Spatial Patterns and Associations of Reaumuria soongarica Populations on Different Slope Aspects at Laohutai, Gaolan (Postprint)

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Abstract

Spatial pattern analysis is an important approach for studying interactions among plant populations and their relationships with the environment. *Reaumuria soongarica* is a dominant species in the semi-arid regions of the Loess Plateau. Through field community surveys and employing Ripley' s K-function in spatial point pattern analysis, we examined the spatial distribution patterns and intraspecific associations of *R. soongarica* populations across different slope aspects in the desert vegetation of Laohutai, Gaolan, Gansu. The results indicate that *R. soongarica* constitutes an increasing population, with its distribution showing significant variation among slope aspects. On south- and southwest-facing slopes, Class I and II individuals exhibited significantly aggregated distribution at small scales; as age class and spatial scale increased, the aggregation intensity of *R. soongarica* populations gradually decreased, eventually approaching random distribution. On west- and northwest-facing slopes, the proliferation of *Ajania achilloides* and *Stipa breviflora* suppressed *R. soongarica* growth and intensified interspecific competition, resulting in predominantly random distribution patterns across all age classes of *R. soongarica*. Across different slope aspects, Class I and II individuals displayed negative association at small scales, with the degree of association decreasing as scale increased; Class III and IV individuals showed significant negative association with Class I and II individuals, while no significant association was detected between Class III and IV individuals, suggesting that individuals of similar age classes are spatially independent. In conclusion, in the semi-arid regions of the Loess Plateau, microhabitat effects constitute a crucial factor influencing *R. soongarica* population distribution, in addition to the species' own biological and ecological characteristics.

Full Text

Spatial Pattern and Correlation of *Reaumuria soongarica* on Different Slopes of Laohu Platform in Gaolan County

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Abstract

The spatial pattern of plant populations serves as an important method for studying plant population interactions and the relationship between populations and their environment. *Reaumuria soongarica* is a dominant species in arid regions of the Loess Plateau. Understanding the spatial pattern of *R. soongarica* can improve our knowledge of adaptive characteristics of shrubs to different slope aspects. Based on field investigations, the spatial distribution patterns and correlations of *R. soongarica* populations in different slope aspects of Laohu Platform, Gaolan County, Gansu Province were analyzed using Ripley' s K function method of spatial point pattern analysis. The spatial position of each *R. soongarica* individual was determined in 10 m × 10 m study plots across different slope aspects. The results showed that the *R. soongarica* population was in a growth stage, and its distribution exhibited significant differences among various slopes. Age class I and II individuals of *R. soongarica* populations showed significant aggregated distribution at small scales, with clumping intensity gradually weakening as age class and spatial scale increased, finally tending toward random distribution on south and west-south slope aspects. On west and north-west slope aspects, the distribution pattern of all *R. soongarica* individuals was dominated by random distribution due to the growth of large numbers of *Ajan···achilloides* and *Stipa breviflora* caused by suppression and interspecific competition. In different slope aspects, *R. soongarica* populations between class I and II individuals showed negative correlation at small scales, but the correlation degree decreased with increasing scale. The relationship between class I with II and class III with IV individuals had significantly negative correlation. There was no significant relationship between age classes III and IV, which showed that individuals with similar ages were independent in spatial distribution. In the arid region of the Loess Plateau, the main influencing factors of *R. soongarica* population distribution were its own biological and ecological characteristics, while the influence of microhabitats was also very important. This paper could provide technical support for soil erosion control in Gansu Province.

Keywords: Loess Plateau; *Reaumuria soongarica* population; age-class struc-

ture; point pattern; slope aspects

1. Introduction

Reaumuria soongarica is a dominant shrub species in arid regions, playing a crucial role in maintaining ecosystem stability and preventing soil erosion. Previous studies have examined its population structure and spatial distribution patterns in desert areas of Inner Mongolia and other regions. However, research on how slope aspect influences the spatial patterns of different age classes remains limited. This study investigates the spatial distribution and correlations of *R. soongarica* populations across different slope aspects on the Loess Plateau.

2. Methods

2.1 Study Area and Data Collection Field investigations were conducted in August 2017 on Laohu Platform in Gaolan County, Gansu Province. The study area is located at an elevation of 1820 m, characterized by typical arid zone vegetation. Four slope aspects were selected for analysis: south (0°), west-south (45°), west (90°), and north-west (135°). In each slope aspect, 10 m × 10 m quadrats were established to record the spatial coordinates of all *R. soongarica* individuals.

2.2 Age Classification *R. soongarica* individuals were divided into four age classes based on height and crown width measurements: - **Class I:** Height < 30 cm (seedlings) - **Class II:** Height 70–110 cm (juveniles) - **Class III:** Height 110–150 cm (mature) - **Class IV:** Height > 150 cm (senescent)

2.3 Spatial Pattern Analysis Spatial point pattern analysis was performed using Ripley' s K function. The K function calculates the expected number of points within distance t of a typical point:

$$K_{ab}(t) = n_a \times n_b \sum I_t(u_{ij}) \quad (i \neq j)$$

where *n_a* and *n_b* are the numbers of points for species a and b; *I_t(u_ij)* is an indicator function that equals 1 if the distance between points i and j is less than t, and 0 otherwise.

To facilitate interpretation, the K function was transformed into the L function:

$$L_{ab}(t) = \sqrt{\frac{K_{ab}(t)}{\pi}} - 1$$

The interpretation of *L(t)* values follows: - *L(t) < 0*: regular distribution at scale t - *L(t) = 0*: random distribution at scale t - *L(t) > 0*: aggregated distribution at scale t

Monte Carlo simulations with 99 permutations were used to generate confidence envelopes (= 0.05) for significance testing.

3. Results

[Figure 1: see original paper] shows the spatial distribution of *R. soongarica* individuals across different slope aspects. The population density varied significantly, with highest densities observed on south-facing slopes.

[Figure 2: see original paper] presents the age structure of *R. soongarica* populations. The population was dominated by class I and II individuals, indicating a growing population.

[Figure 3: see original paper] illustrates the spatial distribution patterns for different age classes. Class I and II individuals exhibited aggregated distributions at small scales (0–2.5 m and 0–4 m, respectively), with aggregation intensity decreasing as scale increased. Class III and IV individuals showed random distribution patterns across all scales.

[Figure 4: see original paper] displays the spatial correlations between different age classes. Significant negative correlations were observed between class I and II individuals at small scales, particularly on south and west-south slopes. No significant spatial correlations were found between class III and IV individuals.

4. Discussion

The spatial distribution patterns of *R. soongarica* populations are primarily influenced by the species' biological characteristics and microhabitat conditions. The aggregated distribution of young individuals (classes I and II) at small scales reflects the species' reproductive strategy and seed dispersal mechanisms. As individuals mature, density-dependent competition leads to self-thinning and a shift toward random distribution.

On west and north-west slopes, the presence of competing species such as *Ajan··· achilloides* and *Stipa breviflora* suppresses *R. soongarica* establishment, resulting in random distribution patterns even for younger age classes. This interspecific competition, combined with harsher microclimatic conditions on these aspects, limits population establishment and growth.

The negative spatial correlations between adjacent age classes (I vs. II, III vs. IV) suggest asymmetric competition, where older, larger individuals suppress the growth and establishment of younger individuals. The lack of correlation between classes III and IV indicates that mature individuals become spatially independent as they reach similar competitive abilities.

Microhabitat heterogeneity, including soil moisture, nutrient availability, and microtopography, significantly influences population distribution patterns. These factors vary with slope aspect, creating complex interactions between biotic and abiotic factors that shape population structure.

5. Conclusion

Reaumuria soongarica populations on Laohu Platform exhibit aspect-dependent spatial patterns. Young individuals show aggregated distributions that transition to random patterns with increasing age and scale. Interspecific competition on certain aspects modifies these patterns, highlighting the importance of both intrinsic biological characteristics and extrinsic environmental factors. These findings provide valuable insights for ecological restoration and soil erosion control strategies in arid regions of the Loess Plateau.

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Note: Figure translations are in progress. See original paper for figures.