DISTRIBUTION PATTERN OF SUBDOMINANT SPECIES IN THE MOUNTAINTOP MOSSY DWARF FOREST OF THE YANGMING MOUNTAINS IN HUNAN PROVINCE, CHINA

CHEN, Y. H.[1*] – WANG, Z. L.[1] – PENG, Z. H.[2] – LONG, Y. L.[3]

[1]*Hunan Institute of Science and Technology, Yueyang 414000, China*

[2]*College of Landscape Architecture, Central South University of Forestry and Technology, Changsha 410004, China*

[3]*Horticulture & Landscape College, Hunan Agricultural University, Changsha 410128, China*

[*]*Corresponding author*
e-mail: lory2366@163.com

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Abstract. The mountaintop mossy dwarf forest is a community formed of evergreen broad-leaved forests in subtropical mountains under extreme climatic and environmental conditions. Understanding the distribution pattern and scale of the subdominant tree species among this forest type can provide insights for effective forest management measures and the mechanisms of community assembly in subtropical forests. In this study, we established 3 plots to explore the distribution patterns of the subdominant species in the mountaintop mossy dwarf forest in three directions in the Yangming Mountains in Hunan Province, China. An adjacent lattice method was used to survey the subdominant species (i.e., *Hydrangea paniculata*). At seven spatial scales, aggregation intensity index such as variance /mean ratio (*v/m*), negative binomial parameter (*k*), clumping index (*I*), mean crowding index (*m**), patchiness index (*m/m**), aggregation index (*Ca*), and green index (*GI*) were used to analyze distribution patterns of populations. The results showed that the subdominant species only in the northern plots presented a clumped distribution on 25 m^2 sampling scale. However, with increasing surveying scales, the distribution patterns changed from clustered to uniform or random. The spatial distribution characteristics at different developmental stages showed that population aggregation intensities developed from strong via weak to random. Population dominance and resultant distribution patterns were mainly caused by biological characteristics such as seed propagation and vegetative reproduction, and the influence of environmental factors, such as plot orientation and slope direction.
Keywords: *population spatial pattern, Hydrangea paniculata population, clustering intensity, pattern size; Yangming Mountains in Hunan Province*

Introduction

In the process of community succession, the genetic factors of species, interspecific competition, climate change and human disturbance can affect the individual distribution of species (Zhang et al., 2016). The population distribution pattern is the configuration state or layout of the individual in space, and it is also the result of the comprehensive action of various internal and external factors in the community. It reflects the status and role of the population in the community and the spatial relationship between the individuals (Jia et al., 2015), and has an important influence on the growth, reproduction, death, regeneration and resource utilization of the species (Luo et al., 2009). For a certain population, its distribution pattern is not static, the same species in different habitat conditions, even in different developmental stages are also significantly different (Zhu et al., 2011; Zhao et al., 2016). Studying the population distribution pattern can quantitatively describe the horizontal structure and quantitative characteristics of the

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population, reveal the intraspecific and interspecific relationships, the causes of the distribution pattern, the environmental adaptation mechanism, and the dynamic changes of the population and community (Zhang et al., 2009). There are many methods for determining the population distribution pattern, but different methods have different application scopes, advantages and disadvantages in practical analysis. Most of the determination methods are scale-dependent. Multi-scale and multi-index comprehensive analysis can generally obtain reliable conclusions (Luo et al., 2009). Previous research focused mostly on the population distribution patterns of different forest types such as tropical (Lan et al., 2008; Zhang et al., 2024), subtropical broad-leaved forest (Hu et al., 2016), temperate broad-leaved forest (Xu and Wang, 2010) and different life forms such as arboreal plants (Yang et al., 2007; Lin et al., 2008), shrubs (Zhang and Shangguan, 2000; Bai et al., 2014) and grassland (Gao et al., 2014). These insights establish a compelling rationale that the spatial distribution pattern of populations in nature is mainly clustered distribution and is influenced by biological factors such as diffusion restriction and density restriction and environmental factors such as habitat heterogeneity (e.g., topography).

The mountaintop mossy dwarf forests are usually located at high elevations and develop in extreme environment (Wu, 1995), especially on isolated mountains or ridges due to the Massenerhebung effect. The mossy dwarf forest plays an important ecological role in subtropical mountain regions. As a "natural reservoir" and a natural good source of water forest (Wu, 1995), it is unique and sensitive, making its ecosystem unrecoverable and irreplaceable if exploited (Qi, 1990; Wang and Li, 2016). Maintaining the stability of these sensitive ecosystems is critical to the preservation of stability and ensures the sustainable development of the mountaintop mossy dwarf forests.

Although mossy dwarf forests are distributed in most provinces of southern China and the northernmost limit is located in Funiu Mountain, Henan Province (Xu and Wang, 2010), it is rare for a large area of clustered distribution on top of the Yangming mountains, which is a watershed between the Yangtze River and the Pearl River Basin. Additionally, these forests are a genetic treasure house of tropical and subtropical flora and fauna, as well as a refuge at the southernmost range of temperate flora and fauna (Duan and Cao, 2012). Although in September 2009, the Yangming Mountains National Nature Reserve has been established in China to protect large subtropical evergreen broad-leaved forests, little information is available on the dynamics (Chen et al., 2018) and spatial distribution patterns of the mossy dwarf forests in this area (Chen et al., 2019).

Little information on the spatial distribution pattern of the populations in mossy dwarf forests is available on changes with orientation, sampling scale and even different developmental stages. These forests are fully unknown for *Hydrangea paniculata* in the mountaintop mossy dwarf forest in the Yangming Mountains National Nature Reserve, Hunan. Recently, we established plots for the following three objectives: (1) to investigate the spatial patterns of populations in the mountaintop mossy dwarf forest in different directions, at different sampling scales, and at different stages of development using adjacent lattice; (2) to estimate aggregation intensities of populations in the mountaintop mossy dwarf forest in different directions, at different sampling scales, and at different stages of development using aggregation intensity indices; and (3) to analyze the main biological and abiotic factors affecting the spatial patterns of the subdominant population in mountaintop mossy dwarf forests. We anticipate that the results generated from this study will help in developing better estimates of regional population spatial pattern of

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mountaintop dwarf forest and addressing challenges of succession dynamics by focusing the forest restoration in tropical and subtropical mountaintop region.

Study Area and Methods

Study Site

This study was conducted in the subdominant population (e.g., *Hydrangea paniculata* communities) located in a mountaintop mossy dwarf forest. The area is on top of the Yangming Mountains in the Yangming Mountain National Nature Reserve (111 °51 ' 36 " ~ 111 °57 '36 " E, 26 °02 '00 " ~ 26 °06 '15 " N), Yongzhou City Hunan Province, China (*Fig. 1*). The study sites are at an elevation of approximately 1480-1520 m. The climate is a typical middle subtropical monsoon humid climate, characterized by cold winters, and hot summers. The average annual temperature is 14.2 °C with a mean maximum of 19 °C in August and minimum of 10.3 °C in January. Annual precipitation is approximately 1607.5 mm. Precipitation occurs in all months of the year. Rainfall is concentrated in July to September and accounts for approximately 65% of the annual precipitation. The prevailing wind is from the northwest. The main earth-forming parent material is granite.

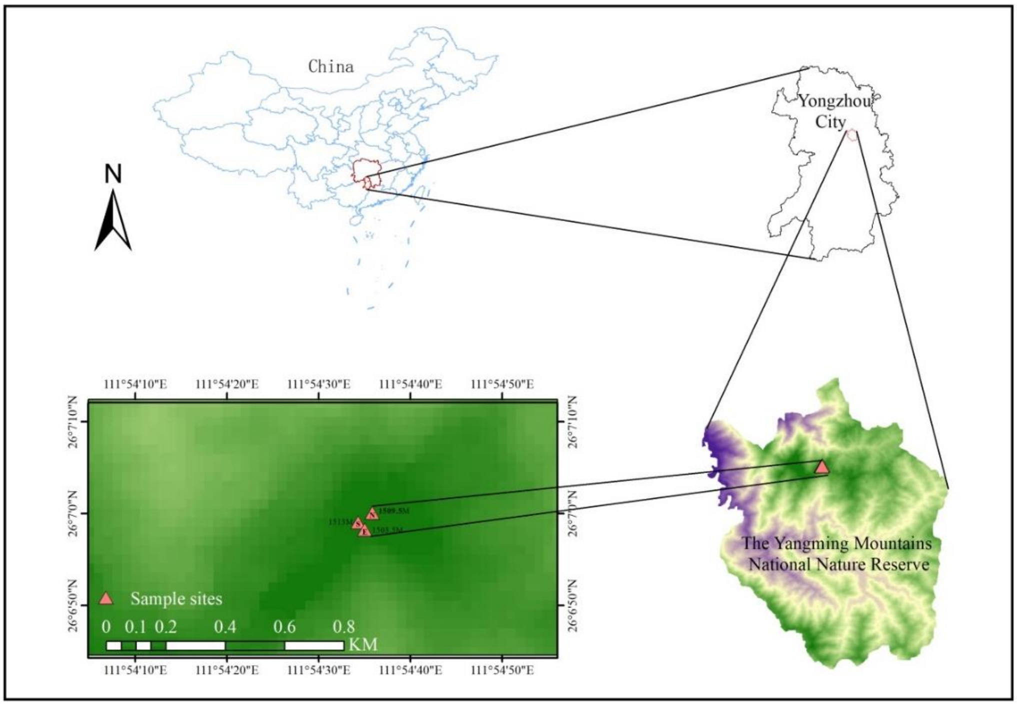

Figure 1. *Study area with elevation and sampling location in the Yangming Mountains National Nature Reserve*

The soil is mountain meadow soil, meadow yellow brown soil, mountain yellow brown soil and red soil (Xu, 2003; Chen, et al., 2006). The zonal vegetation is evergreen broad-leaved forest, including *Rhododendron simsii* shrub, *Rhododendron latoucheae* + *Salix pseudotangii* shrub, *Weigela japonica* shrub, and *Yushania basihirsuta* thicket. The bamboo forest has *Phyllostachys heterocycla* cv. *Pubescens* and *Phyllostachys*

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heteroclada forests. The mountaintop mossy forest is located at the east of the microwave platform with an area of 2-3 hm^2 (Chen et al., 2006) (*Fig. 2*). The main dominant species in this forest is *Rhododendron fortunei*, accompanied by *Hydrangea paniculata*, *Acer davidii*, *Daphniphyllum macropodum* and others (*Table 1*). The main undergrowth shrubs include *Camellia sinensis*, *Viburnum dilatumum*, *Rhododendron simsii*, *Eurya loquaiana*, *Viola verecunda*, *Tripterospermum cordatum*, *Symplocos paniculata* and others. Herbaceous plants include *Lophatherum gracile*, *Antenoron filiforme*, *Hosta plantaginea*, *Pilea peploides*, *Rubus buergeri*, *Dioscorea japonica* and others (Chen et al., 2018, 2019).

Figure 2. *The aeroview photo of study site in the Yangming Mountains National Nature Reserve (from: Shuangpai County Yangmingshan Administration Bureau)*

Table 1. *The basic information for species of tree layer in sampling sites in the mountaintop mossy forest*

Latin names	Family names	Number of individuals	Average height (m)	Average ground diameters (cm)
Rhododendron fortune Lindl.	ERICACEAE	1330	4.77	9.30
Hydrangea paniculata Sieb.	HYDRANGEACEAE	73	4.57	8.38
Rhododendron simsii Planch	ERICACEAE	62	3.91	3.40
Rhododendron mariesii Hemsl. et Wils.	ERICACEAE	6	3.38	3.30
Dendrobenthamia japonica Fang var. chinensis (Osb.) Fang	CORNACEAE	5	5.80	7.20
Enkianthus quinqueflorus Lour.	ERICACEAE	4	4.10	5.25
Acer davidii Franch.	ACERACEAE	4	5.43	5.00
Rhododendron latoucheae Franch.	ERICACEAE	3	3.17	7.33
Litsea mollifolia Chun	LAURACEAE	3	3.03	4.25
Enkianthus chinensis Franch.	ERICACEAE	2	3.58	1.78
Lyonia ovalifolia (Wall.) Drude	ERICACEAE	2	4.75	3.50
Gleditsia sinensis Merr.	MIMOSACEAE	2	6.10	10.00
Viburnum dilatatum Thunb.	CAPRIFOLIACEAE	1	3.00	10.50
Viburnum plicatum Thunb. var. tomentosum (Thunb.) Miq.	CAPRIFOLIACEAE	1	4.60	10.00
Clerodendrum mandarinorum Diels	VERBENACEAE	1	5.20	7.00
Albizia kalkora (Roxb.) Prain	MIMOSACEAE	1	6.50	3.50
Eurya loquaiana Dunn	THEACEAE	1	3.50	2.50
Lindera glauca (Sieb. et Zucc.) Bl.	LAURACEAE	1	4.50	2.00
Acer oliverianum Pax	ACERACEAE	1	5.60	16.20
Total	-	1523	4.43	8.71

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Field Methods

In August of 2016, based on the previous experience and examples of sampling area in subtropical evergreen broad-leaved forest plots (Gross, 2008; Fang et al., 2009), the number of mossy dwarf forest species in the mountaintop mossy dwarf forest in the Yangming Mountains was plotted as a species-area curve (*Fig. 3*) according to the size of the sampling area, and the minimum sampling area was determined to be 400 m^2. Therefore, we set up one plot with an area of 20 m × 30 m on the north (N) (26°06' 59.61"N, 111°54' 37.69"E, elevation:1509.5m), then second plot with an area of 20 m × 20 m on the south (S) (26°06' 58.02"N, 111°54' 37.87"E; elevation: 1513 m), and third plot with an area of 20 m × 20 m east (E) (26°06' 58.88"N, 111°54' 39.94"E; elevation: 1503.5 m) of this area. The adjacent grid method was used to divide the plot into 5 m × 5 m small plots for investigation. We recorded height, crown width, stem diameter at ground and breast height, and branching height of every live tree. We also selected one small quadrat of 10 m × 10 m to record height, coverage, and number of shrubs and selected five small quadrats of 1 m × 1 m to record height, coverage, and abundance of herbaceous plants. Additionally, we measured the spatial location of each plot using a hand-held GPS locator of Garmin eTrex20 and determined slope direction and slope using an optical compass.

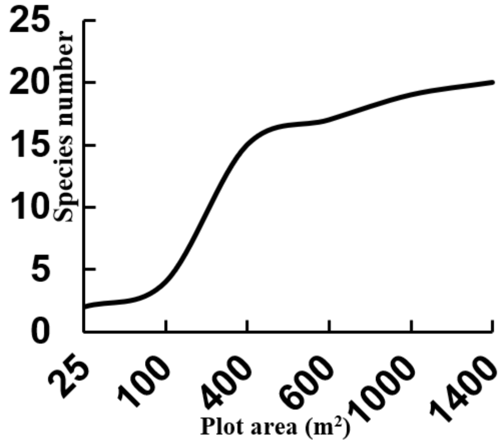

Figure 3. *The species-area relationship in the mountaintop mossy dwarf forest on the Yangming Mountains (Chen et al., 2019)*

A common method for investigating spatial patterns is to use a spatial representation, rather than a temporal one, of different stages of plant development (Zheng et al., 2017). Due to the long-life of *Hydrangea paniculata*, it is more destructive to determine the age of trees utilizing growth taper or fallen trees. Although age-class and diameter-class are different, the response of the same species to the environment is consistent in the same environment (Frost and Rydin, 2000; Lu et al., 2022). we classified subdominant species (i.e., *Hydrangea paniculata*) based on diameter at breast height (DBH) into saplings (≤ 2.5 cm, h>33 cm) (I), young trees (>2.5 cm and ≤ 7.5 cm) (II), medium trees (> 7.5 cm and ≤ 22.5 cm) (IV), and large trees (> 22.5 cm) (V) (Qiu et al., 2022; Lu et al., 2022).

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Laboratory and Analytical Methods

There are many mathematical models for describing the spatial distribution pattern of a plant population. Variance mean ratio and combining t-test, were chosen to describe the spatial patterns of four developmental stages of subdominant species at three azimuths and under seven sampling scales (5 m×5 m, 5 m×10 m, 5 m×15 m, 10 m×10 m, 10 m×15 m, 15 m×15 m, 15 m×20 m). Additionally, Negative binomial parameter (*k*), Cluster index (*I*), Average crowding index (*m* *), Block index (*m* */ *m*), Classic index (C_A), and green index (*GI*) were supplemented to describe the spatial patterns of subdominant species to avoid limitation. The spatial pattern can be described as random, uniform, and aggregated, when the four values of all six indexes are in accordance with the result. The functions are calculated as Zhang et al. (2016); Levine (2003); Zhang (2004):

(1) Variance mean ratio and deviation index (Levine, 2003; Zhang, 2004; Zhang et al., 2016; Zhao et al., 2016)

$$v = \frac{\sum x^2 - (\sum x)^2/n}{n-1};\ m = \frac{\sum x}{n};\ c_{x=} \frac{v}{m} \quad \text{(Eq.1)}$$

where *m* is the mean and *v* are the variance. The same applies below. Where n is the number of the small sample square, *x* is the number of trees in each square, if the $C_x > 1$, the spatial pattern is described as random; if the $C_x < 1$, the spatial pattern is described as a cluster; if $C_x = 1$, the spatial pattern is described as uniform. To assess the significance of the deviation of v/m to 1, a *t*-test can be carried out: $t = (\frac{v}{m} - 1)\sqrt{\frac{2}{n-1}}$. If $-t_{0.05} \leq t \leq +t_{0.05}$, it is consistent with random distribution, if $t > t_{0.05}$, cluster distribution, and if $t < -t_{0.05}$, uniform distribution.

(2) Negative binomial parameter (Levine, 2003; Zhang, 2004; Zhang et al., 2016; Zhao et al., 2016)

$$k = \frac{m^2}{v-m} \quad \text{(Eq.2)}$$

where *m* is the mean and *v* are the variance. When *k* > 0, the smaller the *k*-value is, the greater the aggregation degree. If the *k*-value tends to infinity (generally above 8), it is approximated to the Poisson distribution, if *k* < 0, a uniform distribution. Additionally, the *k*-value may be used to distinguish the distribution pattern type of a population and measure the aggregation intensity.

(3) Clumping index (Levine, 2003; Zhang, 2004; Zhang et al., 2016; Zhao et al., 2016)

$$I = \frac{v}{m} - 1 \quad \text{(Eq.3)}$$

where *m* is the mean and *v* are the variance. In the formula, *I*=0, random distribution; *I* > 0, cluster distribution; and *I* < 0, uniform distribution.

(4) Classic Index (Levine, 2003; Zhang, 2004; Zhang et al., 2016; Zhao et al., 2016)

$$C_A = \frac{1}{k} \quad \text{(Eq.4)}$$

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where C_A is classic index and k is the negative binomial parameter. In the formula, C_A= 0, random distribution; C_A>0, cluster distribution; and C_A<0, uniform distribution.

(5) Patchiness index (Levine, 2003; Zhang, 2004; Zhang et al., 2016; Zhao et al., 2016)

$$\frac{m^*}{m} = 1 + \frac{1}{k} \qquad \text{(Eq.5)}$$

where m^*/m is patchiness index and k is the negative binomial parameter. In formula, $\frac{m^*}{m}$=1, random distribution; $\frac{m^*}{m}$>1, cluster distribution; and $\frac{m^*}{m}$ <1, uniform distribution. It shows how many other individuals on average have to crowd.

(6) Green index (Levine, 2003; Zhang, 2004)

$$GI = \frac{\frac{v}{m} - 1}{N - 1} \qquad \text{(Eq.6)}$$

where m is the mean and v are the variance. In formula, GI = 0, random distribution; GI > 0, cluster distribution; and GI <1, uniform distribution.

To analyze the pattern size of subdominant species in the mountaintop mossy dwarf forest, we applied the adjacent lattice method to divide the block groups, which were divided according to the variable scale sample method. The area and number of each small quadrat in block groups are shown in *Table 2*. Referencing to Greig Smith block-mean-square (Zhao, 2016).

Table 2. *Sampling area of scale analysis of population spatial patterns (Chen et al., 2019)*

Block	Quadrat area (m^2)	Quadrat number
1	25(5×5)	56
2	50(5×10)	28
3	75(5×15)	18
4	100(10×10)	14
5	150(10×15)	8
6	200(10×20)	7
7	225(15×15)	4
8	300(15×20)	4

We referred to the block-mean-square analysis of Greig Smith and revised it as follows. First, the sum-square of the observed individuals of each block was calculated. The difference was found between adjacent blocks after the sum-square was averaged. Second, the corresponding differences were divided by the number of small quadrats in the next block, and the mean-square values corresponding to the previous block were obtained. Third, we made a graph taking the mean-square value as the Y-axis and the unit area as the X-axis. Then, pattern size was defined (Zhao et al., 2016). *t*-test statistical analysis was performed using the SPSS 23 software program. Data statistics and pattern analysis charts were performed using the excel 2010 software program.

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Results

Distribution Pattern of Subdominant Species in Seven Sampling Scales

The distribution patterns of the subdominant species in four developmental stages under seven sampling scales are shown in *Table 3*. Among which, two of four developmental stages (i.e., young and medium trees) exhibited a cluster distribution. The aggregation intensity of young trees and medium trees decreased in turn with the increase of the sampling scale. In the same developmental stage, the population aggregation intensity also decreased with the increase of sampling scale, in which the aggregation intensity of young trees was the maximum at the 200 m^2 sampling scale and the minimum at the 300 m^2 sampling scale, that of medium trees had a maximum at the 25 m^2 sampling scale and a minimum at the 200 m^2 sampling scale. The aggregation intensity of young and medium trees fluctuated with the further increase in sampling scale, and the rebound decreased after a small increase. It can be seen that the aggregation intensity of 2 developmental stages of the subdominant species of the mountaintop mossy dwarf forest on the Yangming mountains changed with the change of sampling scale. However, compared with the dominant species of the mountaintop mossy dwarf forest on the Yangming mountains, its aggregation intensity was significantly weakened, which also showed the sub-dominant position of *Hydrangea macrophylla* population in the community (Chen et al., 2019).

Table 3. *Distribution pattern of the Hydrangea Paniculate population under different age classes in different scales*

Class	Quadrat scale	Distribution pattern				Aggregated intensity					
		$\frac{v}{m}$	t-value	$t_{0.05}$	Distribution type	k	I	m*	C_A	$\frac{m^*}{m}$	GI
total	5×5	2.42	7.47	2.00	C	0.92	1.42	2.73	1.09	2.09	0.02
	5×10	7.80	2.61	2.05	C	4.16	1.31	1.99	4.60	0.76	0.03
	5×15	17.86	6.72	2.11	C	4.06	1.66	8.38	0.25	1.25	0.02
	10×10	24.34	5.21	2.16	C	1.42	3.67	8.88	0.70	1.70	0.05
	10×15	5.84	9.05	2.37	C	1.81	4.84	13.59	0.55	1.55	0.07
	10×20	7.51	11.27	2.45	C	1.60	6.51	16.94	0.62	1.62	0.09
	15×15	10.03	11.06	3.18	C	1.58	9.03	23.28	0.63	1.63	0.16
	15×20	8.26	8.89	3.18	C	2.48	7.26	25.26	0.40	1.40	0.10
II	5×5	1.62	3.27	2.00	C	1.40	0.62	1.50	0.71	1.71	0.01
	5×10	2.48	5.44	2.05	C	1.18	1.48	3.23	0.85	1.85	0.03
	5×15	3.32	6.76	2.11	C	1.17	2.32	5.04	0.85	1.85	0.05
	10×10	4.03	7.73	2.16	C	1.15	3.03	6.53	0.87	1.87	0.06
	10×15	5.20	7.85	2.37	C	1.46	4.20	10.32	0.69	1.69	0.09
	10×20	7.90	11.96	2.45	C	1.01	6.90	13.90	0.99	1.99	0.14
	15×15	8.27	8.91	3.18	C	1.48	7.27	18.02	0.68	1.68	0.17
	15×20	8.51	9.20	3.18	C	1.63	7.51	19.76	0.61	1.61	0.15
III	5×5	2.36	7.15	2.00	C	0.31	1.36	1.79	3.18	4.18	0.06
	5×10	2.48	5.44	2.05	C	0.58	1.48	2.34	1.73	2.73	0.06
	5×15	2.56	4.55	2.11	C	0.82	1.56	2.84	1.22	2.22	0.07
	10×10	3.00	5.10	2.16	C	0.86	2.00	3.71	1.17	2.17	0.08
	10×15	3.37	4.43	2.37	C	1.11	2.37	4.99	0.90	1.90	0.11
	10×20	2.71	2.96	2.45	C	2.01	1.71	5.14	0.50	1.50	0.07
	15×15	4.29	4.02	3.18	C	1.07	3.29	6.79	0.94	1.94	0.23
	15×20	5.72	5.79	3.18	C	1.22	4.72	10.47	0.82	1.82	0.21

Note: **P < 0.01. I: Sapling tree; II: Young tree; III: medium tree; IV: Large tree, The same below. R: Random distribution; C: Cluster distribution; U: Uniform distribution; The same below

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According to the variance-mean-ratio and *t*-test value, in general, the subdominant species' distribution pattern of the two azimuth sampling plots presented random, uniform distribution except for the northern sampling plots presenting cluster distribution on the scale of 25 m^2 (*Table 4*). According to the properties of each decision index, the smaller the negative binomial parameter(k) value is, the larger the cluster index(I), average crowding index(m^*), aggregation index (C_A), and clustering index($\frac{m^*}{m}$) are, and the greater the clustering degree of the population is (Zhang et al., 2016). On the sampling scale of 25 m^2, the aggregation intensity of the subdominant species in the northern, southern and eastern sampling plots decreased from cluster, via uniform to random (*Table 4*), indicating that, in same sampling scales, the aggregation intensity was different with plot azimuth and slope direction. As the sampling scale increased, the distribution pattern of subdominant species shifted from cluster to uniform. These results showed that the distribution pattern of the subdominant species was not only related to the plot azimuth and slope direction, but also related to the sampling scales.

Table 4. *The distribution pattern of the subdominant population(Hydrangea Paniculate) at different directions*

Plots	Quadrat scale	Distribution pattern				Aggregated intensity					
		$\frac{v}{m}$	t-value	$t_{0.05}$	Distribution type	k	I	m*	C_A	$\frac{m^*}{m}$	GI
N	5×5	1.93	3.17	2.07	C	2.54	0.93	3.31	0.39	1.39	0.02
	5×10	1.80	1.89	2.20	R	5.91	0.80	5.55	0.17	1.17	0.01
	5×15	1.98	1.84	2.37	R	7.25	0.98	8.11	0.14	1.14	0.02
	10×10	2.09	1.73	2.57	R	8.68	1.09	10.59	0.12	1.12	0.00
	10×15	2.64	2.01	3.18	R	8.70	1.64	15.89	0.11	1.11	0.03
	10×20	1.95	0.95	12.71	R	20.06	0.95	19.95	0.05	1.05	0.02
S	5×5	0.90	-0.26	2.13	U	-4.59	-0.10	0.34	-0.22	0.78	-0.01
	5×10	1.12	0.23	2.37	R	7.15	0.12	1.00	0.14	1.14	0.02
	5×15	2.67	2.36	2.45	R	0.72	1.67	2.87	1.39	2.39	0.28
	10×10	1.67	0.82	2.57	R	2.63	0.67	2.42	0.38	1.38	0.10
	10×15	0.67	-0.24	3.18	U	-9.00	-0.33	2.67	-0.11	0.89	-0.06
	10×20	1.29	0.20	12.71	R	12.25	0.29	3.79	0.08	1.08	0.04
E	5×5	1.65	1.79	2.13	R	0.86	0.65	1.21	1.16	2.16	0.07
	5×10	1.63	1.19	2.37	R	1.77	0.63	1.76	0.56	1.56	0.07
	5×15	2.61	2.28	2.45	R	1.12	1.61	3.41	0.90	1.90	0.18
	10×10	2.19	1.45	2.57	R	1.90	1.19	3.44	0.53	1.53	0.13
	10×15	0.14	-0.61	3.18	U	-4.08	-0.86	2.64	-0.24	0.76	-0.12
	10×20	1.00	0.00	12.71	R	0	0.00	4.50	0	0	0.00

Note: N: northern plot; S: southern plot; E: eastern plot. R: Random distribution; C: Cluster distribution; U: Uniform distribution; The same below

Pattern Size of the Subdominant Species

Fig. 4 and *Fig. 5* showed that the mean-square value of seven blocks of the subdominant species of the aggregation intensity in the three azimuth plots showed 1-2 significant peaks on the 2 developmental stages on the 7 sampling scales. On the 100 m^2 sampling scale, one peak of the young trees appeared in the southern plots and its mean-square value was 1.6. On the 150 m^2 sampling scale, the significant peak of the young trees in the northern plots, medium trees in the northern plot and in the southern plot

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appeared. Their mean-square value was 173.17, 31.1 and 0.75 respectively. On the 200 m^2 sampling scale, the significant peaks of the young trees appeared in the eastern plots, and its mean-square value was 8. On the 225 m^2 sampling scale, one peak of the young trees appeared in the southern plot and medium in the eastern plot, and their mean-square value were all 21, indicating that the aggregation pattern of young trees and medium trees of subdominant species was increased with increasing sampling scale.

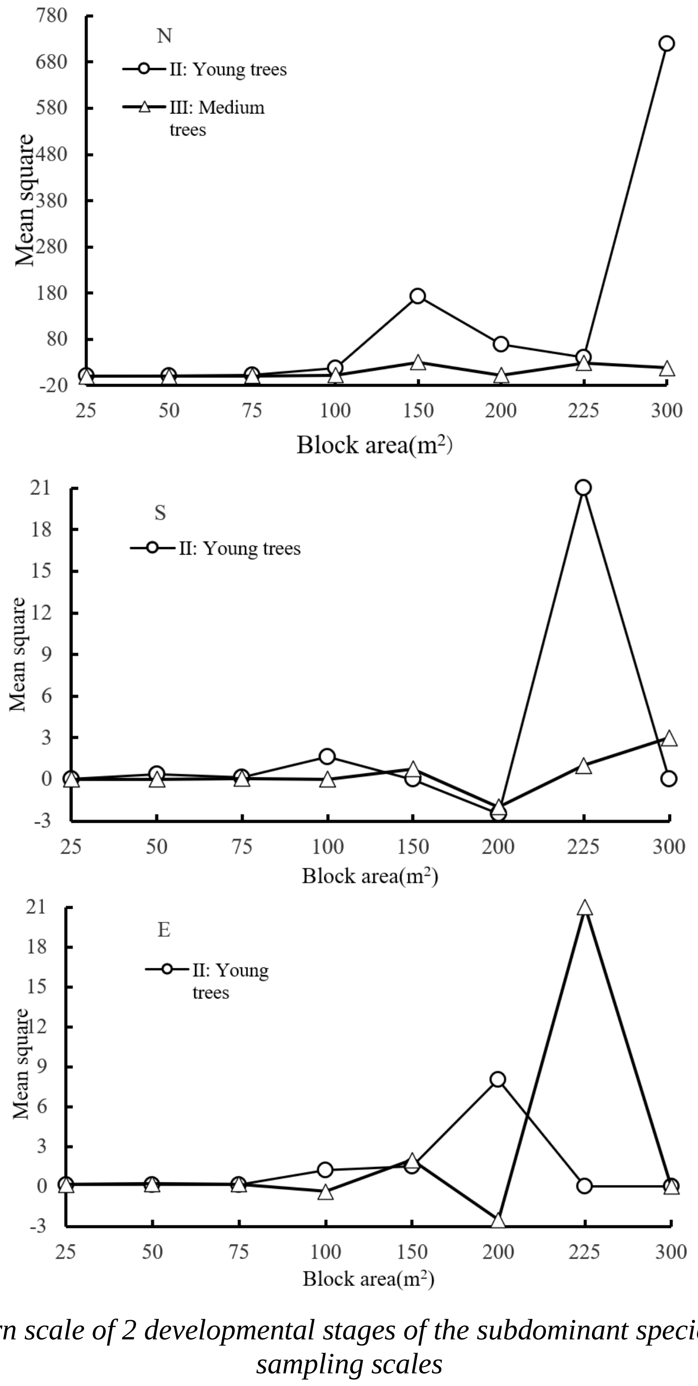

Figure 4. *Pattern scale of 2 developmental stages of the subdominant species in 3 plots in 7 sampling scales*

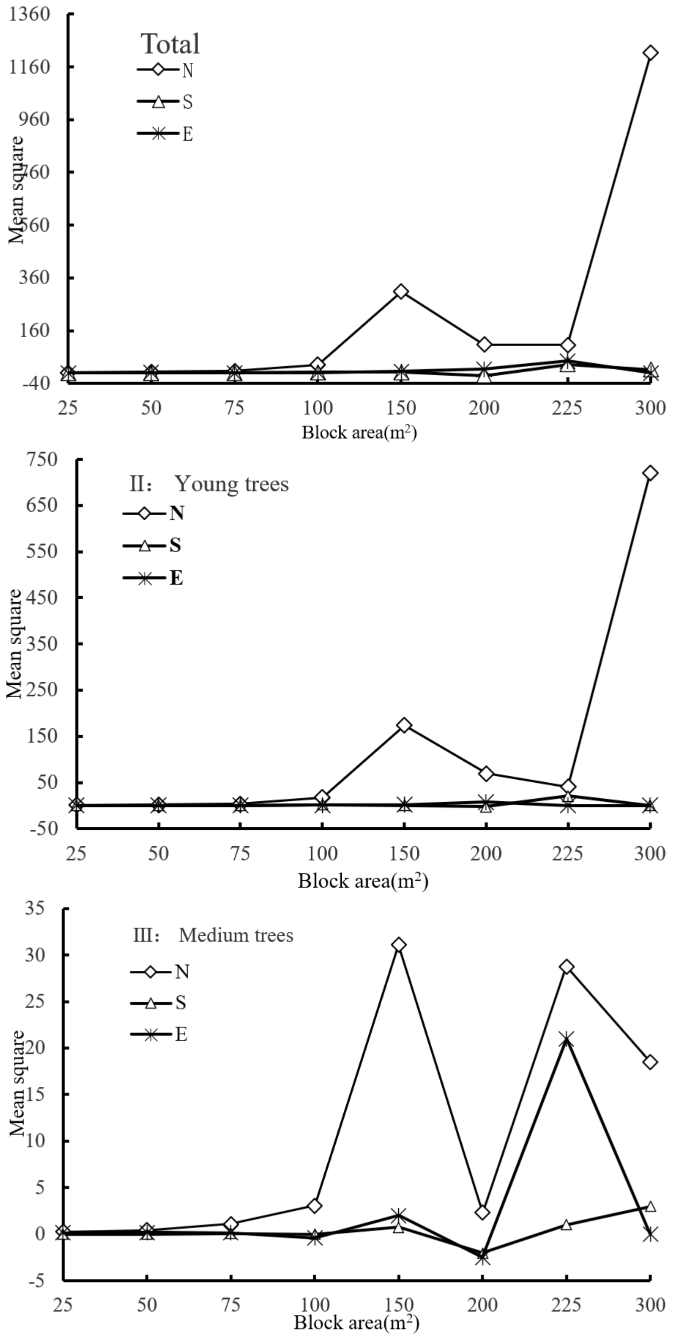

Figure 5. *Pattern scale of 2 developmental stages of the subdominant species in 3 plots in 7 sampling scales*

The mean-square value of seven blocks of young trees appeared in an obvious peak with the increase of sampling scale from 25 m^2 to 200 m^2, indicating that the patch sizes of the young trees was 200 m^2 and its pattern strength (mean-square value) was 21.5. The mean-square value of medium trees appeared an obvious peak value with the increase of sampling scale from 25 m^2 to 225 m^2 (*Fig. 6*), indicating that the patch size of the medium trees was 225 m^2 and its pattern strength was 8.5 m^2. However, the aggregation intensity and size of the subdominant species were much smaller than those of the dominant species (Chen et al., 2019).

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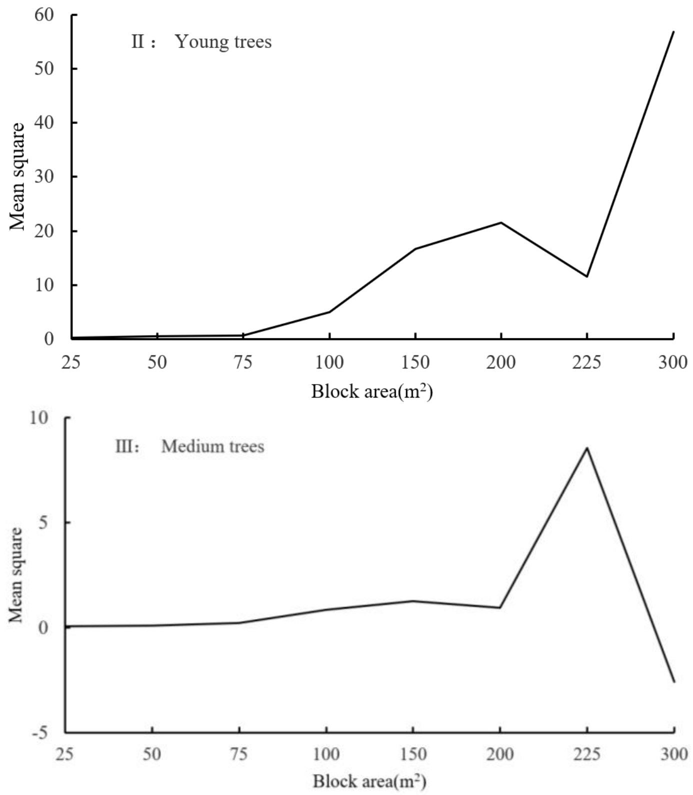

Figure 6. *Pattern scale of 2 developmental stages of subdominant species*

Discussion

Distribution Pattern of Subdominant Species in the Mountaintop Mossy Dwarf Forest on Yangming Mountains

The population distribution pattern is scale dependent and closely related to sampling scale (Wang and Yu, 2015). For example, with the increase of sampling scale, the distribution pattern of the secondary forest population in the warm temperate zone changed from aggregation distribution to random and regular distribution (Zhu et al., 2011); the population of *Betula albo-sinensis* in the Taibai Mountain showed aggregation distribution in a certain scale. Above this scale, the distribution is random (Xu and Wang, 2010). In this study, the spatial distribution pattern of the subdominant species in the mountaintop mossy dwarf forest on Yangming Mountain presented cluster distribution on seven sampling scales, and the aggregation intensity decreased with the increase of sampling scales. However, relative to the dominant species (Chen et al., 2019), the degree of aggregation is weaker, and eventually tends to random distribution. The following reasons may explain our data. First, we found that the dominant species, *Rhododendron fortunei*, had the characteristics of vegetative reproduction, as the trees often had 2-5 trunks from the basic stem, and up to 7 trunk clumps all developed into medium or even large trees in field findings (Xu and Wang, 2010). However, *Hydrangea paniculata*, which had not the characteristics of reproduction as well as *Rhododendron fortunei*, usually had only one stem. As a result, the population gradually declined in the community. Second, flowers of *Hydrangea paniculata* are mostly sterile flowers, difficult to obtain natural hybrid seeds, while its seeds are extremely small, difficult to distinguish

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by the naked eye (Lu et al., 2015; Qiao et al., 2020). Third, most of them are scattered around the mother trees, when the seeds are maturity. Although it could be seen that the subdominant species in the mountaintop mossy dwarf forest on Yangming mountain presented an aggregation distribution pattern, relative to the dominant species (Chen et al., 2019), the aggregation intensity is weaker, and eventually tends to random distribution, which attributed to its extremely small seeds, complex dormancy mechanism, hard to germinate and propagate naturally, not cold-resistant (Lu et al., 2015). which is mainly determined by its biological characteristics (Liu, 2024).

Most studies have shown that on a small scale, the population spatial distribution pattern was mainly affected by its own biological characteristics, and on a large scale, the population spatial distribution pattern was more affected by habitat heterogeneity and the role of the microenvironment (Jin et al., 2006; Yang, 2007; Liu et al., 2011, 2016).

Three regions of the subdominant species in mountains are located on top of Yangming mountain in Hunan province, above an altitude of 1300 m and the line of cloud and mist, under conditions of sufficient air humidity but different orientation and slope direction. The winding road around the east side separates the mountaintop mossy dwarf forest into southern, northern and eastern regions. The eastern slope is to the east, northern slope is to the north, one part of the southern region is northward, and the other part is eastward; therefore, there are different microenvironments. The different microenvironments have an important influence on the spatial distribution pattern of the subdominant species in the mountaintop mossy dwarf forest.

In a natural forest, the general trend of aggregation development in the process of population development from a small path to a large diameter is from aggregation, via random, to rule (Liu et al., 2011). The distribution pattern of arboreal plants with long life span changes with each development stage. For example, the population of *Betula platyphylla* in the Taibai Mountains showed different spatial distribution patterns at different age stages (Lin et al., 2008), and the population of *Taiwania flousiana* was clustered. However, the distribution pattern of aging from young to medium age has shifted from initially an aggregation distribution to random distribution (Liu et al., 2012), which is a comprehensive reflection of the biological characteristics of the population and its habitat conditions (Liu et al., 2016; Liu, 2024). The aggregation intensities of saplings and young trees was higher those that of the medium and large trees in the aggregation distribution of subdominant species in the mountaintop mossy dwarf forest on Yangming Mountain, these data were in accordance with the density limitation of natural community population aggregation distribution and the regularity of habitat heterogeneity (Zhao, 2016).

The individual distribution pattern of the four developmental stages of subdominant species in the mountaintop mossy dwarf forest on the Yangming Mountain was different. Young, small and medium trees presented a cluster distribution, but large trees presented random distribution on the 25 m^2 scale. It might be related to the limited propagation distance of seeds and the large natural dehiscent seeds of capsule after maturation (Zhao, 2016). In addition, *Hydrangea paniculata* is a light-demanding plant. The gap light environment had a certain effect on the establishment of sapling trees and may make sapling trees and young trees appear in an aggregation distribution. The random distribution of individuals in the large stage is mainly due to the increase of tree height, DBH, crown width of the population, limited environmental resources, and the self-thinning or other thinning of the population, which leads to the transition from aggregation distribution to random distribution.

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Pattern Sizes of Subdominant Species in the Mountaintop Mossy Dwarf Forest on Yangming Mountains

Individuals of cluster populations usually gather into patches of varying sizes, which are known as pattern size (Guo et al., 2015). It was not clear and accurate to show the patch size of the population until the mean-square peak value appears after block 2 (Wang et al., 1995). In this study, our results supported the conclusions of Wang et al, i.e., that the mean-square peak value of the three developmental stages of trees appeared at blocks 5-6, indicating that the patch sizes of sapling, young and medium trees were 150 m^2-200 m^2. In addition, the mean-square peak value of trees in the three-azimuth sampling plots was a cluster distribution, and their mean-square peak value appears at blocks 4, 5, and 6, indicating that the patch sizes of trees in them were 150 m^2-200 m^2.

Conclusions

This study found that the sub-dominant populations in the mountaintop mossy dwarf forest on Yangming Mountain in Yongzhou City, Hunan Province generally showed an aggregated distribution pattern, and although the scale of the aggregation pattern was different, it was significantly weaker than the dominant species, showing a sub-dominant position in the community. The spatial distribution pattern of the secondary dominant population in different directions and its changes with the sampling scale are as follows: in the three directions of north, south and east, the spatial distribution pattern of the secondary dominant species *Hydrangea paniculate* with the increase of sampling scale, the aggregation intensity of the secondary dominant species *Hydrangea paniculate* from strong to weak, and even to random and uniform direction. The spatial distribution pattern of *Hydrangea paniculate* in the north sample square is from aggregation to random distribution, while the spatial distribution pattern of *Hydrangea paniculate* in the east and south samples is even random to uniform distribution. The spatial distribution pattern of the subdominant populations at different age stages of the forest showed that with the increase of population age, the aggregation intensity of the subdominant populations changed from strong to weak, and even to random distribution. The formation of the subdominant population and its distribution pattern of the dwarf forest in Yangming Mountain is mainly determined by the biological characteristics of the *Hydrangea paniculata* population and the influence of environmental factors such as orientation and slope direction, but the strong position of the dominant species is not ruled out. Based on the findings of this study, the dominance of the community is mainly dominated by dominant species, but if the dominant species of the community are in absolute dominance and control, it will lead to the emergence of a single dominant species community and affect its diverse and sustainable ecological environment. Therefore, it is necessary to conduct in-depth research on the community structure and formation mechanism of the special vegetation type of mountain top dwarf forest, so as to implement effective management and protection work.

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