

POINT PATTERN ANALYSIS OF THE ENDANGERED PLANT *MALANIA OLEIFERA*

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Abstract. *Malania oleifera* is a rare and endangered relict plant of a single genus and species endemic to China. It is highly valuable for protection, scientific research and the economy. Based on data from a 1 hm² secondary forest plot in the Yachang Orchid Reserve, Guangxi, single- and dual-variable paired correlation functions were employed to analyze its spatial distribution, diameter-at-breast height (DBH, diameter-at-breast height) patterns, and associations with 25 major tree species. This study provides a basis for exploring its endangerment mechanisms and informing conservation and development strategies. Results indicate: the population exhibits an inverted “J”-shaped diameter class structure with stable composition; *Malania oleifera* exhibits spatially aggregated distribution, with aggregation intensity gradually decreasing as the scale increases; Habitat heterogeneity shapes a survival strategy characterized by “weak aggregation and strong habitat dependence” for garlic fruit across different DBH classes; The resource utilization and habitat adaptability of garlic fruit differ significantly from other dominant tree species in the community; Spatial associations between garlic fruit and 25 major tree species in the plot reached 24%, with 12% showing negative correlations and 12% showing positive correlations with garlic fruit. Inter-species associations were largely unrelated due to scale effects offsetting positive and negative interactions.

Keywords: *endangered plants, garlic fruit, pairwise correlation function, spatial pattern, spatial correlation*

Introduction

Malania oleifera is a monotypic species of *Malania* in the family of *Olacaceae*. It is a rare plant endemic to China and is also known as Shantongguo or Malanhou in the Zhuang language (Li et al., 2019). It is only naturally distributed in the narrow areas of southeastern Yunnan and western Guangxi (Yang et al., 2020; Liang et al., 2001). It mostly grows in limestone low mountain areas at altitudes of 300-1200 m. It mostly grows in limestone low mountain areas of southwest China (Wang et al., 2019; Guo et al., 2018). The oil yield of its kernel oil can reach 64.5%, and it is rich in tetracosenoic acid, also known as nervonic acid (Xu et al., 2019). It is an essential nutrient for brain development and maintenance of physiological functions. It plays an important role in improving

neural activity and preventing brain neurasthenia (Li et al., 2020; Yang et al., 2019). It can be used as medicine and health care products (Zhou et al., 2002). In recent years, due to global environmental change, human disturbance, and plant reproductive barriers, the wild resources of *Malania oleifera* have been gradually reduced. It is listed as a national second-class protected wild plant (Fu et al., 1992). Therefore, the protection of *Malania oleifera* resources is imminent.

The distribution characteristics of the population are closely related to the study of spatial pattern. The formation of plant population pattern, on the one hand, depends on the characteristics of the species itself, on the other hand, is closely related to the community environment. The analysis of population spatial pattern is an important means to study community structure, population interaction and the relationship between population and environment. It is widely used in the study of multi-scale spatial distribution pattern of plant population and multi-scale spatial correlation between multiple species. Based on this, statistical and ecological hypotheses are proposed and the consistency of these hypotheses and actual data is discussed. It has always been one of the hotspots in ecological research (Zhang, 1995, 1998; Stoyan, 2000; Wiegand, 2004). Studying the spatial distribution pattern of populations is helpful to further understand the internal ecological processes of pattern formation, such as habitat filtering, resource competition, seed dispersal ability, etc., from the aspects of the biological characteristics of populations and the interaction with environmental factors, and these factors have different effects on species at different species or scales (Liang et al., 2022). At present, the research work on *Malania oleifera* in China is mostly focused on the extraction and development and utilization of its oil (Liu et al., 2007; Ma et al., 2004), seedling breeding and cultivation (Yin et al., 2007; Yu et al., 2023), population structure and dynamic characteristic. However, the spatial distribution pattern and interspecific association of *Malania oleifera* have not been reported. This study investigates the spatial distribution patterns and interspecific associations between *Malania oleifera* population and dominant tree species in the Yachang Orchid National Nature Reserve. Pairwise correlation function $g(r)$ was employed to analyze scale effects in spatial distribution and interspecific relationships. The study aims to clarify the driving mechanisms of habitat heterogeneity and interspecific interactions on the distribution of *Malania oleifera* population, reveal the causes of its clustered distribution and the mechanisms of interspecific coexistence, fill gaps in the spatial ecology research of this species, and provide theoretical basis for exploring the mechanisms of its endangered status and formulating in situ conservation and population recovery strategies.

Research area and research methods

Overview of the study area and the surrounding environment

The study plots were established within the National Nature Reserve for Orchidaceae Plants in Yachang, Leye County, Guangxi Zhuang Autonomous Region (Fig. 1). This area is situated in the karst mountainous region of southwest China, located in the transitional zone between the Yungui Plateau and the Guangxi hills. It represents one of the core distribution areas for wild populations of *Malania oleifera* (Fig. 2). The topography of the study plots is characterized by karst landforms, predominantly consisting of medium-sized and low mountains (Wang et al., 2010). The zonal climate type in this area is the mid-subtropical monsoon climate zone, which is deeply affected by the monsoon circulation and the burning wind effect. In summer, the ocean moist air

mass prevails, while in winter, the continental cold air mass prevails. The region enjoys a mild climate with minimal annual temperature variation. Summers are free from extreme heat, and winters generally avoid severe cold, though frost and snowfall occur during certain periods. The annual average temperature is 16.3°C, the extreme maximum temperature is 41.1°C, the minimum temperature is -3°C. The average annual sunshine duration was 1467.0 h. Soil types include cinnamon red soil, mountain red soil and yellow soil. Due to less precipitation, the Hongshui River Valley below 500 m altitude is mainly distributed in brown laterite, 500-1000 m is mainly distributed in mountain red soil, more than 1000 m is mountain yellow soil, and some of the top of the mountain is developed into meadow soil. Affected by the parent rock of the soil, black lime soil and brown lime soil are developed in the limestone area.

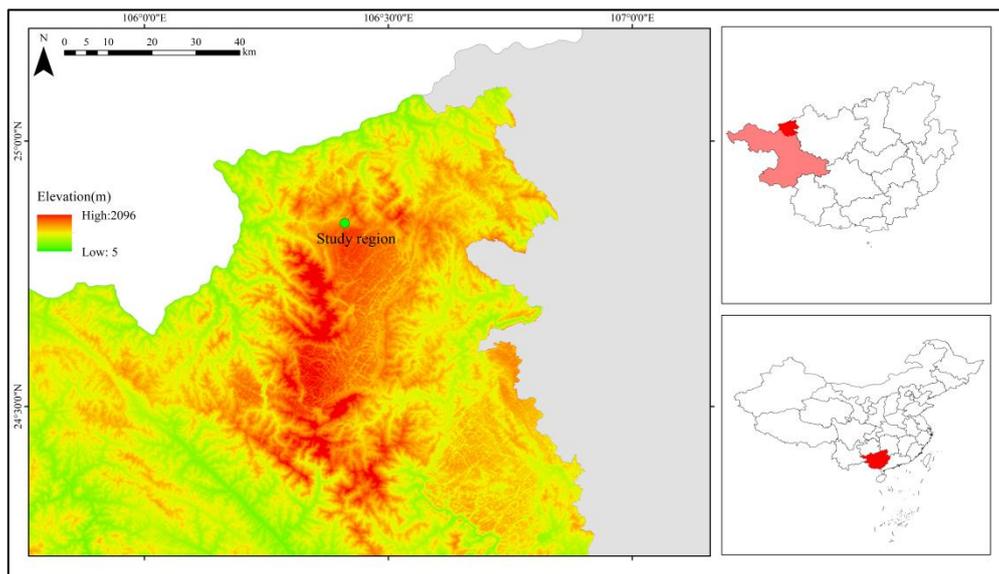


Figure 1. Map of the study area and the location of the test sample



Figure 2. Surrounding habitat of the *Malania oleifera*

Investigation method

In August 2023, a fixed plot was set up in the Yachang Orchidaceae National Nature Reserve, with the geographical origin coordinates of 106°24'37.69"E and

24°50'44.26"N. The plot with a length of 100 m × 100 m was divided into 25 quadrats of 20 m × 20 m, and each quadrat was subdivided into 16 small quadrats of 5 m × 5 m. The species, species name, DBH, tree height and their relative coordinates of all woody species with DBH ≥ 1 cm in each quadrat were investigated and recorded.

Data analysis

Measurement of breast height diameter and tree height

Breast height diameter is measured using a caliper at 1.3 meters above ground level on the main trunk. If the trunk is inclined, measure perpendicular to the trunk cross-section. If the trunk has knots or protrusions, take the average of the upper and lower normal sections. For small trees with branching points below 1.3 m, measurements are taken and recorded near the branching point. Tree height is measured using a measuring pole for small trees and a Brulès height gauge for large trees (measuring at a horizontal distance of 15 m; tree height = horizontal distance × tan(θ) + eye height).

Calculation of important value

According to the method of Wang et al. (2010), the relative abundance (RA), relative frequency (RF), relative dominance (RD) and important value (IV) of each species in the community were calculated. The calculation of the important value of the species is shown in Equation 1:

$$IV = RA + RF + RD \quad (\text{Eq.1})$$

where RA = the number of plants of a species / the total number of plants of all species; RF = the number of occurrences of a species in the statistical sample / the total number of occurrences of all species; RD = the sum of the basal area of a species / the basal area of all species. According to the ranking of important values, the main tree species in the top 25 of the important values and the dominant tree species in the top 5 of the important values were selected.

Point pattern analysis

The statistical principle of point pattern analysis was first proposed by Ripley (1981), and then through continuous improvement and development, detailed mathematical principles can be referred to Diggle (1983) and Zhang (1998). In this paper, the coordinates of plant individuals in space are taken as the basic data. Each individual can be regarded as a point in two-dimensional space, so that all individuals form a point map of spatial distribution, and then the pattern analysis is based on the point map.

In the analysis of population distribution pattern, this paper uses the pairwise correlation function $g(r)$ to calculate the spatial pattern of the population at multiple scales. The pairwise correlation function is an extension of Ripley's K equation. Using the distance between points, the number of points in the ring area with any point as the center of the circle, radius r , and specified width is calculated to analyze the spatial point pattern, that is:

$$g(r) = (2\pi r) - 1dK(r) / dr \quad (\text{Eq.2})$$

It replaces the circular region with a radius of r in Ripley 's k function with a circular region of a specified width, so it is a probability density function (Stoy, 1994; Wiegand, 2004). It improves that Ripley 's K function as a cumulative distribution function has a small-scale cumulative effect on large scales (Ye et al., 2008), and helps to explore the ecological process of pattern formation. Similarly, the spatial association between species can be analyzed by bivariate point pattern analysis using pairwise correlation functions, that is:

$$g_{12}(r) = (2\pi r)^{-1} dK_{12}(r) / dr \quad (\text{Eq.3})$$

It calculates the number of species 2 in a circular region of radius r centered on each individual of species 1 (Diggle, 1983; Wiegand, 2004). In this paper, we use Monte-Carlo fitting test (the number of fitting is 99) to calculate the upper and lower envelopes, that is, 99% confidence interval. The $g(r)$ values at different scales were calculated using the actual distribution data of the population (point map). In the univariate analysis, if $g(r)$ is a random distribution between the envelopes, higher than the upper envelope is an aggregated distribution, and lower than the lower envelope is a uniform distribution; in the bivariate analysis, if the $g_{12}(r)$ value is between the envelope lines, it indicates that the two types of patterns are not related, higher than the upper envelope line is a significant positive correlation, and lower than the lower envelope line is a significant negative correlation. The zero model used in this paper is a completely random zero model. Point pattern analysis was performed using the Spatstat package in R software (R 4.5.1).

Results and analysis

Diameter structure of Malania oleifera

It can be seen from (Fig. 3) that the diameter structure of all tree species in the plot is similar to the inverted 'J' type, and the number of individuals decreases with the increase of diameter class. The number of individuals with $DBH \leq 5$ cm accounts for 31% of the total number of trees in the plot. Similarly, the diameter class structure of *Malania oleifera* showed an inverted J-shaped diameter class distribution. The overall diameter class was mainly concentrated in $DBH = 1-10$ cm, and there were few individuals with diameter class above 20 cm. From the overall trend, the diameter structure of *Malania oleifera* was similar to that of all tree species in the plot, with small diameter individual reserves and stable population. In addition to *Malania oleifera*, the research area also contains plants such as *Amesiodendron chinense*, *Rhaphiolepis indica*, *Itea yunnanensis*, *Sinoadina racemosa*, *Myrsine semiserrata* and *Myrsine seguinii*, along with the dominant plant communities they form. In addition to Garlic Fruit, the study area also contains plants such as Slender Dragon, Grouper Tree, Yunnan Mouse Thorn, Chicken Tree, Needle-toothed Ironwood, and Dense-flowered Tree, along with the dominant plant communities they form. Specific species are listed in Table A1.

Spatial distribution pattern of Malania oleifera

The results of univariate point pattern analysis showed that the spatial aggregation degree of *Malania oleifera* in the study area gradually decreased with the increase of scale, and the distribution characteristics transitioned from aggregation distribution to random distribution, as shown in (Fig. 4). The results showed that the aggregation intensity of

Malania oleifera gradually decreased with the increase of research scale. Among them, from the 0-2 m scale, it shows an aggregated distribution, at the 2-5 m scale, it shows a random distribution, and at the 5-38 m scale, it tends to random distribution. In addition, the aggregation intensity of *Malania oleifera* at a small scale less than 5 m was significantly higher than that at other scales. From the scatter diagram of the distribution of *Malania oleifera* (Fig. 5), it can also be seen that the distribution of *Malania oleifera* in the sample plot is not uniform, and most of them are randomly distributed.

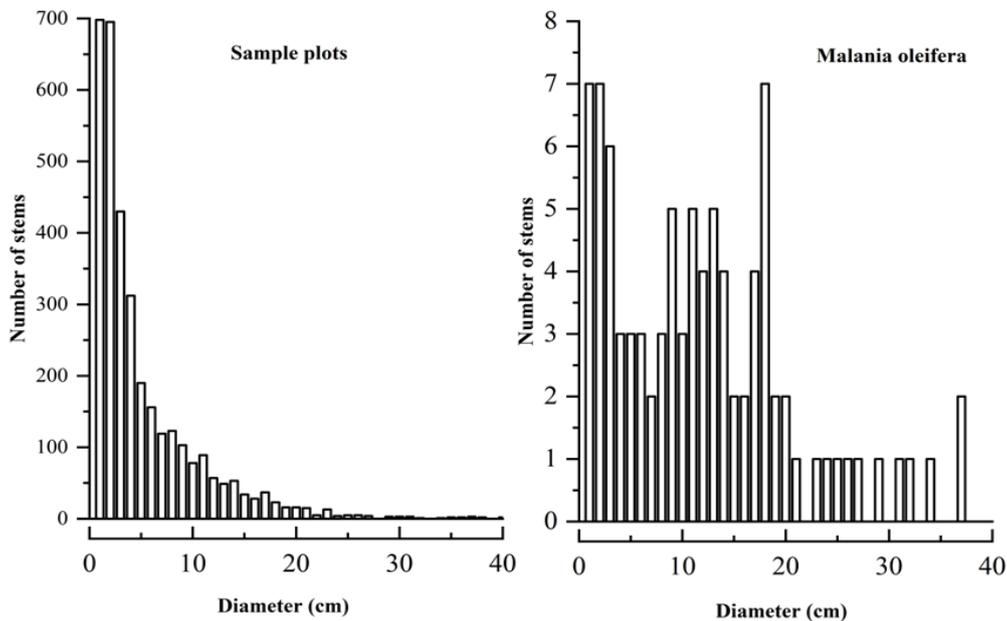


Figure 3. Diameter distribution of all tree species and *Malania oleifera* Size Distribution within the 1-ha plot

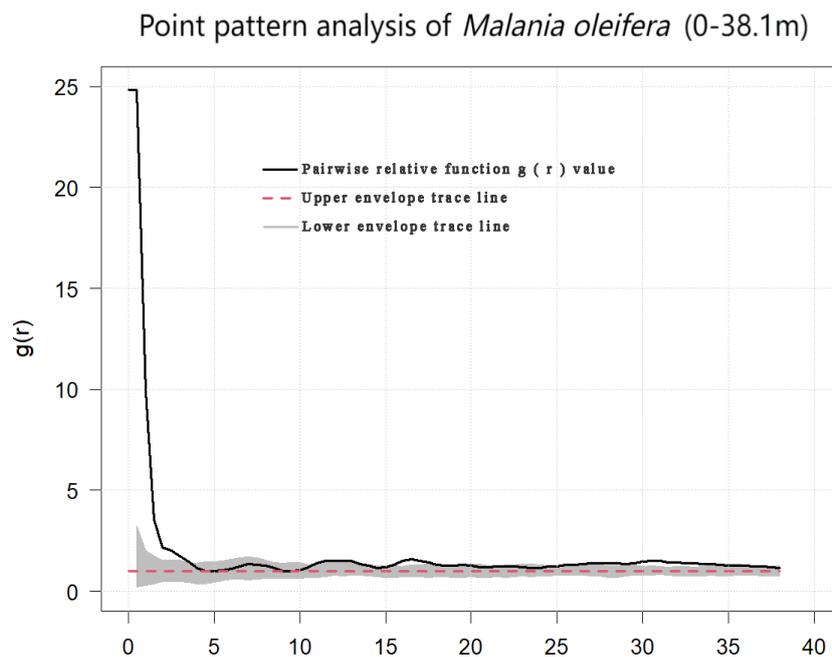


Figure 4. Point pattern analysis of *Malania oleifera*

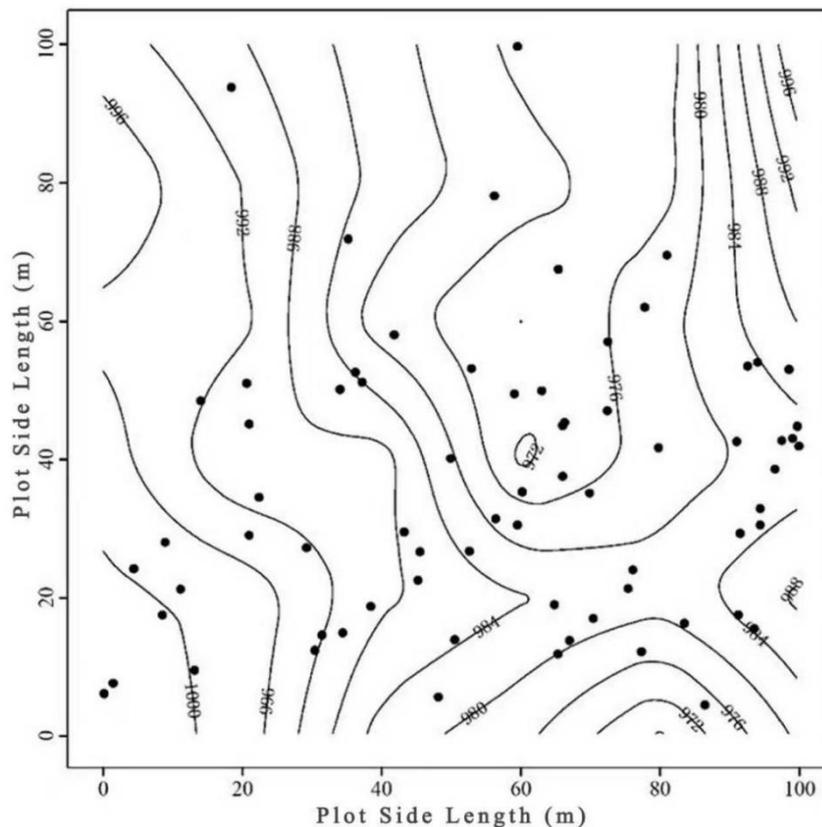


Figure 5. Topography map of the plot and distribution pattern of *Malania oleifera*

Spatial distribution pattern of Malania oleifera

Figure 6 shows the spatial distribution of *Malania oleifera* according to DBH (DBH, diameter at breast height) level. Different color points represent *Malania oleifera* plants of ≤ 5 cm, 5-10 cm, 10-20 cm and >20 cm, respectively. All the diameter classes of *Malania oleifera* are scattered in the sample plot. Among them, the number of saplings with $\text{DBH} \leq 5\text{cm}$ is large and widely distributed. At the same time, the middle trees of 5-10 cm, 10-20 cm and the big trees of > 20 cm also exist. The distribution of individuals at all levels is natural, reflecting that the population has sufficient young individual reserves, can complete the growth process from saplings to big trees, and has the potential for sustainable growth.

Spatial association between Malania oleifera and main tree species at different scales

Combined with the sample data, as well as the number of plants, DBH, height and important value of 25 tree species (Table A2), the populations with the top 25 important values in the secondary forest community of *Malania oleifera* were selected to analyze the interspecific spatial correlation with the *Malania oleifera* population. The pairwise correlation function was used to analyze the spatial correlation between species. The results showed that species pairs had different spatial correlations at different scales. The top 25 tree species in the importance value of the plot were mainly trees and small trees, and shrubs were the least (Table A2). In order to facilitate the analysis and grasp the interspecific association as a whole, this paper divides the 40 m scale into 5 small-scale

sections of 8 m, and the significant positive (negative) correlation of ≥ 3 scales is expressed as the overall significant positive (negative) spatial association between species. From *Table A3*, it can be seen that the 25 main populations studied have different degrees of spatial correlation with *Malania oleifera* at different spatial scales. Among them, 19 species have no significant spatial correlation at most scales, 3 species have significant spatial positive correlation at most scales, and 3 species have significant spatial negative correlation at most scales (*Table A3*).

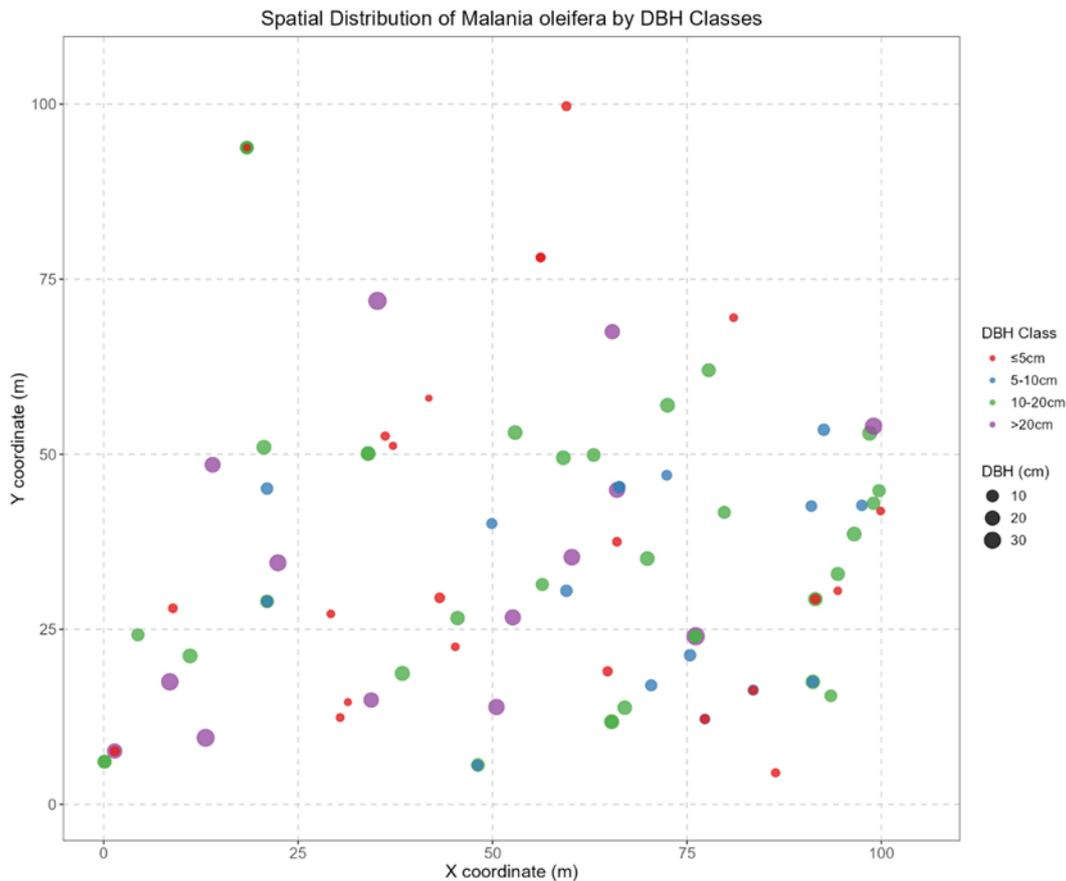


Figure 6. Spatial distribution pattern of diameter at breast height (DBH) for *Malania oleifera*

Discussion

Diameter structure

Diameter class structure is an important index of plant community stability and growth and development (Ye et al., 2008). There are individual reserves of small diameter class in *Malania oleifera* in this plot, and the population is stable. The trees in the plot are mainly low-diameter trees, and large-diameter standing trees are rare. It can be seen that the community is in the stage of progressive succession and belongs to the secondary forest type. The landform type of garlic fruit plot studied in this paper is karst landform, which will be affected by drought and human disturbance. These disturbances made it difficult for the community of *Malania oleifera* to reach maturity, and the progressive succession was intense and in the early stage of progressive succession, resulting in a large difference in the hierarchical structure and height of the climax community between

the secondary forest and the tropical evergreen monsoon forest, which was similar to the results of the study on the community characteristics of *Camellia nitidissima* (Wei et al., 2008).

Population distribution pattern

The spatial distribution pattern of plant populations is affected by the biological characteristics of the population itself, intraspecific and interspecific relationships, and environmental conditions, and is closely related to the spatial scale (Ma et al., 2013; Jin et al., 2018). Previous studies have shown that woody plants usually exhibit aggregated distribution at small scales and random or uniform distribution at large scales (Zhu et al., 2022; Lin et al., 2023). Some studies suggest that endangered plants show higher aggregation in spatial distribution, which is more obvious at small scales, and environmental heterogeneity will change the distribution pattern of species (Condit et al., 2000). The aggregation intensity of *Malania oleifera* gradually decreased with the increase of spatial distance, which was consistent with the current main conclusions. For *Malania oleifera*, its fresh fruit is large and heavy, usually around the mother plant, and the distance of transmission is not far (Ripley, 1977). So that the *Malania oleifera* showed a significant spatial pattern of aggregation distribution on a small scale (Xu et al., 2018). This is consistent with Tang's et al. (2025) study on the spatial pattern and correlation of the rare and endangered plant *Camellia* population, and Zhao and Hui's (2023) study on the small-scale point pattern of dominant alpine cushion plants in different climatic zones in China. The limitation of seed dispersal may be one of the important reasons for the aggregation pattern of *Malania oleifera*.

The spatial distribution pattern usually formed at a small scale is mainly affected by the biological characteristics of the population itself, while the spatial distribution pattern at a larger scale is more affected by habitat heterogeneity. *Malania oleifera* seedlings are wet and shade-loving, and inappropriate growth environment causes death to seedlings (Su et al., 2023). Its high requirements for habitats lead to large aggregation intensity on small scales. The investigation found that the *Allium* in the plot was mainly distributed on both sides of the more humid and dark valleys, under the trees or shrubs on the slopes, which was consistent with the spatial pattern of aggregation distribution. This distribution pattern leads to a smaller area suitable for the survival of *Malania*, and it is not easy to expand the distribution area.

Spatial distribution of DBH

Due to the high development of carbonate rocks and the high permeability of rocks in karst landforms, the surface of the study area is broken and forms a huge and relatively continuous ecological environment space in the wide and thick rock strata below the soil layer, thus forming different microhabitats. The spatial distribution of soil characteristics in mineral nutrients (such as nitrogen and phosphorus) and water also has strong heterogeneity (Russo et al., 2016). The growth environment of *Malania oleifera* is characterized by significant soil patching and high rock exposure rate. Habitat heterogeneity has a significant screening effect on the spatial distribution of different DBH grades of *Malania oleifera* (Hughes et al., 1997). From the perspective of spatial distribution, the distribution of *Malania oleifera* with small diameter ≤ 5 cm is relatively scattered, which indicates that it has stronger adaptability to small environment and can germinate in various soil blocks. The distribution range of 5-10 cm and 10-20 cm of the

middle diameter class was wider, and there was a certain spatial overlap with the individuals of the large diameter class >20 cm. However, the number of large diameter classes is small and the distribution is sparse. This is because large-diameter trees need more stable resources and growth environment, and the suitable environment in karst landforms is often scarce and scattered, which makes it difficult for large-diameter trees to gather and grow. This spatial distribution characteristic related to the diameter class not only continues the initial distribution of *Malania oleifera* seeds germinated in a small range around the mother tree due to gravity propagation, but also reflects that in the karst environment, the competition and resource selection between the same species have a shaping effect on the distribution of *Malania oleifera* at different growth stages. This is consistent with the conclusion of “small-scale aggregation and large-scale randomization” obtained from the previous point pattern analysis, indicating that *Malania oleifera* has a “less aggregated and more dependent on the appropriate environment” in the karst environment.

Interspecific association

Interspecific association or species association is one of the important characteristics of forest community. It is the basis of community formation and evolution and important quantitative and structural indicators. It is also a manifestation of interspecific relationship and the basis of community classification (Hughes et al., 2022). The spatial association of plant populations is a stable coexistence state formed by the interaction between different populations under the long-term effect of the environment (Lei et al., 2022). When there is a positive spatial correlation between populations, it shows a mutually beneficial relationship, and the demand for environmental resources is complementary or similar; when there is a negative spatial correlation between populations, it indicates that there is a mutually exclusive competitive relationship between species, and the demand for environmental resources is to grab organisms or the same; when the population is spatially unrelated, it shows that there is an independent relationship between species, and the demand for environmental resources is not affected by each other (Liu, 2021). The results showed that the positive spatial correlation indicated that these species, such as *H. scabra*, *T. rotundifolia*, and *O. longifolia*, appeared together with *Malania oleifera*. Their ecological characteristics and differences and complementarities in environmental requirements made them promote each other's growth and coexist in the community. Tree species with negative correlation with *Malania oleifera*, such as *Cyclobalanopsis glauca*, *Lithocarpus harlandii*, and *Platycarya strobilacea*, are large-leaved deep-rooted trees with high canopy closure, which can inhibit photosynthesis and haustorium development of *Malania oleifera* saplings through strong shading and root competition. Most ‘unrelated’ tree species are not truly ecologically neutral, but the positive and negative effects of scale dependence offset each other, resulting in the overall insignificance. Subsequently, individual-level survival analysis can be introduced for further analysis.

The special habitat of Malania oleifera

The nature of secondary forest and the small environment formed by the community of *Malania oleifera* are suitable for the survival and reproduction of *Malania oleifera*. The seeds of *Malania oleifera* are large, and the seeds of *Malania oleifera* in natural habitats usually cannot enter the soil, but germinate on the surface of the soil. If the seeds

are exposed to strong light, the radicle will wither, resulting in a large number of seeds dying in the early stage of germination. In addition, studies have shown that 40% shade is more favorable for the growth and development of *Malania oleifera* seedlings (Xiong et al., 2024); its leaves have weak photosynthetic capacity and are difficult to adapt to strong light environments (Zhang et al., 2007). These studies have shown that *Malania oleifera* can only survive and reproduce normally under a certain canopy density, and its population survival is limited by the understory environment created by other tree species. Before clarifying the exact endangered mechanism of *Malania oleifera*, it is necessary to strengthen in-situ protection in its distribution area to create an optimal environment conducive to its survival and natural reproduction, especially to protect its special understory niches, such as shaded valleys and slopes.

Conclusion

In the population of *Malania oleifera*, the individuals with small DBH are in the majority, the small diameter class reserve is sufficient and the population is stable. The community is a secondary forest and is in the early stage of progressive succession. Affected by drought and human disturbance, the community structure and height do not reach the climax community level. The population distribution has significant scale dependence. The small scale is significantly aggregated due to the limited gravity propagation of seeds and the wet and shade preference of seedlings. The large scale tends to be random due to the regulation of habitat heterogeneity, which is in line with the law of ‘small-scale aggregation and large-scale dispersion’ of woody plants. The soil patching and resource heterogeneity of the karst landform further lead to the differential distribution of individuals with different DBH of *Malania oleifera*, forming an adaptation strategy of ‘weak aggregation and strong habitat dependence’. In terms of interspecific association, it is positively correlated with tree species such as *Mallotus philippensis*, and negatively correlated with large-leaved trees such as *Cyclobalanopsis glauca*. Most tree species have no correlation due to scale effect offsetting positive and negative effects. In terms of habitat demand, *Malania oleifera* is highly dependent on the shaded niche under secondary forests, such as valleys and arbor forests, while avoiding strong light. In summary, *Malania oleifera* achieves population survival through synergistic adaptation to karst habitats, interspecific relationships, and its own growth characteristics. In the future, it is necessary to strengthen in-situ protection and focus on maintaining its special understory habitats to avoid endangered risks.

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APPENDIX

Table A1. Complete list of species composition, genera and species, and number of individuals within the plot

Scientific name (no author)	Latin Binomial Name (with author, no synonyms)	Family	Genus	Number of Individuals
<i>Pinus yunnanensis</i> var. <i>tenuifolia</i>	<i>Pinus yunnanensis</i> var. <i>tenuifolia</i> Cheng et Law	<i>Pinaceae</i>	<i>Pinus</i>	11
<i>Tsuga chinensis</i>	<i>Tsuga chinensis</i> (Franch.) Pritz.	<i>Pinaceae</i>	<i>Tsuga</i>	1
<i>Cinnamomum parthenoxylon</i>	<i>Cinnamomum parthenoxylon</i> (Jack) Meisn.	<i>Lauraceae</i>	<i>Cinnamomum</i>	6
<i>Cinnamomum jensenianum</i>	<i>Cinnamomum jensenianum</i> Hand.-Mazz.	<i>Lauraceae</i>	<i>Cinnamomum</i>	89
<i>Cinnamomum wilsonii</i>	<i>Cinnamomum wilsonii</i> Gamble	<i>Lauraceae</i>	<i>Cinnamomum</i>	23
<i>Cryptocarya concinna</i>	<i>Cryptocarya concinna</i> Hance	<i>Lauraceae</i>	<i>Cryptocarya</i>	2
<i>Lindera floribunda</i>	<i>Lindera floribunda</i> (C. K. Allen) H. P. Tsui	<i>Lauraceae</i>	<i>Lindera</i>	4
<i>Machilus glaucifolia</i>	<i>Machilus glaucifolia</i> S. K. Lee & F. N. Wei	<i>Lauraceae</i>	<i>Machilus</i>	70
<i>Phoebe bournei</i>	<i>Phoebe bournei</i> (Hemsl.) Y. C. Yang	<i>Lauraceae</i>	<i>Phoebe</i>	3
<i>Mahonia duclouxiana</i>	<i>Mahonia duclouxiana</i> Gagnep.	<i>Berberidaceae</i>	<i>Mahonia</i>	110
<i>Nandina domestica</i>	<i>Nandina domestica</i> Thunb.	<i>Berberidaceae</i>	<i>Nandina</i>	7

<i>Liquidambar formosana</i>	<i>Liquidambar formosana</i> Hance	Altingiaceae	<i>Liquidambar</i>	1
<i>Itea yunnanensis</i>	<i>Itea yunnanensis</i> Franch.	Iteaceae	<i>Itea</i>	282
<i>Cladrastis platycarpa</i>	<i>Cladrastis platycarpa</i> (Maxim.) Makino	Fabaceae	<i>Cladrastis</i>	5
<i>Fordia cauliflora</i>	<i>Fordia cauliflora</i> Hemsl.	Fabaceae	<i>Fordia</i>	9
<i>Lysidice rhodostegia</i>	<i>Lysidice rhodostegia</i> Hance	Fabaceae	<i>Lysidice</i>	1
<i>Cerasus campanulata</i>	<i>Cerasus campanulata</i> (Maxim.) A. N. Vassiljeva	Rosaceae	<i>Cerasus</i>	2
<i>Eriobotrya serrata</i>	<i>Eriobotrya serrata</i> Vidal	Rosaceae	<i>Eriobotrya</i>	39
<i>Laurocerasus zippeliana</i>	<i>Laurocerasus zippeliana</i> (Miq.) Browicz	Rosaceae	<i>Laurocerasus</i>	49
<i>Pyracantha fortuneana</i>	<i>Pyracantha fortuneana</i> (Maxim.) Li	Rosaceae	<i>Pyracantha</i>	21
<i>Pyrus calleryana</i>	<i>Pyrus calleryana</i> Decne.	Rosaceae	<i>Pyrus</i>	9
<i>Raphiolepis indica</i>	<i>Raphiolepis indica</i> (L.) Lindl. ex Ker Gawl.	Rosaceae	<i>Raphiolepis</i>	288
<i>Stranvaesia davidiana</i>	<i>Stranvaesia davidiana</i> Dcne.	Rosaceae	<i>Stranvaesia</i>	2
<i>Hovenia acerba</i>	<i>Hovenia acerba</i> Lindl.	Rhamnaceae	<i>Hovenia</i>	3
<i>Rhamnus brachypoda</i>	<i>Rhamnus brachypoda</i> C. Y. Wu ex Y. L. Chen & P. K. Chou	Rhamnaceae	<i>Rhamnus</i>	11
<i>Rhamnus utilis</i>	<i>Rhamnus utilis</i> Decne.	Rhamnaceae	<i>Rhamnus</i>	2
<i>Celtis sinensis</i>	<i>Celtis sinensis</i> Pers.	Ulmaceae	<i>Celtis</i>	150
<i>Celtis timorensis</i>	<i>Celtis timorensis</i> Span.	Ulmaceae	<i>Celtis</i>	7
<i>Ulmus castaneifolia</i>	<i>Ulmus castaneifolia</i> Hemsl.	Ulmaceae	<i>Ulmus</i>	3
<i>Ficus subpisocarpa</i>	<i>Ficus subpisocarpa</i> Gagnep.	Moraceae	<i>Ficus</i>	6
<i>Ficus erecta</i>	<i>Ficus erecta</i> Thunb.	Moraceae	<i>Ficus</i>	8
<i>Maclura cochinchinensis</i>	<i>Maclura cochinchinensis</i> (Lour.) Corner	Moraceae	<i>Maclura</i>	14
<i>Morus alba</i>	<i>Morus alba</i> L.	Moraceae	<i>Morus</i>	27
<i>Cyclobalanopsis glauca</i>	<i>Cyclobalanopsis glauca</i> (Thunb.) Oerst.	Fagaceae	<i>Cyclobalanopsis</i>	57
<i>Lithocarpus harlandii</i>	<i>Lithocarpus harlandii</i> (Hance ex Walp.) Rehder	Fagaceae	<i>Lithocarpus</i>	42
<i>Quercus aliena</i>	<i>Quercus aliena</i> Blume	Fagaceae	<i>Quercus</i>	11
<i>Quercus variabilis</i>	<i>Quercus variabilis</i> Blume	Fagaceae	<i>Quercus</i>	12
<i>Platycarya strobilacea</i>	<i>Platycarya strobilacea</i> Siebold & Zucc.	Juglandaceae	<i>Platycarya</i>	48
<i>Euonymus laxiflorus</i>	<i>Euonymus laxiflorus</i> Champ. ex Benth.	Celastraceae	<i>Euonymus</i>	9
<i>Itoa orientalis</i>	<i>Itoa orientalis</i> Hemsl.	Salicaceae	<i>Itoa</i>	3
<i>Xylosma longifolia</i>	<i>Xylosma longifolia</i> Clos	Salicaceae	<i>Xylosma</i>	74
<i>Xylosma controversa</i>	<i>Xylosma controversa</i> Clos	Salicaceae	<i>Xylosma</i>	3
<i>Mallotus philippensis</i>	<i>Mallotus philippensis</i> (Lam.) Müll. Arg.	Euphorbiaceae	<i>Mallotus</i>	116
<i>Mallotus barbatus</i>	<i>Mallotus barbatus</i> (Wall.) Müll. Arg.	Euphorbiaceae	<i>Mallotus</i>	61
<i>Triadica rotundifolia</i>	<i>Triadica rotundifolia</i> (Hemsl.) Esser	Euphorbiaceae	<i>Triadica</i>	88
<i>Tirpitzia sinensis</i>	<i>Tirpitzia sinensis</i> (Hemsl.) Hall.	Linaceae	<i>Tirpitzia</i>	81
<i>Syzygium rehderianum</i>	<i>Syzygium rehderianum</i> Merr. & L. M. Perry	Myrtaceae	<i>Syzygium</i>	20
<i>Choerospondias axillaris</i>	<i>Choerospondias axillaris</i> (Roxb.) B. L. Burtt & A. W. Hill	Anacardiaceae	<i>Choerospondias</i>	79
<i>Pistacia chinensis</i>	<i>Pistacia chinensis</i> Bunge	Anacardiaceae	<i>Pistacia</i>	18
<i>Rhus chinensis</i>	<i>Rhus chinensis</i> Mill.	Anacardiaceae	<i>Rhus</i>	5
<i>Toxicodendron sylvestri</i>	<i>Toxicodendron sylvestri</i> (Siebold & Zucc.) Kuntze	Anacardiaceae	<i>Toxicodendron</i>	18
<i>Amesiodendron chinense</i>	<i>Amesiodendron chinense</i> (Merr.) Hu	Sapindaceae	<i>Amesiodendron</i>	330
<i>Clausena dunniana</i>	<i>Clausena dunniana</i> H. Lévl.	Rutaceae	<i>Clausena</i>	74
<i>Malania oleifera</i>	<i>Malania oleifera</i> Chun et S. Lee ex S. Lee	Oleaceae	<i>Malania</i>	91

<i>Cornus controversa</i>	<i>Cornus controversa</i> Hemsl.	Cornaceae	<i>Cornus</i>	1
<i>Sinosideroxylon pedunculatum</i>	<i>Sinosideroxylon pedunculatum</i> (Hemsl.) H. Chuang	Sapotaceae	<i>Sinosideroxylon</i>	1
<i>Diospyros chunii</i>	<i>Diospyros chunii</i> F. P. Metcalf & L. Chen	Ebenaceae	<i>Diospyros</i>	24
<i>Diospyros dumetorum</i>	<i>Diospyros dumetorum</i> W. W. Smith	Ebenaceae	<i>Diospyros</i>	13
<i>Diospyros miaoshanica</i>	<i>Diospyros miaoshanica</i> S. Lee	Ebenaceae	<i>Diospyros</i>	11
<i>Myrsine seguinii</i>	<i>Myrsine seguinii</i> H. Lév.	Primulaceae	<i>Myrsine</i>	152
<i>Myrsine semiserrata</i>	<i>Myrsine semiserrata</i> Wall.	Primulaceae	<i>Myrsine</i>	153
<i>Huodendron biaristatum</i>	<i>Huodendron biaristatum</i> (W. W. Smith) Rehd.	Styracaceae	<i>Huodendron</i>	6
<i>Sinoadina racemosa</i>	<i>Sinoadina racemosa</i> (Siebold & Zucc.) Ridsdale	Rubiaceae	<i>Sinoadina</i>	218
<i>Fraxinus insularis</i>	<i>Fraxinus insularis</i> Hemsl.	Oleaceae	<i>Fraxinus</i>	13
<i>Fraxinus chinensis</i>	<i>Fraxinus chinensis</i> Roxb.	Oleaceae	<i>Fraxinus</i>	11
<i>Ligustrum sinense</i>	<i>Ligustrum sinense</i> Lour.	Oleaceae	<i>Ligustrum</i>	58
<i>Clerodendrum mandarinorum</i>	<i>Clerodendrum mandarinorum</i> Diels	Lamiaceae	<i>Clerodendrum</i>	1
<i>Vitex yunnanensis</i>	<i>Vitex yunnanensis</i> W. W. Smith.	Lamiaceae	<i>Vitex</i>	29
<i>Ilex salicina</i>	<i>Ilex salicina</i> Hand. -Mazz.	Aquifoliaceae	<i>Ilex</i>	1
<i>Ilex chinensis</i>	<i>Ilex chinensis</i> Sims	Aquifoliaceae	<i>Ilex</i>	11
<i>Ilex macrocarpa</i>	<i>Ilex macrocarpa</i> Oliv.	Aquifoliaceae	<i>Ilex</i>	2
<i>Viburnum cinnamomifolium</i>	<i>Viburnum cinnamomifolium</i> Rehder	Adoxaceae	<i>Viburnum</i>	1
<i>Viburnum cylindricum</i>	<i>Viburnum cylindricum</i> Buch. -Ham ex D. Don	Adoxaceae	<i>Viburnum</i>	2
<i>Pittosporum pauciflorum</i>	<i>Pittosporum pauciflorum</i> Hook. & Arn.	Pittosporaceae	<i>Pittosporum</i>	104
<i>Pittosporum glabratum</i>	<i>Pittosporum glabratum</i> Lindl.	Pittosporaceae	<i>Pittosporum</i>	3
<i>Gamblea ciliata</i> var. <i>evodiifolia</i>	<i>Gamblea ciliata</i> var. <i>evodiifolia</i> (Franchet) C. B. Shang et al.	Araliaceae	<i>Gamblea</i>	8
<i>Kalopanax septemlobus</i>	<i>Kalopanax septemlobus</i> (Thunb.) Koidz.	Araliaceae	<i>Kalopanax</i>	49
<i>Schefflera delavayi</i>	<i>Schefflera delavayi</i> (Franch.) Harms	Araliaceae	<i>Schefflera</i>	41
<i>Schefflera heptaphylla</i>	<i>Schefflera heptaphylla</i> (L.) Frodin	Araliaceae	<i>Schefflera</i>	1

Table A2. Statistical table of number of trees, average diameter at breast height, average height, and importance value for 25 tree species in the *Malania oleifera* and sample plot

Tree species	Number of trees	Average diameter at breast height (cm)	Average height (m)	Relative density	Relative frequency	Relative dominance	Important value
<i>Malania oleifera</i>	91	12.52	7.77	0.03	1.00	9.75	10.78
<i>Choerospondias axillaris</i>	79	20.90	13.38	0.02	1.00	18.71	19.73
<i>Itea yunnanensis</i>	282	10.61	6.49	0.08	1.00	17.30	18.38
<i>Sinoadina racemosa</i>	218	6.98	6.40	0.06	1.00	6.79	7.85
<i>Pinus yunnanensis</i> var.	11	32.61	14.36	0.00	0.44	6.48	6.92

<i>tenuifolia</i>							
<i>Amesiodendron chinense</i>	330	4.42	5.00	0.10	1.00	5.29	6.38
<i>Celtis sinensis</i>	150	5.14	5.17	0.04	1.00	2.61	3.65
<i>Cyclobalanopsis glauca</i>	57	7.39	6.54	0.02	0.88	2.41	3.31
<i>Triadica rotundifolia</i>	88	6.30	5.45	0.03	1.00	2.21	3.24
<i>Vitex yunnanensis</i>	29	11.50	7.97	0.01	0.75	2.02	2.78
<i>Machilus glaucifolia</i>	70	6.31	5.60	0.02	1.00	1.72	2.74
<i>Cinnamomum jensenianum</i>	89	4.94	5.31	0.03	1.00	1.54	2.57
<i>Rhaphiolepis indica</i>	288	2.87	3.54	0.09	1.00	1.29	2.38
<i>Pittosporum pauciflorum</i>	104	3.89	4.54	0.03	1.00	1.33	2.36
<i>Laurocerasus zippeliana</i>	49	2.45	2.48	0.01	0.94	1.05	2.00
<i>Xylosma longifolia</i>	74	4.31	4.42	0.02	1.00	0.88	1.91
<i>Quercus variabilis</i>	12	13.13	9.25	0.00	0.50	1.40	1.90
<i>Lithocarpus harlandii</i>	42	5.75	6.35	0.01	0.94	0.95	1.90
<i>Myrsine semiserrata</i>	153	2.55	2.92	0.05	1.00	0.83	1.88
<i>Mallotus philippensis</i>	116	3.39	3.99	0.03	1.00	0.75	1.79
<i>Tirpitzia sinensis</i>	81	3.66	4.17	0.02	1.00	0.75	1.79
<i>Platycarya strobilacea</i>	48	4.98	5.52	0.01	0.88	0.82	1.77
<i>Morus alba</i>	27	7.53	6.30	0.01	0.81	0.88	1.71
<i>Ligustrum sinense</i>	58	3.88	4.72	0.02	1.00	0.55	1.71
<i>Pistacia chinensis</i>	18	7.85	6.58	0.01	0.81	0.65	1.57
<i>Myrsine seguinii</i>	152	2.20	2.70	0.045	1.00	0.38	1.42

Table A3. Spatial correlation of the top 25 species by importance value in the plot with dominant species at different scales

Tree species	Life form	Scale					
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		0-8 m	8-16 m	16-24 m	24-32 m	32-40 m
<i>Mallotus philippensis</i>	S	0	+	+	+	+
<i>Rhaphiolepis indica</i>	S	0	+	0	0	0
<i>semiserrata</i>	S	0	0	0	0	0
<i>Pittosporum pauciflorum</i>	S	0	+	0	0	0
<i>Tirpitzia sinensis</i>	S	0	+	0	+	0
<i>Ligustrum sinense</i>	S	0	0	0	0	0
<i>Myrsine seguinii</i>	S	0	0	0	0	0
<i>Triadica rotundifolia</i>	ST	+	+	+	+	0
<i>Xylosma longifolia</i>	ST	0	+	+	+	+
<i>Itea yunnanensis</i>	ST	0	0	0	0	0
<i>Cinnamomum jensenianum</i>	ST	0	0	0	+	0
<i>Vitex yunnanensis</i>	ST	0	0	0	0	0
<i>Cyclobalanopsis glauca</i>	T	0	0	0	0	-
<i>Platycarya strobilacea</i>	T	0	0	0	0	-
<i>Lithocarpus harlandii</i>	T	0	0	0	0	-
<i>Amesiodendron chinense</i>	T	0	0	0	0	0
<i>Sinoadina racemosa</i>	T	0	0	0	0	0
<i>Celtis sinensis</i>	T	0	0	0	0	0
<i>Choerospondias axillaris</i>	T	0	0	+	0	0
<i>Machilus glaucifolia</i>	T	0	0	0	0	+
<i>Laurocerasus zippeliana</i>	T	0	0	0	0	0
<i>Morus alba</i>	T	0	0	0	0	0
<i>Pistacia chinensis</i>	T	0	0	0	0	0
<i>Quercus variabilis</i>	T	0	0	0	0	0

“+” indicates a significant positive correlation, “-” indicates a significant negative correlation, and “0” indicates no correlation; S, Shrub; T, Arbor; ST, Small arbor trees