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우면산 등산로 주변 서양등골나물의 분포 경향

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Distribution Pattern of *Ageratina altissima* Along Trails at Mt. Umyeon in Seoul, Korea

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ABSTRACT

***Ageratina altissima* is an invasive plant species known to threaten native plant communities in Korea. *A. altissima* is thought to invade shady forests from disturbed open areas; however, uncertainty remains as to how shade and litter depth might affect establishment. A study of *A. altissima* distribution characteristics in areas adjacent to trails was undertaken at Mt. Umyeon in Seoul, Korea. Increasing densities of *A. altissima* were found to correlate with greater light availability and decreasing litter depth (p < 0.001) within 10 m distance from trail locations and on ridges rather than further within forests and valleys. The effects of soil moisture content, soil gravel content and soil pH on distribution were not found to be significant, suggesting that *A. altissima* is adaptable to a broad range of soil conditions. Results indicate that forest areas close to trails may be particularly susceptible place to *A. altissima* invasion, demonstrating the need to carefully consider implications for *A. altissima* expansion in trail management.**

***Key words*: Invasive species, Coverage, Density, Relative light intensity, Litter depth**

I. INTRODUCTION

The establishment of nonnative species within natural environments where they were never found before has been called biological invasion (Drake, 1988; Williamson, 1996). Nonnative species, which threaten biodiversity of native ecosystems, are defined as invasive alien species (Convention on Biological Diversity, 2010). *Ageratina altissima* (L.) R.M. King et H. Rob. (white snakeroot), introduced from North America, was designated as an invasive alien plant species by the article 2 (18) under the Natural Environment Conservation Act of the Korean Ministry of Environment (Ministry of Environment, 2001) and as a harmful non-indigenous plant species by the article 2 (4) under the Protection of Wild Fauna and Flora Act in Korea (Ministry of Environment, 2007).

A. altissima is a native perennial herb species in the family Compositae and can grow to a height of 1.5 m with a short rhizome at the bottom. It has opposite ovate leaves, which are 2-10 cm long and 1.5-6 cm wide with serrated margins and an acute tip. White flowers bloom in August and September (Park, 1995). *A. altissima* reproduces from both seeds and rhizomes (Koh *et al*., 1995) and is known to invade gap areas, however, limited information is available on dispersal

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mechanisms between different regions. In Korea, *A. altissima* was first found in 1978 (Lee and Yim, 1978) with both first occurrence and current distribution centered around the Seoul area, especially at Mt. Namsan (Kim *et al*., 2003). Lee *et al*. (2004) noted that, in absence of removal and management intervention, *A. altissima* is spreading quickly into urban green areas. Better ecological understanding can help to inform management planning to contain *A. altissima* (Lee *et al*., 1998).

Light and topographic conditions are major factors that affect plant distribution and biodiversity (Lee and Yim, 1978; Hamilton and Limbard, 1982; Lee and Cho, 2000; Park *et al*., 2010). *A. altissima* at Mt. Namsan has been found to be most abundant around trails and valleys where openings in canopy cover provide for greatest light availability (Suh *et al*., 1997; Kil *et al*., 2004). However, the relationship between distribution of *A. altissima* and light condition is controversial. In North America where *A. altissima* is a native species, it is known to be moderately shade tolerant (Smith et al., 2014) and studies in Korea, also have shown that *A. altissima* can proliferate under half-shaded conditions (Koh *et al*., 1995) or in full shade (Suh *et al*., 1997). Lee *et al.* (2004) reported that *A. altissima* showed a sharp increase in density when the canopy coverage of tree and subtree layers is greater than 50%. Whereas, significant positive correlation between *A. altissima* coverage and light intensity and significant negative correlation between *A. altissima* coverage and dominant tree coverage were found by Kil *et al.* (2004). Jeong (2005) found a decrease in *A. altissima* density under forest canopy to be associated with a decrease in light intensity. Most Korean studies of *A. altissima* were conducted in Mt. Namsan area. Research in other areas of Korea may help to better understand factors influencing *A. altissima* distribution dynamics.

This study was aimed to document the distribution patterns of *A. altissima* around trails and valleys at Mt. Umyeon and analyze environmental factors to affect the distribution of *A. altissima*.

II. MATERIALS AND METHODS

2.1. Study area

Mt. Umyeon is located in Umyeon-dong, Seocho-gu in Seoul, Korea. The mean annual temperature of Mt. Umyeon is 12.0-13.8°C. The mean annual precipitation is 1,369.8 mm and over 70% of the precipitation concentrates in the summer. Most slopes at Mt. Umyeon are less than 20°. The soil is classified as Songsan series which is a member of coarse loamy, mesic family of Typic Dystrudepts (National Academy of Agricultural Science, 1973). The parent material is biotite. The forest is dominated by *Quercus mongolica* Fisch.

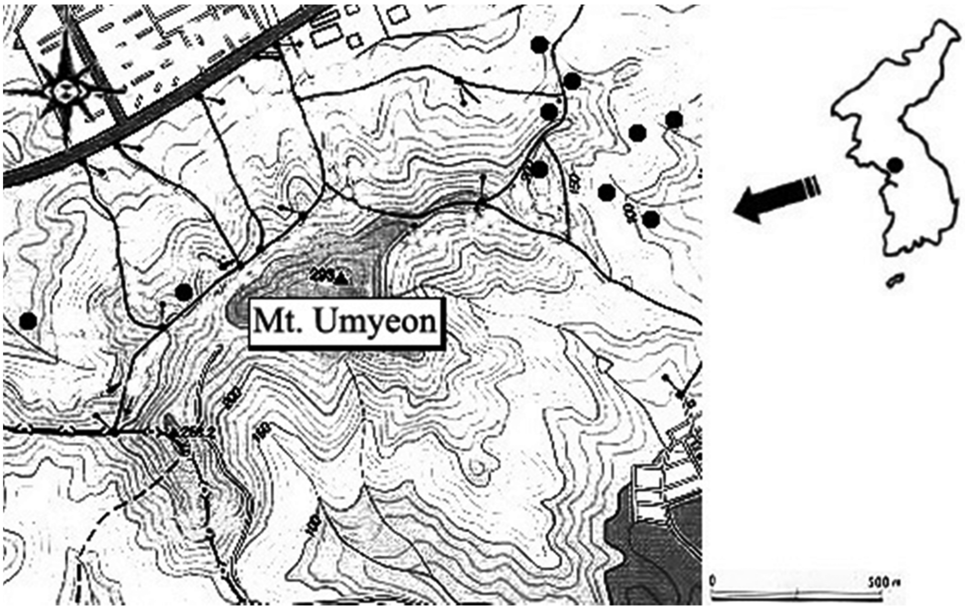


Fig. 1. Location of study sites along hiking trails at Mt. Umyeon, Seoul, Korea. Black dots indicate transects for vegetation survey.

ex Ledeb., *Castanea crenata* Siebold et Zucc., and *Robinia pseudoacacia* L.

2.2. Field methods

In October 2010, ridges and valleys at Mt. Umyeon were selected for study. Five transects were laid out on the ridges and five in the valleys beginning at trails and proceeding towards forest interiors. Five 1 m × 1 m quadrats were located 3 m apart along each transect beginning 3 m distant from the transect initiation point on the trail. A total of 50 quadrats were placed along 10 transects. Vegetation was surveyed in herb layers less than 50 cm height. Species, crown coverage, and stem density of vegetation were measured within each quadrat.

Relative light intensity (%) and depth of litter layer (cm) were measured at each quadrat. Relative light intensity was calculated as the ratio of light intensity at 50 cm above ground in a quadrat to full sun light intensity which was measured using a photometer. Soil samples were collected at 0-20 cm depth from 30 quadrats for soil moisture content, soil gravel content and soil pH analysis.

2.3. Data analysis

An importance value for each species (%) was calculated as the sum of the relative crown coverage and relative density of each species divided by two (Curtis and McIntosh, 1951).

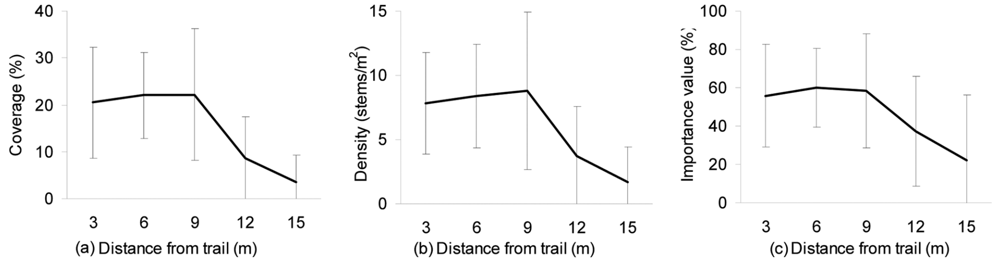
The coverage, density and importance value of *A. altissima* between ridges and valleys at the same distance from the trails were compared using a t-test (Zar, 2009). A single factor ANOVA was used to compare the abundance of *A. altissima* to the distance from trails. A multi-factor ANOVA was used to compare the abundance of *A. altissima* between ridges and valleys considering distances from trails. Correlation analysis and simple regression analysis were used to investigate the relationship between the abundance of *A. altissima* and environmental factors. R was used for the analysis (http://www.r-project.org).

III. RESULTS

The greatest abundance of *A. altissima* was found within ca. 10 m distance from trails at Mt. Umyeon. The coverage, density, and importance value of *A. altissima* decreased with increasing distance from the trails (Fig. 2). The distribution of *A. altissima* showed a significant decrease beyond 9 m distance from the trail in coverage ($p = 0.0002$), density ($p = 0.0010$), and importance value ($p = 0.0174$).

A difference in the abundance and distribution of *A. altissima* was noted in ridges when compared to valleys (Fig. 3). The coverage, density and importance value of *A. altissima* at the same distance from the trail were found to be higher on the ridge quadrats than in valley quadrats. The coverage and density of *A. altissima* within valleys decreased as measurements were taken within the forest further away from the trail intersects. In contrast, the coverage and density of *A. altissima,* found on the ridge quadrats, increased with distance to the trail up to 9 m, after which decreasing coverages and densities were observed. Measurements of coverage and density on ridges were found to be significantly higher than those taken within valleys at 9-12 m and 6-12 m distance, respectively, from the trail ($p < 0.05$), while they were not significantly different closer to trails or within interior forests.

Coverage, density and importance value of *A. altissima* were positively correlated with relative light intensity ($p < 0.001$) and negatively correlated with depth of litter layer ($p < 0.0001$). Soil moisture content measurements suggest that there may be a negative relationship with *A. altissima* abundance and distribution, though findings were not determined to be significant.



(a) Distance from trail (m) (b) Distance from trail (m) (c) Distance from trail (m)

Fig. 2. Changes in (a) coverage (%), (b) stem density (# stems m^{-2}), and (c) importance value (%) of *Ageratina altissima* by the distance (m) from the trails.

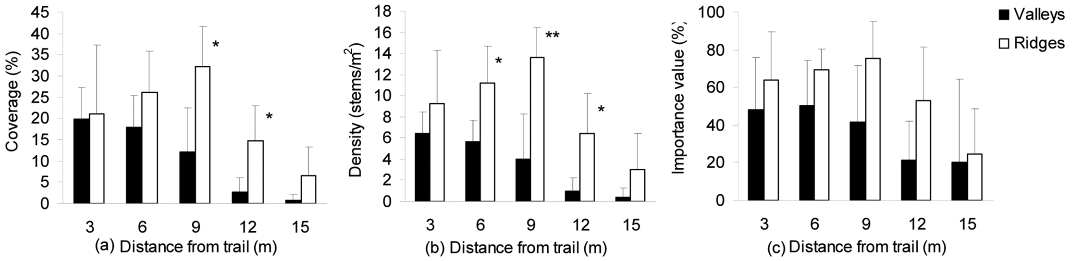


Fig. 3. Comparison of (a) coverage (%), (b) stem density (# stems m^{-2}), and (c) importance value (%) of *Ageratina altissima* at each distance (m) from the trails between valleys (black bar) and ridges (white bar).
$^{*}p < 0.05$, $^{**}p < 0.01$, using a t-test.

Table 1. Correlation coefficients of coverage, density, and importance value of *A. altissima* with relative light intensity (%), litter depth (cm), soil moisture content (%), soil gravel content (%), and soil pH

Characteristic	Coverage	Density	Importance Value
Relative Light Intensity	0.681***	0.638***	0.470***
Depth of litter layer	-0.693***	-0.768***	-0.542***
Soil moisture content	-0.221	-0.383*	-0.360
Soil gravel content	0.106	0.045	0.027
Soil pH	-0.051	0.019	0.052

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

The relative light density at the same distance from the trail was higher at ridges than at valleys beyond 6 m distance from the trail (Fig. 4a). On ridges, relative light intensity, which was ca. 55% at 3 m from the trail, increased with increasing distance from the trail reaching a peak at 6-9 m. However, relative light intensity on ridges sharply decreased beyond 9 m distance from the trail. In valleys, relative light intensity continuously decreased with notable acceleration beginning at 6–9 m distance from the trail. The differences in relative light intensity between ridges and valleys were found to be the largest at 9 m distance from the trail.

Litter layers at the same distance from the trail were observed to be deeper in valleys than on ridges beyond 3 m distance from the trail (Fig. 4b). On ridges, litter layers were similar of ca. 1.8 cm up to 9 m distance from the trail but deepened to 3 cm at 15 m distance from the trail. In valleys, litter layers continuously deepened as distance from the trail increased, measuring from 1.8 cm at 3 m distance to 4 cm depth at 15 m distance from the trail. The difference in litter depths between ridges and valleys were observed to be the largest at 9 m distance from the trail.

IV. DISCUSSION

Changes in the abundance and distribution of *A. altissima* observed across a gradient from trail intersects to interior forests corresponded with the changes in light condition and litter depth.

Greater light availability was observed near trails and on ridges as compared with interior forests and valleys. Cor-

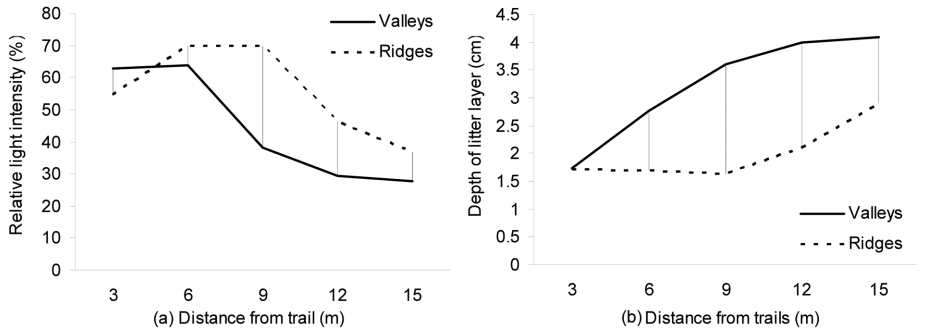


Fig. 4. (a) Relative light intensity (%) and (b) depth of litter layer (cm) by the distance from the trails in valleys (solid line) and ridges (dotted line).

respondingly greater abundance of *A. altissima* was found as light availability increased. Kil *et al.* (2004) and Jeong (2005) found similar results. Parendes and Jones (2000) concluded that the availability of light on trails increases opportunity for establishment of invasive species.

The contrasting abundance of *A. altissima* on shaded or half-shaded sites as reported in other studies might be related to the competitive survival strategies of *A. altissima* under differing environmental conditions. For example, research by Chun (2002) suggests *A. altissima* can survive under shaded condition by changing photosynthate partitioning to allocate more photosynthates to leaves than stems.

The depth of litter layers was found to be thinner on ridges and around trails than in valleys and inside the forest. The negative correlation between depth of litter layer and *A. altissima* abundance may be related to a shallow root system located near soil surface. For example, a thick litter layer was found to hinder rooting or germination of *A. altissima* (Kil, 2003). In agreement with Kil (2003), results of this study indicate that, as the depth of litter layer increased, the abundance of *A. altissima* decreased.

In contrast to prior studies conducted at Mt. Namsan, which found greater abundance within valleys rather than on ridges (Suh *et a*l., 1997; Kil *et al*., 2004), study of *A. altissima* abundance and distribution at Mt. Umyeon indicated more prolific establishment occurred on ridges than in valleys. The more light and thinner litter layers associated with ridges in comparison to valleys at Mt. Umyeon, appear to be significant determining factors for success of *A. altissima* establishment at least at this location. Contrasting findings from studies at Mt. Namsan and Mt. Umyeon suggest that strategies for the management and control of *A. altissima* could be most effective when drafted in careful consideration of local environmental conditions and for area-specific implementation (Constán-Navaa *et al.*, 2010).

Soil moisture content, soil gravel content, and soil pH were not significantly correlated with the coverage, density, and importance value of *A. altissima,* indicating that *A. altissima* may be adaptable to a broad range of soil conditions implying heightened risk of spread to diverse areas and a compelling need for aggressive response (Kil, 2003).

V. CONCLUSIONS

At Mt. Umyeon, the distribution of *A. altissima* increased in conditions of greater light and shallower litter layers and was found in greatest abundance within 10 m distance from trails where light and forest floor conditions provide favorable conditions for the distribution. However, *A. altissima* did not show a significant relationship with soil moisture or soil pH, indicating that this species could be adaptable to a wide range of soil conditions. Study results indicate that the area around trails was particularly susceptible to invasion of *A. altissima*. Careful trail management with special attention to the adjacent margins within 10 m will be strategically important for controlling expansion of *A. altissima* on Korean landscapes.

적 요

서양등골나물(*Ageratina altissima*)은 우리나라의 육상생태계를 교란시키는 외래종으로 알려져 있다. 교란 지역으로부터 그늘이 지는 숲 속으로 침입하는 것으로 알려져있으나, 한국에서 나타나는 서양등골나물의 분포 특성에 대해서는 양지와 음지에 대한 다양한 보고가 있다. 본 연구는 서울 우면산을 대상으로 광도 및 토양 특성과 서양등골나물의 분포의 관계, 등산로 주변 서양등골나물 분포 양상을 살펴보았다. 서양등골나물의 분포는 상대광도가 증가함에 따라 증가하고, 낙엽층이 깊어지면 감소하는 것으로 나타났다($p < 0.001$). 서양등골나물은 우면산에서 주로 등산로 주변에서 분포하고 있었으며, 특히 등산로로부터 숲으로 10m 이내에 대부분이 분포하고 있었는데($p < 0.01$), 이 지역은 빛과 임상 상태가 서양등골나물에게 유리한 지역이었다. 서양등골나물은 계곡보다는 능선에서 더 많이 분포하였으며, 지형에 따른 차이는 등산로로부터의 거리 10m를 전후로 한 9m, 12m 위치에서 가장 컸다($p < 0.05$). 토양의 수분함량, 석력함량, pH 등은 서양등골나물의 분포와 뚜렷한 상관관계를 보이지 않는 것으로 나타났으며, 이는 서양등골나물이 다양한 토양 환경에 대한 적응성을 가지고 있다는 것을 알려주었다. 본 연구는 등산로가 외래종의 침입에 취약한 지역임을 보여주었으며, 향후 등산로 관리에서 외래종의 침입에 대한 대책의 필요성을 알려주었다.

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