Numerical analysis of inter-specific relationships in Arbor layer of Pinus syluestriformis community in Changbai Mountain area, China

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Abstract. Pinus syluestriformis is a rare and endemic tree species in Changbai Mountain, China's national first-class protected plant. In recent years, with the increase in population and environmental damage, the number is becoming less and reaching the edge of extinction. The interspecific association characteristics of dominant species in Arbor layer of Pinus syluestriformis community were analyzed by using 2×2 contingency table, variance analysis, association coefficient, chi-square test, and Spearman rank correlation test. The results showed that: (1)The overall relevance showed negative correlation. Both *AC* and *PCC* were used to describe the degree of association between species, and they had high similarities. In the pure forest, Pinus syluestriformis and the main arbor species were positively correlated, but did not reach a significant level.In the scattered forest, the correlations between Pinus syluestriformis and the main arbor species were positively correlated with only Acer barbinerve, Albizia kalkora, and Tilia amurensis, and negatively correlated with other species. (2)In the pure forest, Spearman rank correlation analysis showed 72 pairs were positively correlated. In the scattered forest, 14 dominant species with high important values in the community were selected for analysis. Spearman rank correlation coefficient reflected that 23 pairs were positively correlated. (3) The results of the tests are positive and negative correlation ratio <1, which reflected the unstable early succession stage of plant community. The community was susceptible to the interference of external factors and succeeded.

1. Introduction

The study of interspecific association of the community can effectively reflect the distribution of each species in the community, as well as the degree of adaptation of each species to environmental factors and the interspecific correlation of species under specific environmental factors, which will help to further identify the community structure, type and community succession trend, etc[1]. The objective measurement of individuals from different species on spatial connectivity is of great significance for studying the interaction of two species and the composition and dynamics of the community[2]. There have been many reports on the plant interspecific association research at home and abroad [3-5], but the research content is mostly concentrated on the utilization of resources by plants and the resulting interspecific competition and community structure. There is no report on the plant interspecific association of Pinus syluestriformis community in Changbai Mountain, China.

Pinus syluestriformis is a rare and endangered tree species in Changbai Mountain, China's national first-class protected plant. The natural population is distributed in the northern slope of Changbai

Mountain and Changbai Mountain Nature Reserve in China, with a small area of about 200 hm^2. In recent years, with the increase in population and environmental damage, the number of Pinus syluestriformis is becoming less and reaching the edge of extinction.

Therefore, the interspecific association analysis method can not only reflect the species diversity of Pinus syluestriformis community in Changbai Mountain, but also help to reveal the stability and succession mechanism of Pinus syluestriformis population, and provide certain support for the breeding and protection of Pinus syluestriformis. It is of great significance for the development of natural vegetation restoration and ecological reconstruction as well as biodiversity conservation.

2. Research Area and Research Method

2.1. Overview of the Research Area

The research area is located in Changbai Mountain Nature Reserve, Jilin, China. The zonal climate belongs to the continental mountain climate with monsoon influence. The annual average temperature is 4.4°C, with extreme maximum temperature of 37.5°C and extreme minimum temperature of -40°C. The soil is mostly dark brown soil on volcanic ash, with thin soil layer, the pH of 4.2-4.9. The plants belong to the Changbai mountain flora.

2.2. Sampling Method

In 2015, one plot of 30m × 30m was set up in the pure forest of of Pinus syluestriformis. two plots of 30m×30m were set up in the scattered forest. The species, crown width, coverage and DBH of woody plants were investigated and recorded in detail.

- DBH represented diameter at breast height.
- Selected woody plants required DBH ≥ 1.3cm.

2.3. Data Analysis

2.3.1. Overall Association Analysis The correlation between multiple species was simultaneously determined by the variance ratio method (*VR*), and statistics W was used to test the correlation between multiple species. The calculation formula could be found in the References [7, 8].

2.3.2. Interspecific Association Analysis Based on 2×2 contingency tablet, a comprehensive analysis of the nature and degree of species pair association were made using the *Yates* correction coefficient formula based on chi-square test, combined with the point correlation coefficient (*PCC*), association coefficient (*AC*) and other measurement indicators[8].

2.3.3. Inter-species Correlation Analysis Spearman rank correlation analysis were performed with important values as indicators [9].

3. Results and Analysis

3.1. Overall relevance

The multi-species interspecific association coefficient of the pure forest community of Pinus syluestriformis was*VR*=0.950, indicating that there was a negative correlation between species in general. Using the statistics *W* to detect the degree to which the *VR* value deviated from 1. From the Table1, *W* was not in the range (23.269, 50.998). It showed that the overall relevance of the community had not reached a significant level. The multi-species interspecific association coefficient of the scattered forest was *VR*=0.780, indicating that there was a negative correlation between species. Analysis of the extent to which VR values deviated from 1 using statistical *W*. *W* was not in the range (23.269, 50.998). There was insignificant negative correlation of the overall relevance between species.

Table1. Overall relevance between species in Pinus syluestriformis communities.

Community	σ_T^2	S_T^2	*VR*	*W*	($\chi^2_{0.05}$(N), $\chi^2_{0.95}$(N))	Overall relevance
The pure forest	2.718	2.583	0.950	34.303	(23.269，50.998)	Insignificant negative correlation
Scattered forest	1.695	1.321	0.780	28.066	(23.269，50.998)	Insignificant negative correlation

3.2. Interspecific association analysis

The association measure between the species of Pinus syluestriformis and arbor species in different communities was recorded in Table 2. Both *AC* and *PCC* were used to describe the degree of association between species, which had high similarities. In the pure forest, Pinus syluestriformis and main arbor species were positively correlated, but did not reach a significant level. In the scattered forest, the association between Pinus syluestriformis and main arbor species were positively correlated with only *Acer barbinerv*e, *Albizia kalkora* and *Tilia amurensis*, and negatively correlated with other species, but did not reach a significant level, with loose interspecific association. It showed that the individuals in the arbor layer had their own suitable ecological niche, with no strong association with other species.

Table2. Association measure value of Pinus syluestriformis and main arbor species

Community	Main species	AC	χ^2	PCC	Fisher Accurate testing of two-tailed P-value
The pure forest	Betula platyphylla	1.000	2.338	0.051	1.000
	Acer ginnala	0.040	0.298	0.200	0.538
	Ulmus macrocarpa	0.003	2.338	0.051	1.000
	Acer pseudosieboldianum	0.008	0.298	0.091	1.000
	Tilia mandshurica	0.003	2.338	0.051	1.000
	Crataegus maximowiczii	0.008	0.298	0.091	1.000
	Acer triflorum	0.005	0.770	0.073	1.000
	Acer tegmentosum	0.003	2.338	0.051	1.000
	Albizia kalkora	0.003	2.338	0.051	1.000
	Malus baccata	0.018	0.000	0.135	1.000
	Tilia amurensis	0.035	0.201	0.187	0.545
	Fraxinus mandshurica	0.000	0.409	1.000	1.000
	Acer komarovii	0.003	2.338	0.051	1.000
Scattered forest	Larix olgensis	-0.333	0.000	-0.086	1.000
	Picea jezoensis	-1.000	0.343	-0.098	1.000
	Abies nephrolepis	-1.000	0.343	-0.098	1.000
	Acer barbinerve	0.059	0.000	0.140	0.443
	Betula costata	-1.000	1.067	-0.258	0.303
	Pinus koraiensis	-0.333	0.000	-0.086	1.000
	Sorbus pohuashanensis	-1.000	0.343	-0.098	1.000

Quercus mongolica	-0.333	0.167	-0.136	0.685
Acer tegmentosum	-1.000	0.375	-0.204	0.553
Acer mono	-0.429	0.059	-0.122	0.652
Albizia kalkora	0.259	1.235	0.259	0.184
Tilia amurensis	0.304	1.003	0.234	0.235

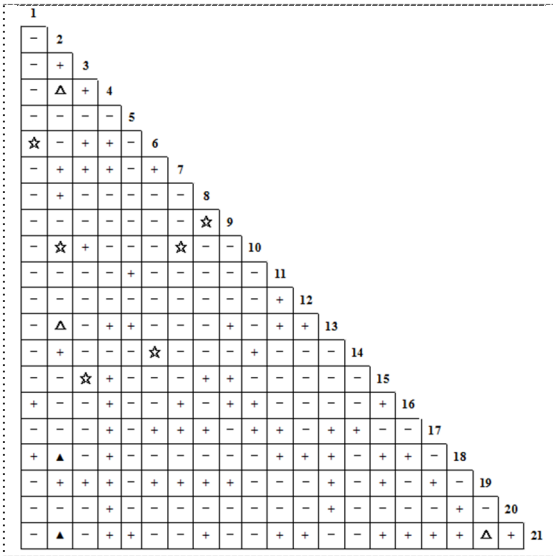

Figure 1. Spearman rank correlation matrix of the pure forest.

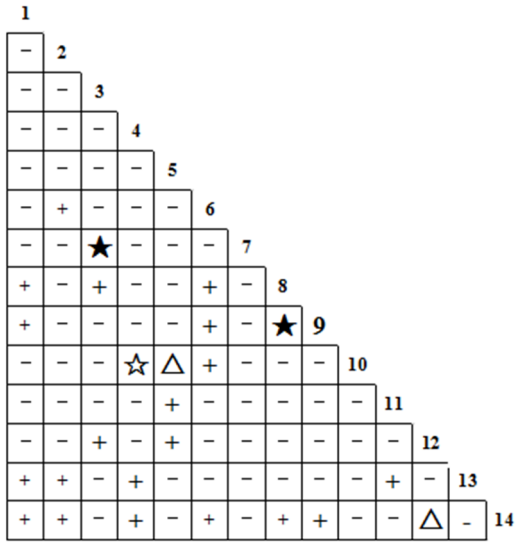

Figure 2. Spearman rank correlation matrix of scattered forest.

- Note: + Insignificant positive correlation, — Insignificant negative correlation,

☆ Significant positive correlation(p<0.05), ★ Extremely significant positive correlation(p<0.01).

3.3. Spearman rank correlation coeffient

Spearman rank correlation analysis showed in Figure 1&2. that among the species pairs from 21 dominant species in the pure forest, 72 pairs were positively correlated, of which 5 pairs reached a significant level, and the rest showed negative correlation, of which 5 pairs reached a significant level. The overall trend was still negative, indicating that these species had different ecological adaptability to habitats and ecological niche differentiation.In the scattered forest, 14 dominant species with high important values in the community were selected for analysis. Spearman rank correlation analysis showed that 23 pairs were positively correlated, of which 3 pairs reached a significant level, and the rest showed a negative correlation.

4. Discussion

The positive and negative correlations between plant species were mainly caused by the ecological characteristics, ecological adaptability and ecological niche differentiation of species, reflecting the response of species to habitat differentiation or the existence of competition, and measuring the inrespecific correlation and the difference of plants' reaction to environmental synthetic ecological factors to some extent.

- In the pure forest of Pinus syluestriformis, the positive correlation between Pinus syluestriformis and other species was more, indicating that these plants had similar ecological habits and strong ecological adaptability to habitats. They could rationally allocate and utilize habitat

resources to achieve long-term coexistence. Plaque cluster distribution exacerbated the intensity of intraspecific competition and weakened interspecific competition, resulting in intraspecific competition greater than interspecific competition. However, Overall relevance was negatively correlated, indicating that the community structure and its species composition would gradually simplify, the interspecific relationship would gradually become negatively correlated, and the community was in an unstable succession stage.

- In scattered forest, Pinus syluestriformis was one of the established species in the community, and overall relevance was negatively correlated. Pinus syluestriformis had negative correlations with most species, which did not reach a significant degree, indicating the individual in the Arbor layer had their own suitable ecological niche, whose correlation with other species was not strong. This reflected the fierce competition for resources among plant species. They had different ecological adaptability and separate ecological niches to habitats. The community was in an unstable succession stage and is easily displaced by external factors.
- The positive correlation between pairs indicates that plants had similar biological characteristics and habitat adaptability, which contributed to the coexistence of species. Therefore, in the ecological restoration of Pinus syluestriformis, species with similar ecological adaptability and positive correlation to habitats should be selected to conduct reasonable population allocation according to habitat conditions.

5. Conclusion

As one of the established species in scattered forest, Pinus syluestriformis had competition and exclusion for resources with other species due to the limited existence of environmental nutrient space and resources. The special habitat conditions of Pinus syluestriformis make it difficult to achieve normal performance by itself. Fortunately, Pinus syluestriformis has a short life span. After a period of time, it will be eliminated by trees such as Pinus koraiensis and Picea asperata. If no measures are taken to artificially promote regeneration, such Pinus syluestriformis forest will naturally die out. The results of the tests are positive and negative correlation ratio <1, which reflects the unstable early succession stage of plant community, The community is susceptible to the interference of external factors and succeeds. The ecological protection and restoration management of Pinus syluestriformis population has a long way to go. In the process of vegetation restoration, it is necessary to fully consider the interspecific association characteristics of plant communities, and select the species that are positively associated or the species that are neutrally associated as the recovery target. The species that are significantly negatively associated, such as Sorbus pohuashanensis, Acer tegmentosum, Ulmus macrocarpa, etc.

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