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Geography distribution and adaptability of germplasm resources for rhododendron

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Abstract. In order to improve the effectiveness for distribution analysis on the germplasm resource of rhododendron plants, a kind of distribution analysis method for the germplasm resource of rhododendron plants based on the fuzzy-reasoning numerical prediction is proposed. Firstly, the distribution area of rhododendron in the Qinling Mountains is set forth; then, a kind of improved TS fuzzy-rule extraction algorithm based on the experience rule and real rule is put forward to design the fuzzy reasoning process, and to achieve the accurate distribution analysis on the germplasm resource of rhododendron plants; finally, the distribution analysis on the germplasm resource of rhododendron plants in the Qinling Mountains is realized through the experiment analysis, which can be used for guiding the practical work.

Key words. Fuzzy reasoning Numerical prediction Rhododendron, Resource distribution
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1. Introduction

The rhododendron normally refers to all kinds of rhododendron plants, which is called as the 3 top high-mountain wild flowers in the world together with the primrose and gentian, as well as one of the most famous ornamental plants in the world garden and Chinese traditional famous flowers at the same time. At present, there are numerous scholars engaging in the rhododendron research, mainly involving in the resource investigation, morphology classification and distribution, photosynthetic biological characteristics, stress resistance, cultivation and propagation technique, genetic diversity analysis and other fields of rhododendron plants; in addition to the detailed investigation on wild rhododendron resource in Tibet (Sejila Mountain), Yunnan (Diancang Mountain and Gaoligong Mountain in Yunnan Province) and Sichuan (Wawushan Mountain, Gongga Mountain and Jinfo Mountain) with large

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rhododendron resource reserve, the domestic scholars has carried out the investigation on rhododendron plant resource at other regions in the southwest area, such as Chongqing, Guizhou, Hunan, Guangxi, Guangdong, Jiangxi, Fujian, Zhejiang, Qinghai, Gansu, Inner Mongolia and the northeast area. However, for the systematic investigation research on the germplasm resource of rhododendron plants in the Qinling Mountains, the garden ornamental vision is rarely used to research the abundant and various rhododendron resources in the area, while even no further evaluation research is made on the relevant ornamental character. Therefore, in order to make clear the rhododendron resource of wild rhododendron plants in the Qinling Mountains, and protect its biodiversity and rhododendron's sustainable utilization, this research systematically investigates and evaluates the distribution and habitat of wild rhododendron germplasm resource in the Qinling Mountains, to provide the material and technical basis for the further research, breeding application and stock breeding of rhododendron germplasm.

2. Problem description

Qinling is the demarcation line of the southern and northern climates in China, and also the watershed of the Yellow River branch – Weihe River and the Yangtze Rivers – Jialing River and Han River. As it is the transitional zone of warm temperate zone and northern subtropics in China, the complex terrain and different climates behind the border form the climate, soil and vegetation difference in the south and north of Qinling Mountains, to constitute the natural demarcation line of south and north climates in China, so as to form the natural intersection for transitions of north and south flora. Together with the special historical process at the quaternary glacier phase, affected by the glacier, with a lot of old and valuable plant species reserved, Qinling Mountains becomes one of the biggest gene pools in China, which not only is distributes with floral elements in the North China, Central China and Qinghai-Tibet Plateau, but also is of self particularity, distributing with many endemic plants. This is of distinctly important academic and economic values for carrying out the introduction and domestication and cultivating the new species. This territory gradually becomes one of the key areas of biological resources and biodiversity with international meaning, as well as one of the geographical and biological researches.

The relevant data of wild rhododendron plant distributed in Qinling Mountains is collected, to determine investigation sites of rhododendron plant resource as Huxian, Fengxian, Meixian, Lueyang, Zhen'an, Ningxia, Foping, Nanzheng, Nan'gao, Zhashui, Lantian, Zhouzhi, Huaxian, Yangxian, Shangzhou District, Shanyang, Xunyang, Zhenping, Zhenba, Ningqiang, Pingli, Liuba, Danfeng, Shiquan and Taibai in Shanxi Province, as well as the Wenxian, Wudu and Zhouqu in Chengdu Province, which totally are 28 districts and counties. Lasting for 3 years from 2009 to 2011, the centralized flowering period of Qinling wild rhododendron is utilized to investigate the local rhododendron resource, and to make clear its species, geological distribution and resource characteristics. During the investigation process, the digital photos are taken and the plant samples are collected, to clear up the rhododendron plant resource wildly distributed in Qinling Mountains and analyze its ornamental characteristic.

3. Fuzzy-reasoning numerical prediction

The numerical value ways for distribution analysis on the germplasm resource of rhododendron plants mainly are the time series prediction, regressive analysis calculation and fuzzy reasoning for. Since the time series analysis method and regression analysis method may get the unreliable prediction result when facing the complex input data of different types, in order to improve the reliability of prediction result, the fuzzy-reasoning prediction way is applied. As shown in the Fig.1.

3.1. Problem description

The Gaussian function is applied to show the subordination relation among the variables, with calculation formula as follows [8]:

$$A(x) = \exp\left(-\frac{(x-c)^2}{2\sigma^2}\right). \tag{1}$$

In the formula, x is the input data variable and σ is the width parameter of Gaussian curve, while c is the constant of Gaussian curve center. This paper assumes the initial value of Gaussian curve as $\sigma = 2$ and $c = 5$.

As for the TS fuzzy reasoning model with multiple inputs and single output in the distribution analysis on germplasm resource of rhododendron plants, its regular form can be expressed as:

$$R_l : \text{If } x_1 \text{ is } F_1^l \text{ and } x_2 \text{ is } F_2^l \text{ and } \ldots \text{ and } x_n \text{ is } F_n^l; \text{ Then } z = z^l(x). \tag{2}$$

In the formula, $R_l\ (l = 1, 2, \cdots, n_r)$ is the lth fuzzy rule, n_r represents the quantity of above fuzzy rules, n is the dimension of inputted observation data, F_i^l is the language representation of Gaussian mermbership function $\mu_{F_i^l}$, and z is the fuzzy reasoning output of above rules, which can be expressed as [9]:

$$f(x) = \frac{\sum_{l=1}^{n_r}\left(\left(\prod_{i=1}^{n}\mu_{F_i^l}\left(x_i, \sigma_i^l, \gamma_i^l\right)\right) z^l(x)\right)}{\sum_{l=1}^{n_r}\left(\prod_{i=1}^{n}\mu_{F_i^l}\left(x_i, \sigma_i^l, \gamma_i^l\right)\right)}. \tag{3}$$

In the formula, $f : R^n \to R$, with calculation form $\mu_{F_i^l}$ of as shown in the Formula (4). Then, the TS fuzzy relation output can be represented as:

$$z^l(x) = f^l(x_1, x_2, \cdots, x_n) = \omega_0^l + \sum_{i=1}^{n}\omega_i^l x_i^l. \tag{4}$$

In the formula, ω_i^l is the conclusive weight parameter.

3.2. Improved TS fuzzy model

In the gathered data for germplasm resource of rhododendron plants, there are the historical data and current data, these two kinds of which have different influence to the current reasoning, therefore, an improved TS fuzzy data reasoning is proposed here, with the improvement form of fuzzy rule as follows:

RE_p: If x_1 is $FE_1^p\left(l_1^p, u_1^p\right)$ and x_2 is $FE_2^p\left(l_2^p, u_2^p\right)$ and ... and x_n is $FE_n^p\left(l_n^p, u_n^p\right)$;

$$\text{Then } z = z^p\left(x\right). \tag{5}$$

In the formula, as RE_p is the pth fuzzy rule (based on the experiment data), $FE_1^p\left(l_1^p, u_1^p\right)$ is the language representation, and $\left(l_i^p, u_i^p\right)$ is corresponding to the value range of membership function, then the center of the Formula (1) can be initialized as:

$$\gamma_i^p = \frac{l_i^p + u_i^p}{2}. \tag{6}$$

The calculation formula for the width parameter σ of Gaussian curve is:

$$\sigma_i^p = \frac{\left(u_i^p - l_i^p\right)}{2\sqrt{-\ln k}}. \tag{7}$$

The subtractive clustering way is applied here to extract the sample point, and carry out the rule transformation, with calculation formula of sample difference being:

$$D_l = \sum_{j=1}^{n_d}\left(\exp\left(\sum_{i=1}^{n}\frac{-\left(x_i^l - x_i^j\right)}{\sigma_i^2}\right)\exp\left(\frac{-\left(y^l - y^j\right)^2}{\sigma_y^2}\right)\right). \tag{8}$$

The amendment diversity of residual data:

$$D_l = D_l - D_{u_m}\left[\exp\left(\sum_{i=1}^{n}\frac{-\left(x_i^l - x_i^{u_m}\right)}{\left(\sigma_i/2\right)^2}\right)\right]\times\exp\left(\frac{-\left(y^l - y^{u_m}\right)}{\left(\sigma_y/2\right)^2}\right). \tag{9}$$

Repeatedly amend the diversity of residual data in the above formula, and take the data with maximum difference as the next rule, with the terminated condition of above iterative processes as $D_{u_m} \leq 0$.

To embody the different function of observed historical data on germplasm resource of rhododendron plant to the germplasm resource predication of rhododendron plant, the following definitions are used to carry out the fusion of experiment rule and data rule.

Definition 1: **(coincidence)** coincidence index $OL_i^{j,k}$ of TS rule R_j and R_k

can be defined as [10]:

$$\begin{cases} OL_i^{j,k} = \left(\frac{OS}{AS}\right)^a = \left(\frac{U_i^j - L_i^k}{U_i^k - L_i^j}\right)^a , \\ a = sgn\left(U_i^j - L_i^k + U_i^k - L_i^j\right) . \end{cases} \tag{10}$$

In the formula, U and L respectively are the upper and lower limits of Gaussian membership function, and then the coincidence of experiment rule and data rule can be represented as:

$$OLe_i^p = \max\left(OL_i^{p,l}\right), l = 1, 2, \cdots, n_t . \tag{11}$$

Concrete concept of the Definition 1 is as shown in the Fig.1.

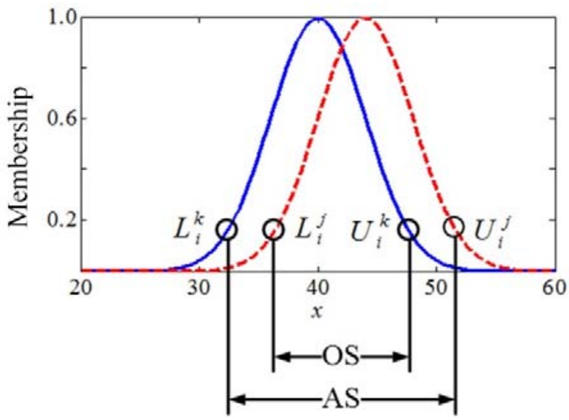

Fig. 1. Schematic diagram of coincidence

3.3. Parameter extraction of fuzzy model

To balance the overall property and local property of TS model, the following improved objective function is applied:

$$\begin{aligned} J(k) = & \frac{(1-\lambda)}{n_t} \sum_{p=1}^{n_t} \left(\hat{y}_p(k) - y_p\right)^2 \\ & + \frac{\lambda}{n_e} \sum_{j=1}^{n_e} \left(\hat{y}\left(\gamma^{d_j}(k)\right) - z^{d_j}\left(\gamma^{d_j}(k)\right)\right)^2 \\ = & (1-\lambda) J_1(k) + \lambda J_2(k) . \end{aligned} \tag{12}$$

In the formula, z^{d_j} represents the output value of fused fuzzy rule with number as j, and γ^{d_j} is the center point of experiment rule, while J_2 is the outputted deviation for overall and local models of the center point γ^{d_j}. Then, the extraction process for premise parameter of TS fuzzy rule is as follows:

$$\begin{aligned}\gamma_i^l(k+1) =& \gamma_i^l(k) - \eta\lambda \frac{\partial J_2(k)}{\partial \gamma_i^l}\Big|_{\gamma_i^l=\gamma_i^l(k)} \\ &- \eta(1-\lambda)\frac{\partial J_1(k)}{\partial \gamma_i^l}\Big|_{\gamma_i^l=\gamma_i^l(k)}\end{aligned} \tag{13}$$

$$\begin{aligned}\sigma_i^l(k+1) =& \sigma_i^l(k) - \eta\lambda \frac{\partial J_2(k)}{\partial \sigma_i^l}\Big|_{\gamma_i^l=\gamma_i^l(k)} \\ &- \eta(1-\lambda)\frac{\partial J_1(k)}{\partial \sigma_i^l}\Big|_{\gamma_i^l=\gamma_i^l(k)}\ .\end{aligned} \tag{14}$$

The calculation of four partial derivatives is involved in the Formula (17) and (18), with its calculation formula given as follows:

$$\begin{cases}\dfrac{\partial J_1(k)}{\partial \gamma_i^l} = \displaystyle\sum_{p=1}^{n_t}\left[\frac{2e_p(k)A(k)\left(x_i^p(k)-\gamma_i^l(k)\right)}{n_t\sum\limits_{g=1}^{n_r}A(k)\left(\sigma_i^l(k)\right)^2}\right]z^l(x^p) \\ \dfrac{\partial J_2(k)}{\partial \gamma_i^l} = \dfrac{2}{n_e}\displaystyle\sum_{j=1}^{n_e}\left(e^{d_j}(k)\sum_{g=1}^{n_r}\left(\frac{A(k)\left(\gamma_i^{d_j}(k)-\gamma_i^l(k)\right)}{\sum\limits_{g'=1}^{n_r}A(k)\sigma_i^g(k)^2}\right)\right)z^l(x^p) \\ A(k) = \displaystyle\prod_{q=1}^{n}\mu_{F_q^l}\left(x_q^p(k), \gamma_q^l(k), \sigma_q^l(k)\right) \\ e^{d_j}(k) = \hat{y}\left(\gamma^{d_j}(k)\right) - z^{d_j}\left(\gamma^{d_j}(k)\right)\end{cases} \tag{15}$$

In the formula, the η is the study parameter (factor) of fuzzy rule. The representation forms of the $\partial J_1(k)/\partial\sigma_i^l$ and $\partial J_2(k)/\partial\sigma_i^l$ are similar to the Formula (15). After defining the above formulas, the extraction steps of the improved TS fuzzy rule are as follows:

Step 1: (Algorithm initialization) initialize the parameters of TS fuzzy rule: k, K_i, K_y, h_i^p, $i=1,2,\cdots,n$, $p=1,2,\cdots,n_e$, set the termination iterations n_e and termination objective error value E_r extracted by the fuzzy rule;

Step 2: (Structure identification) utilize the Formula (1) $\sim$ (5) to map the experiment to the experiment rule, build the rule based on the gathered data with Formula (6) $\sim$ (11), and fuse the above experiment and data rules based on the Definition 1;

Step 3: (Parameter extraction) extract the Ts fuzzy rule parameter with Definition (12) $\sim$ (15), and perform the parametric solution by applying the LMS algorithm;

Step 4: (Termination of judgment) judge whether satisfy the algorithm termination condition set by the Step 1, if yes, then exit the algorithm and output the result; otherwise, turn to the Step 3, and continue to utilize the LMS algorithm to extract the parameter.

4. Simulation experiment and analysis

4.1. Standard test function simulation

The triangle composite function is taken as the simulation function, with form as follows:

$$f(x) = \frac{\cos\left(0.0023x^2\right)x^3}{10^4}. \tag{16}$$

Randomly select 35 points x_i within the value range $[20, 90]$, and get their corresponding output values $f(x)$ according to the Function (24), train the improved TS model with above 25 groups of data as the training data, and then evenly choose 20 groups of data within the value range $[20, 90]$. According to the inflection point information of test function, generate following 10 groups of experiment rules as shown in the Table 1.

Table 1. Experiment rule

Rule No. (Rule)	$x\left(FE_1^i\right)$	z^i
1	(37.9, 47.8)	7.8
2	(47.9, 58.5)	−13.7
3	(54.6, 65.6)	21.6
4	(61.9, 71.1)	−30.1
5	(68.4, 79.4)	39.4
6	(73.9, 83.3)	−48.8
7	(79.7, 90.2)	60.7
8	(87.4, 92.5)	−72.7
9	(92.5, 97.8)	84.5
10	(96.5, 99.5)	−93.9

The TS algorithm, the DTS algorithm [13] and the FHATS algorithm proposed by this paper are chosen for the simulation comparison algorithm. In the Section 3, the algorithm parameters are set as [13]: $k = 0.1$, $K_i = K_y = 8$, $OLeM = 0.7$, $h^p = 0.8$, $p = 1, 2, \cdots, 10$, $n_e = 100$, $E_r = 1$. The core set proportion of hierarchical agglomerative method is 0.3, with simulation comparison curve as shown in the Figure 2, as well as the prediction error result as shown in the Table 2.

It can be directly seen from the Fig.4, for the conformity between the prediction results of several comparison algorithms and the real data, the FHATS algorithm and DTS algorithm proposed by this paper can relatively accurately follow up and predict the real track, with its waveform and numeric relatively close to the real value; in general, it can be obviously seen that the FHATS algorithm is closer to

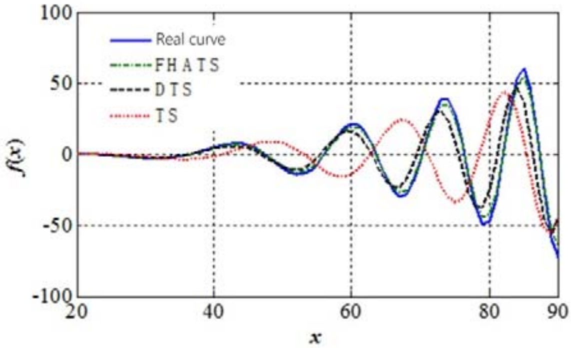

Fig. 2. Prediction curve comparisons

the real track than the DTS algorithm, while the original TS algorithm deviates a lot from the real value on the model analog output, even occurs the phenomenon contrary to the direction, of which the output result is completely error at this time. From the compared numerical results for iteration step, convergence time and convergence error of three kinds of comparison algorithms given in the Table 3, it can be seen that, the whole performance of FHATS algorithm is better than that of DTS and TS algorithms.

Table 2. Simulation convergence numeric comparison

Prediction method	Iteration step	Time	Error
TS	325	5.3	21.32
DTS	217	5.1	6.23
FHATS	153	3.7	0.72

4.2. Establishment of evaluation model

According to the above analysis on resource characteristic and sustainable utilization of wild rhododendron ornamental plants, the hiberarchy model for comprehensive evaluation of development and utilization of wild Qinling rhododendron plat resource is built, with this model being divided into: 4 layers of objective layer, restraint layer, standard layer and bottommost layer.

(1) Objective layer (A): Under the premise of guaranteeing the ecological environment is not destroyed and gradually improved, the ornamental value of wild rhododendron plant resource easy to be cultivated and naturalized with high ornamental value and diversiform application types shall be selected to develop and utilize, to satisfy the demand of people's life to the ornamental plant.

(2) Restraint layer (C): Various kinds of factors restricting and limiting the resource development and utilization of wild Qinling rhododendron ornamental plant, including the aesthetics, biology, ecology, sociology and other aspects. The evaluation system chooses the ornamental value, other (whole) ornamental value, and resource development potential and other factors of flower traits with greatest effect to the resource development and utilization of wild Qinling rhododendron ornamen-

tal plants as the restraint layer to A.

(3) Standard layer (P): The concrete selection index embodying above restraint layer, with combined application of qualitative and quantitative evaluations to determine the score for every index. Therefore, the reasonable selection of evaluation index is one of the bases for comprehensive evaluations.

(4) Bottommost layer (D): Wild resource species of Qinling rhododendron ornamental plant to be evaluated.

4.3. Analysis of experimental results

According to the above principles, through the comment on the garden professionals, 4 matrixes of A-C, C-P are built, and the maximum characteristic value of corresponding judgment matrix, as well as the corresponding characteristic vector, are calculated, as shown in the Table 3∼6. The C.R. values of A-C and C-P matrixes are less than 0.1, illustrating that the matrix is of content consistency.

Table 3. Judgment matrixes A-C and consistency inspection

A	**C_1**	**C_2**	**C_3**	**W**
C_1	1	3	2	0.540
C_2	1/3	1	1/2	0.63
C_3	1/2	2	1	0.297

Table 4. Judgment matrixes C-P and consistency inspection

C_1	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**P_8**	**W**
P_1	1	3	5	7	1	3	1	1	0.197
P_2	1/3	1	2	3	1/3	1	1/3	1/3	0.069
P_3	1/4	1/2	1	2	1/4	1/2	1/4	1/4	0.044
P_4	1/5	1/3	1/2	1	1/5	1/3	1/5	1/5	0.030
P_5	1	3	5	7	1	3	1	1	0.197
P_6	1/3	1	2	3	1/3	1	1/3	1/3	0.069
P_7	1	3	5	7	1	3	1	1	0.197
P_8	1	3	5	7	1	3	1	1	0.197

The selection of good breeding material (parent) is a fundamental link in the breeding work. Through the investigation on the germplasm resource of wild Qinling rhododendron plant, on the basis of sufficiently grasping its habit, form, flowering phase, flower color, flower shape and other materials, the supplementation shall be made with combination of literature, and evaluation shall be made to every index of species to be evaluated by proposed by the evaluation method. Now take the rhododendron dendrocharis as the example, the evaluation value is as shown in the Table 5.

Table 5. Comprehensive evaluation and grade of wild qinling rhododendron

No.	Species Name	Score	Grade
1	Purple rhododendron	5.128	I
2	Rhododendron souliei	5.094	I
3	Rhododendron tatsienense	5.040	I
4	Rhododendron dendrocharis	5.032	I
5	Rhododendron trichanthum	5.032	I
6	Rhododendron maculiferum	4.905	II
7	Rhododendron vernicosum	4.879	II
8	Rhododendron wasonii	4.878	II
9	Rhododendron ambiguum	4.863	II
10	Rhododendron flavidum	4.863	II
11	Rhododendron pachytrichum	4.857	II
12	Rhododendron polylepis	4.732	II
13	Rhododendron strigillosum	4.711	II
14	Rhododendron watsonii	4.700	II
15	Rhododendron oreodoxa	4.688	II
16	Rhododendron decorum	4.659	II

According to the distribution condition and intuitive experiment of comprehensive evaluation value, sustainable development and utilization for ornamental value of 16 kinds of wild rhododendron plants investigated in Qinling is divided into 3 grades: Grade I ($\geq$5.0): the species with high ornamental value and developed and utilized in large scale totally are 5 species. Grade II (4.5-5): the species with high ornamental value and moderate development totally are 11 species.

5. Conclusions

This paper puts forward a kind of distribution and analysis method for germplasm resource of rhododendron plants based on the fuzzy-reasoning numerical predication, designs the fuzzy reasoning process based on the improved TS fuzzy-rule extraction algorithm of experiment rule and real rule, achieves the actuate distribution and analysis on germplasm resource of rhododendron plant and realizes the distribution and analysis on germplasm resource of rhododendron plant in the Qinling Mountains by the experiment analysis.

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