and the analytic hierarchy process (AHP) was applied to evaluate the economic value of 8 different sources of excellent plants of *R. rubrum* Linn. The results indicated that "RXF02", "RXF03" and "RXM05" performed well in the number of spikes per plant, average number of panicles, average yield per plant, and cold resistance, and the comprehensive scores were 9.68, 9.44 and 9.41, respectively.

Key words *Ribes rubrum* Linn., Analytic hierarchy process (AHP), Economic value evaluation

1 Introduction

Ribes rubrum Linn. belongs to the plant of genus *Ribes L.* and family Saxifragaceae. It is deciduous, rare evergreen or semi-evergreen shrub, mainly distributed in the warm northern regions of Europe and North America[1], are also widely distributed in Asia, South America and North Africa. In China, there are 59 species and 30 varieties of *Ribes L.* plants in China[2], mainly distributed in the southwest, northwest, and northeast. In recent years, the northeastern region of China has introduced and cultivated *R. rubrum* Linn. The fruits of some kinds have become important raw materials for making beverages and sweets. Some species have been used as ornamental plants in Northeast China and North China. However, a large number of wild resources in Northeast China, Southwest China and Northwest China, are still not developed and utilized[3]. According to reports, there are 19 species, 2 varieties and 1 variant in the cold regions of northeast China, 8 species in the Changbai Mountains in Jilin, and 11 species in the Heilongjiang Province. Proper development, introduction, domestication of the *Ribes L.* plants, research on its breeding technology and comprehensive use of its value not only can form a unique berry industry chain in the Northeast China, but also can obtain greater economic, ecological and social benefits.

2 Materials and methods

2.1 Experimental materials The materials were 45 species of excellent single plants collected from Altay, Burqin, Qinghe, and Fuyun of Xinjiang, and Hailin, Dahailin, Muling and Bamiantong of Heilongjiang Province (Table 1). In the *R. rubrum* Linn. source collection area of the experimental base of Forest By-product and Speciality Institute in Heilongjiang Province, the selected materials were excellent single plants that have been introduced into Heilongjiang Province (mainly the Mudanjiang area), and the cultivation time in local area has exceeded 3 years, and the growth status and performance of the traits are relatively stable. The observed data was the average value of three consecutive years.

Table 1 Resource collection and excellent single plant selection of *Ribes rubrum* Linn.

Area/code	Quantity of samples	Excellent single plant//plant
Dahailin/RXH	32	4
Bamiantong/RHB	36	7
Muling/RXM	43	6
Hailin/RXH	35	8
Altay/RXA	52	6
Burqin/RXB	51	7
Fuyun/RXF	60	4
Qinghe/RXQ	33	3
Total	342	45

2.2 Evaluation methods Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisionsmulti-target decision-making problem, based on mathematics and psychology. As a system, the target is divided into multiple targets or criteria, and then subdivided into several levels of multiple indicators (or criteria, constraints), and the hierarchical single order sorting (weight) and total order sorting are calculated by qualitative index fuzzy quantization method as the target (multi-indicator), multi-plan system optimization method[4]. Analytic Hierarchy Process (AHP) is characterized by the in-depth analysis of the nature and influencing factors of the complex decision-making problem, then using the quantitative information to realize mathematically process of the decision-making process, so as to provide

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* Corresponding author. E-mail: 68757862@qq.com

simple decision making method for complex decision problem with multiple targets, multiple criteria, or without structural characteristics. It is especially suitable for situations where it is difficult to directly and accurately evaluate the results of the decision.

2.3 Model building and calculation methods The basic steps of the AHP method are as follows: (i) establish the hierarchy structure of the system and plot a hierarchical structure diagram; (ii) build a comparison judgment matrix to determine the corresponding hierarchical single order sorting; (iii) calculate the weight of each candidate element, and perform the hierarchical total order sorting[4].

In order to ensure the reasonableness of the hierarchical structure, it is necessary to strictly stick to the following principles. (i) Grasp the main factors when simplifying the problem. (ii) Pay attention to the strength relationship between the elements, the elements that have great differences should not be compared at the same hierarchy.

For each variety, 30 plants were randomly selected for fixed-plant observation, and the observation data of 3 consecutive years were combined to calculate the average value. Then, the indicator evaluation system of various varieties of *R. rubrum* Linn. was established according to the relationship among the varieties of traits, mutual influence and hierarchical subordination (Fig. 1).

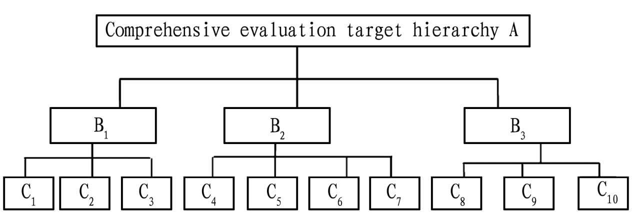

Fig. 1 Comprehensive evaluation hierarchy model for *Ribes rubrum* Linn.

In the AHP comprehensive evaluation model, the judgment matrix of each level is constructed by the 1 – 9 scale method. Through calculating the maximum eigenvalue Λmax of the matrix, the weight (w) value was obtained by the square root method, and the relative importance weights of each hierarchy of factors to the previous factor (Tables 2 – 5) and each evaluation indicator A-P total order sorting value (Table 6) were obtained. Consistency test was carried out on hierarchical single order sorting and total order sorting, and CI value was obtained by $CI = (\Lambda max - N)/(N-1)$, then $CR = CI/RI$ (Table 7).

Table 2 Comprehensive evaluation scale for *Ribes rubrum* Linn.

Scale	Definition
1	Indicating that two factors have equal importance
3	Indicating that one factor is slightly more important than the other factor
5	Indicating that one factor is much more important than the other factor
7	Indicating that one factor is highly more important than the other factor
9	Indicating that one factor is extremely more important than the other factor

Note: 2, 4, 6, and 8 denote the median value of the above two adjacent judgments.

Target hierarchy (A): The economic value of the *R. rubrum* Linn. variety. Constrained hierarchy (B): set three factors, namely, biological characteristics, fruit traits and plant resistance as constrained hierarchy indicators; criteria hierarchy (C): set 10 evaluation indicators, namely, ecological habits, reproductive difficulty, growth, average number of panicles, average spike length, average yield per plant, number of spikes per plant, fruit uniformity, cold resistance, and natural pollination as criteria hierarchy.

Through the consultation and market research results, combined with the biological characteristics of the *R. rubrum* Linn. and the economic characteristics of the fruit, a comprehensive scoring standard was established (Table 8).

Table 3 A-B judgment matrix for comprehensive evaluation of *Ribes rubrum* Linn.

A	B_1	B_2	B_3	W
B_1	1	0.33	0.14	0.106 2
B_2	3	1	0.2	0.260 5
B_3	5	3	1	0.633 3

Note: Λmax = 3.038 7; CR = 0.033 4 < 0.1; RI = 0.58.

Table 4 B_1-C_i judgment matrix and consistency test

B	C_1	C_2	C_3	W
C_1	1.00	0.33	0.33	0.139 9
C_2	3.00	1.00	0.33	0.286 4
C_3	3.00	3.00	1.00	0.573 6

Note: Λmax = 3.137 2; CR = 0.058 < 1; RI = 0.118 3.

Table 5 B_2-C_i judgment matrix and consistency test

B	C_4	C_5	C_6	C_7	W
C_4	1.00	0.33	0.20	0.14	0.056 9
C_5	3.00	1.00	0.33	0.20	0.121 9
C_6	5.00	3.00	1.00	0.33	0.263 3
C_7	7.00	5.00	3.00	1.00	0.557 9

Note: Λmax = 3.065 8; CR = 0.043 9 < 1; RI = 0.90.

Table 6 B_3-C_i judgment matrix and consistency test

B	C_8	C_9	C_{10}	W
C_8	1.00	0.33	0.20	0.109 6
C_9	3.00	1.00	0.50	0.309 2
C_{10}	5.00	2.00	1.00	0.581 3

Note: Λmax = 3.003 7; CR = 0.003 2 < 1; RI = 0.58.

Table 7 Hierarchical total order sorting of comprehensive evaluation

Hierarchy C	B_1	B_2	B_3	Total order sorting W of Hierarchy C
	0.106 2	0.260 5	0.633 3	
C_1	0.1399			0.0149
C_2	0.2864			0.0304
C_3	0.5736			0.0609
C_4		0.0569		0.0148
C_5		0.1219		0.0317
C_6		0.2633		0.0686
C_7		0.5579		0.1453
C_8			0.1096	0.0694
C_9			0.3092	0.195 8
C_{10}			0.5813	0.368 1

Table 8 Scoring criteria for evaluation factors of *Ribes rubrum* Linn.

Indicator	Score					
	9	7	5	3	2	1
Ecological adaptation	Extremely strong	Very strong	Strong	General	Weak	Extremely weak
Reproductive difficulty	Extremely easy	Very easy	Easy	General	Very difficult	Difficult
Growth condition	Excellent growth	Better growth	Good growth	General growth	Poor growth	Worse growth
Average number of panicles//pcs	>8	8.0 – 7.5	7.49 – 7.0	6.9 – 6.5	6.5 – 5.5	<5
Average spike length//cm	6.5 – 6.1	6.0 – 5.6	5.5 – 5.1	5.0 – 4.6	4.5 – 4.1	4.0 – 3.5
Average single plant yield//g	599 – 500	499 – 400	399 – 300	299 – 200	199 – 100	<99
Number of spikes per plant//pcs	89 – 80	79 – 70	69 – 60	59 – 50	49 – 40	39 – 20
Fruit uniformity	Very uniform	Uniform	General	Not uniform	–	–
Cold resistance	Extremely strong	Very strong	Strong	General	Weak	Extremely weak
Natural pollination percentage//%	80 – 76	75 – 71	70 – 61	60 – 51	50 – 41	<40

3 Results and analysis

Through three consecutive years of survey: the aspect of the spike length: 4.1 – 11.7 cm; the average single fruit weight: 3 plants had the average single fruit weight of 0.7 g or greater, respectively RXF02, RXF03, RXM06, 7 plants 0.6 – 0.7 g, respectively, RXB03 , RXM05, RXB05, RXH02, RXF04, RXM01, and RXH08; the grain number per panicle: 4 – 14, and 9 plants had the grain number per panicle more than 10, respectively RXB03, RXM05, RXF04, RXD04, RXA05, RXD02, RXM01, RXA06, and RXH05; the number of spikes per plant: 27 – 141, and 3 plants had 100 or more, respectively, RXD04, RXD02, and RXM01; longitudinal diameter of the fruit: 0.7 – 11.54 cm; the transverse diameter of the fruit: 10.27 – 12.02 cm .

Evaluation grades of 45 varieties of *R. rubrum* Linn. varieties: 9-excellent, 8-better, 7-general, 6-poor, 5-worse; RXF02 had the comprehensive evaluation score above 9.50; RXF03 and RXM05 had comprehensive evaluation score in the range of 9.40 – 9.50 R; RXM06, RXM04, RXB01, RXQ03, and RXF01 had comprehensive evaluation score in the range of 9.20 – 9.30; RXA02, RXA05, RXM01, RXF04 had comprehensive evaluation score in the range of 9.00 – 9.20.

As shown in Table 9, in the scoring process, the survey data of each excellent single plant for three consecutive years were taken, and the average value of each indicator was taken to minimize the subjective difference. The selected varieties may be affected by the local ecological environment during their growth.

Table 9 Comprehensive evaluation

No.	Code	Comprehensive evaluation score
1	RXD01	6.926 3
2	RXH01	6.928 4
3	RHQ02	6.953 6
4	RXD03	6.985 8
5	RXD04	7.002 3
6	RHB07	7.010 3
7	RHB05	7.012 8
8	RXH03	7.037 2
9	RXB04	7.103 3
10	RXH06	7.116 4
11	RXB07	7.135 2
2	RXB06	7.285 1
13	RHB06	7.342 4
14	RXH05	7.372 3
15	RHB04	7.385 8
16	RHB01	7.689 3
17	RXH07	7.784 6
18	RXH08	7.985 3
19	RHB02	8.110 7
20	RXA06	8.203 7
21	RHB03	8.368 3
22	RXA03	8.454 8
23	RXM03	8.511 7
24	RXA01	8.521 3
25	RXH04	8.632 7
26	RXH02	8.655 2
27	RXB02	8.683 0
28	RXM02	8.789 3
29	RXA04	8.796 8
30	RXQ01	8.803 2
31	RXB05	8.822 9
32	RXD02	8.843 8
33	RXB03	8.894 5
34	RXF04	9.007 6
35	RXM01	9.034 2
36	RXA05	9.193 8
37	RXA02	9.198 7
38	RXF01	9.263 9
39	RXQ03	9.278 4
40	RXB01	9.281 2
41	RXM04	9.284 2
42	RXM06	9.295 1
43	RXM05	9.417 3
44	RXF03	9.445 7
45	RXF02	9.682 3

4 Conclusions and discussions

4.1 Conclusions According to the observation and measurement of 10 indicators: ecological habits, reproductive difficulty, growth, average number of panicles, average spike length, average yield per plant, number of spikes per plant, fruit uniformity, cold resistance, and natural pollination, combined with the scoring criteria of each indicator, the comprehensive evaluation was carried out and the results indicate that "RXF02", "RXF03", and "RXM05" had higher comprehensive evaluation score. "RXF02", "RXF03" and "RXM05" plants showed excellent average fruit weight, number of spikes, spike length and grain number per spike, and they were better than other plants in terms of growth status, fruit uniformity and natural pollination. Through three consecutive years of continuous observation, each excellent single plant grew well and the performance of wintering was good, but further measurement is needed in terms of the grain number per spike and the yield per plant.

4.2 Discussions It is recommended to assist the collection and protection of cold-resistant germplasm resources of *R. rubrum* Linn., and accelerate the cultivation of cold-resistant varieties[5] to enrich the varieties of small berries planted in Heilongjiang Province. Besides, it is recommended to make proper plan for the small berry industry and carry out the plan properly, to avoid blindness. Through the propaganda of scientific and technological achievements, it is expected to play an active role in promoting the development of alternative industries for the timber production.

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