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ANALYSIS OF SPATIAL CORRELATION OF THE POPULATIONS OF *PLANTAGO ASIATICA L.* AT MT. GEUMJEONG

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ABSTRACT

Plantago asiatica is a common herbal medicine belonging to the genus *Plantago* in the family *Plantaginaceae* and is native to East Asia. Spatial distribution of this species was studied in an established 4 m x 4 m plot at Mountain Geumjeong in Korea during 2018. The values (R) of spatial distance (the rate of observed distance-to-expected distance) among the nearest individuals were higher than 1 and the significant index of C_R was > 2.58. If by this parameter, the small plots (1 m x 1 m and 2 m x 2 m) of *P. asiatica* were aggregately distributed in the forest community. However, *P. asiatica* was uniformly distributed in two large plots (2 m x 4 m and 4 m x 4 m). The most individuals of *P. asiatica* were clustered and the distribution pattern of the *P. asiatica* was quadrat-sampling dependent. The values dispersion index (C) were lower than 1 except one small plot (1 m x 1 m). Thus aggregation indices (CI) were positive, which indicate an aggregative distribution. The most mean crowding ($M*$) and patchiness index (PAI) showed positive values at all plots.

Keywords: Mountain Geumjeong, *Plantago asiatica*, spatial distribution.

INTRODUCTION

Patch dynamics are discrete disturbances in plant communities and create discrete patches. Many plant communities are mosaics of patches each created by a disturbance in the past (Myster, 2018). Each of these disturbances has a regime that includes characteristics such as its severity, size, timing and duration.

Plant species can be distributed in an aggregated, a random, or a regular pattern, with aggregated distributions being widespread at a different scale in natural forests. Over the past few decades, a number of mechanisms have been found to contribute to species aggregation in forests, including niche segregation, habitat heterogeneity, dispersal limitation, intra- and inter-species competition, and negative density dependence (Du et al., 2017). Ecological specialization is one of the main mechanisms of niche differentiation, which in turn favors species coexistence (Chase & Leibold, 2003).

The spatial distribution of plants is a result of many ecological processes and niches. The spatial distribution of species can affect the degree of competition between neighbouring species, density, variability in size and distribution, regeneration, survival, growth, mortality, crown formation and the biological diversity within forest communities. Spatial pattern analysis becomes more complicated when large-scale environmental heterogeneity masks the dispersal and demographic behaviour of a given species, for example, by forcing it to aggregate in restricted regeneration sites (He et al., 1997). A patchy distribution of limiting resources may then influence demographic processes and the emerging species patterns (Getzin et al., 2008). Numerous scale-dependent measures have been established in order to describe spatial forest structure (Clark & Evans, 1954; Diggle, 1983; Corral-Rivas et al., 2010).

Plantago asiatica L. is a common herbal medicine belonging to the genus *Plantago* in the family *Plantaginaceae* and is native to East Asia. This herb is traditionally used to treat liver disease, stomach problems, and urinary system inflammation (Hong et al., 2013). This plant is a perennial herb that grows to 20–60 cm high, and has big roots. Its leaves, which gather on the ground, have oval blades and are 11–12 cm long and 4–9 cm wide, with obtuse apex and base, and 5 smooth main veins from the leaf base. Recently, the genus *Plantago has been studied in the medical field (Haddadian et al., 2014). They has some useful effects in the medical sciences. They contain many compounds such as phenolic compounds, flavonoids, alkaloids, terpenoids, and vitamin C (*Samuelsen, 2000). Many *P. asiatica* populations close to Geumjeong Mountain Trail are being destroyed.

In this report, the several statistical tools of percentage distribution and population structure of the geographical areas are used to study the spatial distribution of *P. asiatica* in Mt. Geumjeong locate in south of the Korean. A sample of a large (more than 100 individuals) natural population of *P. asiatica* collected at mountain and was used in this study. It is expected to provide useful experimental conditions because of the large undisturbed and isolated site.

METHODOLOGY

Study area

We conducted the spatial analysis in the communities of *P. asiatica* at Mt. Geumjeong in Busan-ci, Korea. The mountain (801.5 m) is highest in Busan. It has a temperate climate with a little hot and long summer. In this region the mean annual temperature is 14.7℃ with the maximum temperature being 29.4℃ in August and the minimum -0.6℃ in January.

Sampling procedure

Many quadrats at Mt. Geumjeong were randomly chosen for each combination of site x habitat, so that, overall, 23 quadrats were sampled for the complete experiment. Spatial ecologists use artificial sampling units (so-called quadrats) to determine abundance or density of species. The number of events per unit area are counted and divided by area of each square to get a measure of the intensity of each quadrat. We randomly located quadrates in each plot which *P. asiatica* established populations. The quadrat sizes were 2 m x 2 m, 2 m x 4 m, and 4 m x 4 m. We mapped all plants to estimate *P. asiatica* density per plot.

Index calculation and data analysis

The spatial pattern of *P. asiatica* was analyzed according to the Neatest Neighbor Rule (Clark & Evans, 1954; Lian et al., 2012) with Microsoft Excel 2014. The distance from an individual to its nearest neighbor, irrespective of direction, provides the basis for this measuring of spacing (Clark & Evans, 1954). The mean observed distance (r_A) was calculated as follows:

$$r_A = \sum_{i=1}^{N} r_i / N \ (i = 1, 2, 3 \ldots N)$$

Where r_i is the distance from the individual to its nearest neighbor. N is the total number of individuals within the quadrat. If this population were distributed at random, the expectation value of mean distance of individuals within a quadrat (r_B) was calculated as follows:

$$r_B = 1/2\sqrt{D}$$

Where *D* is population density and *D* is the number of individuals per plot size. The ratio *R* can be used as a measure of the degree to which the observed distribution approaches or departs from random expectation.

$R = r_A/r_B$

When *R* > 1, it is a uniform distribution and *R* < 1, it is an aggregated distribution. In a random distribution, *R* = 1 and under conditions of maximum aggregation, *R* = 0. If the value of R is not randomly distributed, the significance of the deviation is calculated from the following formula (Clark & Evans, 1954).

$$C_R = \frac{r_A - r_B}{\delta_{rB}}$$

$$\delta_{rB} = 0.26136/\sqrt{ND}$$

When C_R > 1.96, the level of the significance index of the deviation of R is 5%, and when C_R > 2.58, the level is 1%.

Many spatial dispersal parameters were calculated the degree of population aggregation under different sizes of plots by dispersion indices: index of clumping or the index of dispersion (C), aggregation index (CI), mean crowding (M*), patchiness index (PAI), negative binominal distribution index *K*, *Ca* indicators (*Ca* is the name of one index) (Lloyd, 1967) and Morisita index (*IM*) were calculated with Microsoft Excel 2014. The formulae are as follows:

Index of dispersion: $C = S^2/m$

Aggregation index $CI = \frac{S^2}{m} - 1$

Mean crowding $M^* = m + \frac{S^2}{m} - 1 = m + CI = m + C - 1$ -1

Patchiness index $PAI = \frac{m}{\frac{S^2}{m} - 1} = \frac{M^*}{m}$

Aggregation intensity $PI = k = m^2/(S^2 - m) = \frac{m}{CI} = \frac{m}{C-1}$

Ca indicators $Ca = 1/k$

IM = $\frac{n\Sigma m(m-1)}{nm(nm-1)}$

Where S^2 is variance and m is mean density of *P. asiatica*. When $C, M^*, PAI > 1$, it means aggregately distributed, when $C, M^*, PAI < 1$, it means uniformly distributed, when $CI, PA, Ca > 0$, it means aggregately distributed, and when $CI, PA, Ca < 0$ it means uniformly distributed. The mean aggregation number to find the reason for the aggregation of *P. asiatica* was calculated (Arbous & Kerrich, 1951).

$$\delta = mr/2k$$

Where r is the value of chi-square when 2k is the degree of freedom and k is the aggregation intensity. Green index (GI) is a modification of the index of cluster size that is independent of *n* (Green, 1966).

RESULTS

The spatial pattern of individuals

Population densities (D) at Mt. Geumjeong varied from 4.688 to 14.500, with a mean of 10.188 (Table 1). The values (*R*) of spatial distance (the rate of observed distance-to-expected distance) among the nearest individuals were higher than 1 and the significant index of C_R was > 2.58. If by this parameter, the small plots (1 m x 1 m and 2 m x 2 m) of *P. asiatica* were aggregately distributed in the forest community. However, *P. asiatica* was uniformly distributed in two large plots (2 m x 4 m and 4 m x 4 m). The most individuals of *P. asiatica* were clustered and the distribution pattern of the *P. asiatica* was quadrat-sampling dependent.

Table 1. Spatial patterns of *Plantago asiatica* individuals at different sampling quadrat sizes at M Geumjeong

Quadrat size (m x m)	Density	R	C_R	Distribution pattern
1 x 1	14.000	0.754	1.764	Aggregation
1 x 2	14.500	0.793	2.132	Aggregation
2 x 2	10.500	0.693	3.809*	Aggregation
2 x 4	7.250	1.068	0.987	Uniform
4 x 4	4.688	1.068	1.129	Uniform
Mean	10.188	0.875	1.503	-

*: $p < 0.05$.

Table 2. Changes in gathering strength of *Plantago asiatica* at different sampling quadrat sizes at M Geumjeong

Quadrat size (m x m)	No. Quadrat	Aggregation indices						
		C	CI	M^*	PAI	PI	Ca	IM
1 x 1	8	0.695	-0.306	9.766	0.970	-32.966	-0.030	0.977
1 x 2	6	1.375	0.375	10.789	1.036	27.744	0.036	1.040
2 x 2	4	2.256	1.256	11.947	1.118	8.509	0.118	1.120
2 x 4	3	14.083	13.083	32.911	1.660	1.516	0.660	1.661
4 x 4	2	19.152	18.152	42.819	1.736	1.359	0.736	1.737

The degree of population aggregation

The values dispersion index (C) were lower than 1 except one small plot (1 m x 1 m) (Table 2). Thus aggregation indices (CI) were positive, which indicate an aggregative distribution. The most mean crowding (M^*) and patchiness index (PAI) showed positive values at all plots. All plots was also positive PAI. For most plots except eight 1 m x 1 m plots, three indices, C, M^*, and PI were positive and $PAI > 1$. Ca was also shown larger than zero, thus it means uniform distributed.

Morisita index (IM) is related to the patchiness index (PAI) and showed an overly steep slope at the plot 2 m x 4 m in Mt. Geumjeong. Green index varied between -0.024 (1 m x 1 m) to 0.250 (4 m x 4 m) (Fig. 1). The mean aggregation number (δ) analysis showed that the reasons for aggregation of *P. asiatica* differed in quadrats with different plot sizes. The values of δ were varied between 4.330 (4 m x 4 m) to 7.616 (1 m x 2 m) (Fig. 2).

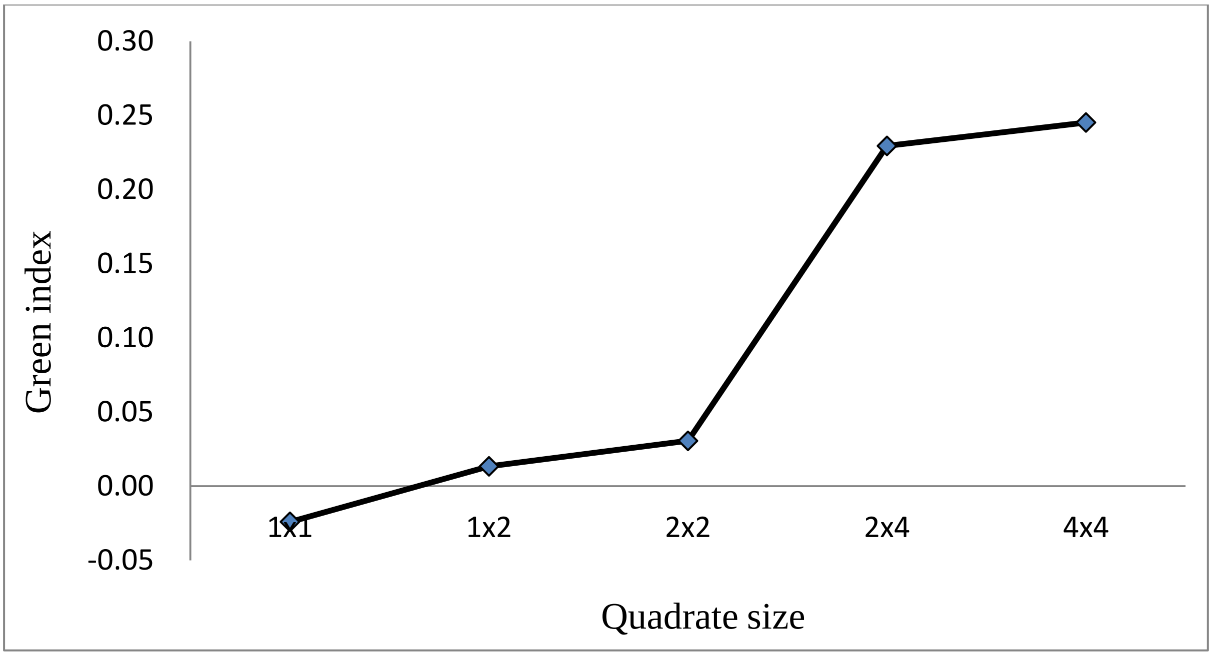

Fig. 1. The curves of patchiness in two areas of *Plantago asiatica* using values of Green index at Mt. Geumjeong

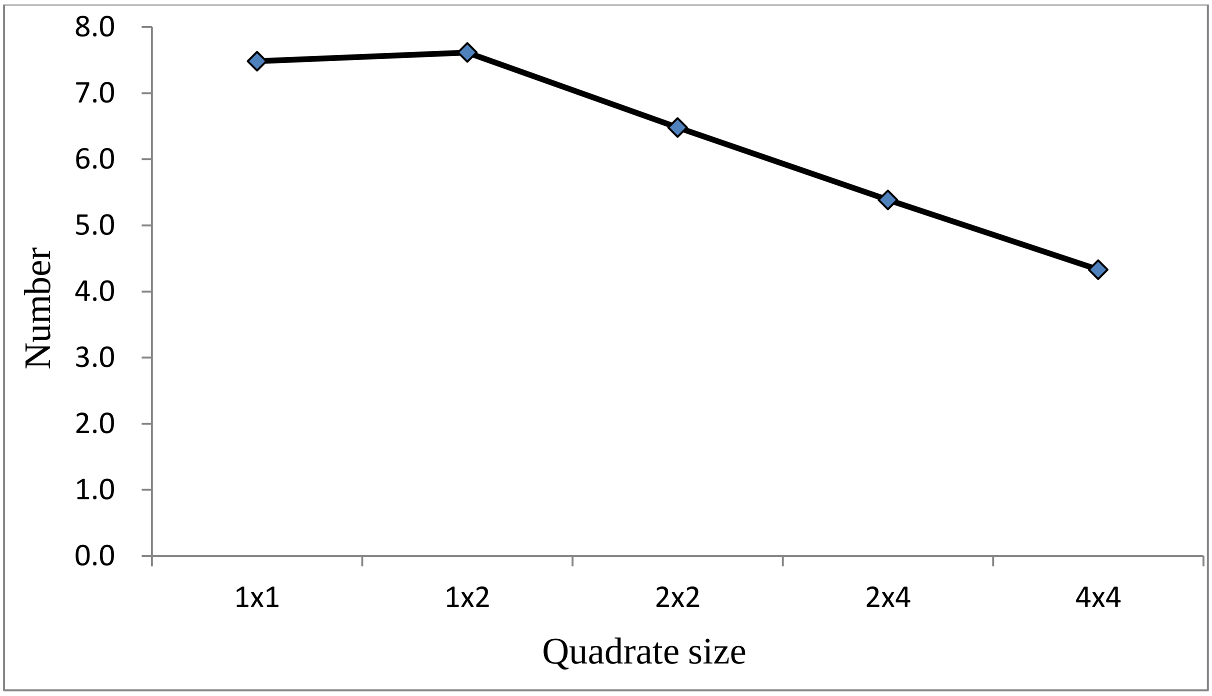

Fig. 2. The mean aggregation number to find the reason for the aggregation of *Plantago asiatica* at Mt. Geumjeong.

DISCUSSION

When R = 1, it is a random distribution; R < 1, it is an aggregation; R > 1, it is a uniform distribution (Lian et al., 2012). According to this rule, individuals within from 1 m x 1 m to 2 m x 2 m distance plots of *P. asiatica* at Mt. Geumjeong are aggregative distribution (Table 1). However, more 2 m x 4 m distance plots were uniform distributions. In only 1 m x 1 m plot, the three indices, C, M^*, PAI were >0, and PI and Ca < 0, thus it means aggregative distributed. Aggregation is mainly caused by the environmental factors (Lian et al., 2012). All plots had low δ > 2. When δ > 2, the aggregation was mainly caused by both species characteristics and environmental factors (Lian et al., 2012). Vegetation composition data has commonly been used to detect relationships between environmental variables and plant species combinations, and to identify ecological species groups (White and Hood 2004). The first, *P. asiatica population* at Mt. Geumjeong is located around the mountain trail, which prevents the mountain climbers from distributing it. Human disturbances often act quickly and with great effect, to alter the physical structure or arrangement of biotic and abiotic elements.

As the second ecological factor, Species with stronger competitive ability may retain more individuals than others species. Woody species, *Pinus densiflora* and *Quercus dentate* had the high species density. High trees interfere with sunshine which is among the most important factors determining the distribution of the plant species.

Condit *et al.* (2000) examined the spatial aggregation of individuals of tree species in six different tropical forest sites. They found that most species were aggregated, that rare species tended to be more aggregated than abundant ones, and that smaller individuals of a species tended to be more aggregated than larger individuals. The observed clustering pattern, they pointed out, was inconsistent with a random distribution of individuals. We show that the clustering described in *P. asiatica* in the Mt. Geumjeong population is similar to that expected for a species with a self-similar spatial distribution. Biotic homogenization is generally quantified as the increase in the pairwise community similarity between two sites (and/or time periods) through similarity index (e.g. Jaccard; Bray-Curtis index) calculated with records of species presence/absence between sites (and/or time periods) (Devictor et al., 2008).

We hope that understanding where the main plant species in this study occur in the Mt. Geumjeong will be used as an ecological basis for the conservation of *P. asiatica* communities. These medical herb communities provide important economic resources. Therefore, conservation strategies are seriously needed.

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