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Ecological Characteristics of Natural Habits of *Deutzia paniculata,* a Rare and Endemic Woody Species in Korea

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Abstract

Deutzia paniculata Nakai, a rare and endemic plant, has limited distribution throughout the North and South Gyeongsang provinces of South Korea. The *D. paniculata* community grows mostly on the stony slopes of forests, valley edges, and rock layers at 250-960 m in altitude, where deciduous trees are dominant and high humidity is maintained. Correlation analysis of vegetation and environmental factors found that the Walter's dogwood-mulberry community was correlated with soil acidity (pH). Whilst the queritron community had correlations with distance from the valley, rock rate and slope. The natural habitat of the Palgongsan Mountain in Daegu is known to have high genetic diversity, had eight *D. paniculata* individuals recorded from 2014 to 2018, and 12 individuals recorded in 2020 (new individuals due to a newly created space within the herbaceous layer caused by grass mowing works), it is therefore unlikely that the community would perish unless there was an artificial disturbance. To conserve the natural habitats of *D. paniculata*, oppression by Sasa borealis, damage, increase in crown density of the upper layer, overexploitation, and absence of seedlings should be carefully investigated. In addition, response measures should also be established and the impact on seed fullness and the reproductive characteristics of *D. paniculata* recorded. To restore declined genetic diversity, individuals from high genetic diversity regions, such as Palgongsan Mountain, should be artificially transplanted.

Key Words: correlation, species diversity, cluster analysis, habitat environment, conservation

Introduction

Plants occupy physical habitats and maintain the wider plant community through ecological processes as a result of complex interactions with environmental factors (Gleason 1926; Grubb 1977; Kim 2017). Plant communities are assemblages of species which can be influenced by various factors (Harper 1977). Rare or endemic plants may require particular conservation efforts. In these cases it is important that we better understand these plant's life cycle characteristics and community dynamics (Elzinga et al. 1998; Kim 2017). For species of conservation interest, it is necessary to

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establish a conservation plan, which requires information about the plant species, including various biological information about corresponding plants in the community such as classification, distribution, number of communities, number of individuals, the pattern of community change and genetic information (Shin et al. 2014; Jung et al. 2016). In particular, the conservation of habitats and communities stems from an understanding of the environments and structures of natural habitats as well as characteristics of species composition and the relationship between the attributes of the target plant community and environmental factors. In addition, it is also highly important to understand the characteristics of the plants themselves (Pianka 1970; Pearman et al. 2008).

A plant's specific life cycle is characterized by its interaction with given environmental conditions. Long term observations are required to understand such characteristics and identify community dynamics (Pianka 1970; Pearman et al. 2008). Further, plants maintain and reproduce their communities in a given environment and subsequently perish over time, therefore the identification of community dynamics can be beneficial for the conservation of plant species (Gleason 1926; Connell and Slatyer 1977; Crawley and Ross 1990; Elzinga et al. 1998; Kim et al. 2016; Kim et al. 2019).

This is because community dynamics allow us to better understand the characteristics of individual plant species and also the sustainability of current plant habitats. To date, efforts to conserve plant species have included studies on distribution, the number of individuals, extent of occurrence, genetic characteristics, characteristics of individual proliferation, vegetation structure and the environmental characteristics of habitats. These studies have generally focused on rare or endemic plants which show limited distributions, as targets for conservation. For optimum conservation efforts further information, such as information on community dynamics, level of community change, and flowering and seed setting rates, needs to be assessed (Kim et al. 2016).

Deutzia paniculata Nakai, a deciduous broad-leaved shrub in the Saxifragaceae family, lives mostly on the side slopes of valleys in forests, cracks in rocks, stony slopes, or mountain ridges (Son et al. 2013).

Currently, this plant is considered rare, found only in some areas of the North and South Gyeongsang provinces in South Korea. Although endemic (Chung and Shin 1986; Kim 2003; Son et al. 2013), it has a substantially narrow extent of occurrence. The International Union for Conservation of Nature (IUCN) Red List, lists the conservation status of *D. paniculata* as 'Critically Endangered', 'Endangered', and 'Vulnerable' (Chang et al. 2001; Korea National Arboretum 2008; National Institute of Biological Resources 2012). A recent study on the genetic diversity of *D. paniculata* reported that it had a lower genetic diversity than the average endemic species, species which self-pollinate and species with vegetative propagation. Despite the fact that *D. paniculata* reproduces through cross-fertilization, it is known to have remarkably low genetic variation. Insect pollinators of *D. paniculata* include the Hymenopteran *Lasioglossum exiliceps* (Vachal) in the Halictidae family and the Dipteran Allograpta balteata (de Geer) in the Syrphidae family (Kim 2003; Chang and Kim 2014; Jung et al. 2016).

To date, studies conducted on *D. paniculata* predominantly focus on its classification and genetic diversity, including a study on the classification of deutzia plants and interspecies relationships, a study on morphological classification and genetic diversity of Korean deutzia, a study on genetic diversity and structure of the *D. paniculata* community and a study on reproductive characteristics and isoenzyme genetic diversity of the endemic species *D. paniculata*. In addition, the structure and distribution of the *D. paniculata* community has been investigated in some areas.

The present study is on site characteristics and vegetation structure in the wild habitats of *Deutzia paniculata* and offers basic information on habitat conservation including recovery plan.

Materials and Methods

Study areas

Known natural habitats of *D. paniculata* were searched for in the National Biological Resource Knowledge Information System (www.nature.go.kr), the Korea National Arboretum sample archive and past study data (Kim 2003; Son et al. 2013; Yoon et al. 2014; Chang and Kim 2014; Jung et al. 2016). The locations identified from these searches were; Gunwi, Gyeongju, Daegu, Miryang, Busan, Ulsan, Wonju, Yangsan, Changwon, Cheongdo, and Taebaek. However, there are some issues with this broad-scale search methodology, as some samples may have been incorrectly identified, information may be out of date, or may be from artificial collection sites such as arboretums, botanical gardens, and farms, not natural habitats. For example, *D. paniculata* is no longer found on the Bulmosan Mountain in Jinhae-gu of Changwon-si. Hence, it was necessary to further check the returned search results.

Of the reported natural habitats, eight study areas were selected; around the Ecological Landscape Protected Area of Unmunsan Mountain in Cheongdo (four regions), around the Sinseonsa of Danseoksan Mountain in Gyeongju (two regions), around the Sinheungsa of Dongdaesan Mountain in Ulsan (one region) and around the Pokpogol of Palgongsan Mountain Nature Park in Daegu (one region). All of the study sites are located in the South Temperate Zone of Korea with a northern latitude of 37°. *D. paniculata* is found in only limited areas in each of the study sites. Of the study areas, the largest habitat for the *D. paniculata* community is in the Ecological Landscape Protected Area of Unmunsan Mountain in Cheongdo,. To accurately identify plant species in each season, field surveys were conducted across three seasons (spring, summer and fall) from March 2017 to September 2019. For each survey, 8 quadrats, each 100 m^2 (10 m×10 m), were established (Fig. 1).

Study methods

Characteristics of growth environments

To identify key characteristics of the study areas, altitude (GPS-V, Garmin), slope (PM-5/360PC, Suunto), bearing (Starter 1-2-3, Silva) and location (Garmin Co Ltd., Oregon300) were recorded. In addition, climate data were analyzed using statistical yearbook records of Cheongdo, Gyeongju, Ulsan and Daegu from the past 30 years (Korea Meteorological Administration 1990-2019). To examine soil characteristics of natural habitats of *D. paniculata*, approximately 300 g of soil was collected from cleared forest floor at depths of between 0-10 cm within the quadrats. Soil samples were transported to the laboratory and allowed to driy naturally. Once dry, samples were sent to Gyeongsangbukdo Agricultural Research & Extension Services for analyses, where soils were analyzed for soil texture, hydrogen ion concentration (pH), electrical conductivity (EC), soil organic matter content (O.M.), available phosphate (P_2O_5), exchangeable cation (Mg^{2+}, Ca^{2+}, K^+), and cation exchange capacity (CEC).

Structure of plant communities

To accurately identify plant species in each season, plant species and vegetation surveys were conducted across two years from spring 2018 to fall 2019. After investigating the degree of coverage of vascular plants in the quadrats, relative density and relative coverage were calculated. To compare the relative dominance of species for each layer in each plant community, Importance Percentage (I.P.), in which importance values were combined and then converted to percentage, as well as Mean Importance Percentage (M.I.P) were calculated (Curtis and McIntosh 1951). In addition, Shannon & Weaver (1963)'s species diversity index (H') was applied to identify diversity and uniformity of species. Maximum diversity (H' max), evenness (J') and dominance (D') were then calculated (Simpson 1949; Pielou 1975).

To find the relationship between natural habitats depending on vegetation structure, plant communities were analyzed based on the importance values for all groups which

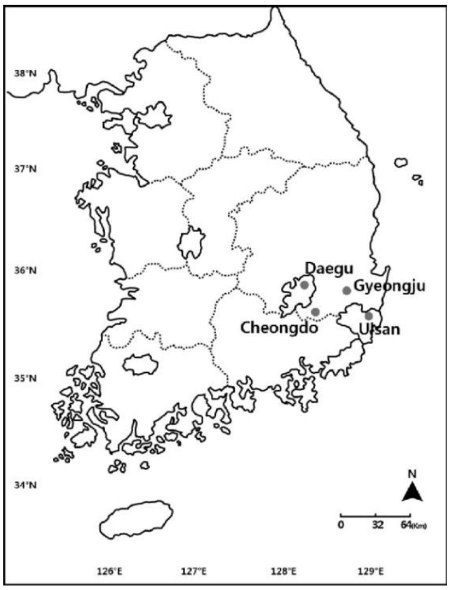

Fig. 1. Map showing the study area.

appeared in the study areas, and the community was classified using a Two-way Cluster Analysis in PC-ORD (version.5.10; McCune and Mefford 2006).

To test whether there was a correlation between the vegetation analysis data and environmental variables (including altitude, slope, distance from valley, rock rate, forest floor and soil physicochemical factors) of *D. paniculata*'s natural habitats, a Pearson's correlation analysis was performed using IBM SPSS (version 19; International Business Machine 2010).

Results and Discussion

Characteristics of growth environments

D. paniculata communities were found to be associated with certain environmental characteristics. *D. paniculata* mostly formed discontinuous or continuous communities in the rock layer adjacent to valleys at an altitude of 265-655 m (mean: 450 m) above sea level. Communities were associated with northwest (NW), northeast (NE) and southeast (SE) slopes with 14-38° angles, and 20-80% rock exposure (Table 1). As a result of the study on the pediment, it was confirmed that it was at a level similar to the characteristics of the growing environment except for the altitude (290-959 m) above sea level (Jung et al. 2016).

The annual mean temperature of the study areas was 13.0°C (Cheongdo), 13.3°C (Gyeongju), 14.1°C (Ulsan) and 14.1°C (Daegu), and annual mean precipitation was 1,208.0 mm, 1,008.8 mm, 1,290.9 mm and 1,090.8 mm respectively. When the regions' temperatures are compared, Ulsan and Daegu was 0.5°C higher at the highest temperature than the mean value, while Cheongdo was 10°C lower at the lowest temperature than the mean temperature value. As for annual mean precipitation, Ulsan had 141.1 mm higher rainfall than the mean precipitation value. Most of the study sites showed typical temperate continental climates that were severely cold in the winter and hot and humid in the summer (Table 2).

Table 1. Habitat status of the *Deutzia paniculata* populations in the investigated areas

Location	Cheongdo				Gyeongju		Ulsan	Daegu
Site number	1	2	3	4	5	6	7	8
Direction	NW	NW	NW	NW	NW	NW	NE	SE
Latitude	35°38'32.1"	35°38'22.4"	35°47'49.3"	35°38'08.3"	35°47'48.2"	35°47'49.0"	35°39'41.4"	35°59'47.1"
Longitude	128°58'56.5"	129°00'04.7"	129°04'55.5"	128°57'37.3"	129°05'00.8"	129°04'55.3"	129°23'14.1"	128°42'57.3"
Altitude (m)	285	546	310	350	655	560	265	629
Slop degree (°)	34	30	14	60	16	38	13	20
Bare rock (%)	80	65	20	80	30	60	30	30
Distance from the valley (m)	8	20	25	30	0.5	0.5	15	10
litter layer (cm)	3	3	3	4	4	3	7	5
Height of the tree (m)	16	12	8	12	13	9	14	9
Height of the arborescent (m)	8	8	5	8	8	-	-	4
Height of the shrub (m)	1.5	2.5	1.5	1.5	2.5	2.5	1.3	1.8
Height of the herb (m)	0.15	0.3	0.2	0.3	0.2	0.3	0.3	0.2

Table 2. Climate analysis of the *Deutzia paniculata* populations in the investigated areas

Location	Highest temperature (°C)	Lowest temperature (°C)	Annual mean temperature (°C)	Annual mean precipitation (mm)
Cheongdo	26.3	-0.6	13	1,208
Gyeongju	25.7	0.5	13.3	1,008.8
Ulsan	26.4	1.9	14.1	1,290.9
Daegu	26.8	0.6	14.1	1,090.8
Average	26.3	0.6	13.6	1,149.6

As for soil texture, the natural habitats of Cheongdo, Gyeongju, and Ulsan had loam soils, while Daegu had a sandy loam soil. Soil acidity (pH) of the sites was between pH 4.7-5.8, with, on average, pH 5.3 corresponding to sub-acidity (Lee 1981; Jeong et al. 2002), which is similar to the average pH (pH 5.5) of forest soils in South Korea. The electrical conductivity (EC) of soils was in the range of 0.34-1.58 ds/m. Soil organic matter content (O.M.) was between 71.75-282.3 g/kg (7.175-28.23%), with an average of 15.8% (Table 3). This is significantly higher than the mean organic matter content (4.5%) of an average layer of forest soil in South Korea. Organic matter content has the largest influence on soil characteristics as it plays a substantial role in soil's physical properties, providing most of the nitrogen and available phosphate (50-60%), and improving cation exchange capacity (CEC). Available phosphate (P_2O_5) content is used as a soil indicator was between 17-61 mg/kg, with an average of 36.25 mg/kg. This phosphate availability is higher than the mean (25.6 mg/kg) of South Korean soils (Jeong et al. 2002). All sites also had a higher cation content (K^+, Ca^{2+}, and Mg^{2+}) than the mean levels for South Korea. Cation exchange capacity (CEC) is an indicator of soil nutrient holding capacity, and was also higher for all sites than the mean value (16-20 cmol+/kg) of Korean forest soil, which seems to be attributable to the effect of increased organic matter content.

Since all of the study site soils had higher organic matter content, available phosphate, cation exchange capacity and exchangeable cation contents than the mean values for forest soils in South Korea, these soils seem to have physicochemical characteristics which make them optimal for plant growth. In addition, it seems that a high nutrient holding capacity of the soils should facilitate increased production of organic matter.

Structure of plant communities

Cluster analyses

Using the importance values of the plant species identified in the eight study areas which had *D. paniculata* communities, relationships among the study areas were analyzed. As for natural habitats of *D. paniculata*, all communities were clustered at a level of 0.35-1.0 (Fig. 2). Next, study quadrats 5, 6 and 7 were clustered, we found that the importance values of *Cornus walteri* F.T. Wangerin and *Morus alba* L. which were not found in the other quadrats or had lower degrees of coverage and small numbers of individuals, were relatively higher. It was postulated that it should therefore, have a greater impact on the determi-

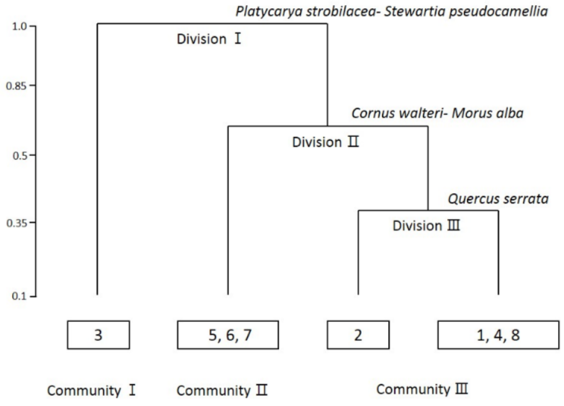

Fig. 2. Dendrogram of the plots based on cluster analysis.

Table 3. Soil characteristic of the *Deutzia paniculata* populations in the investigated areas

Location	Cheongdo				Gyeongju		Ulsan	Daegu	Average
Site number	1	2	3	4	5	6	7	8	-
Soil texture	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Sandy loam	Loam Sandy loam
pH (1:5)	5.5	5.4	4.7	4.8	5.6	5.8	5.6	4.7	5.3
EC (dS/m)	1.58	1.11	0.53	0.72	0.66	0.7	0.34	0.66	0.79
OM (g/kg)	282.3	152.3	192	130.2	200.4	161.7	75.16	71.75	158.23
Av.P_2O_5 (mg/kg)	58	34	23	29	49	61	19	17	36.25
CEC (cmol+/kg)	41.28	36.08	18.62	22.84	30.48	23.22	20.56	13.08	25.77
K^+ (cmol+/kg)	1.11	1.01	0.41	0.55	0.65	0.83	0.35	0.34	0.66
Ca^{2+} (cmol+/kg)	30.6	19.17	2.56	4.45	15.7	17.46	14.54	2.47	13.37
Mg^{2+} (cmol+/kg)	6.98	3.64	1.01	1.21	3.17	3.03	3.67	0.72	2.93

Table 4. Importance percentage (IP) and mean importance percentage (MIP) of major woody species in each plant communities

Scientific name	Community I*					Community II					Community III				
	C	U	S	H	M	C	U	S	H	M	C	U	S	H	M
Lindera erythrocarpa Makino	-	-	12.5	-	2.5	10.2	-	5.2	3.7	7.5	9.3	5.7	-	2	5.7
Carpinus laxiflora (Siebold & Zucc.) Blume	-	17.1	6.2	-	6.4	7.3	-	5.7	2.5	6	5.5	5.7	-	-	3.9
Deutzia paniculata Nakai	-	-	21.6	-	4.3	-	-	12.5	2.1	4.5	-	-	17.3	3.3	3.8
Lindera obtusiloba Blume	-	-	9.2	-	1.8	-	-	5.7	-	1.9	-	8.1	7.8	2	4.2
Acer pictum subsp. *mono* (Maxim.) Ohashi	-	-	-	-	-	-	-	5.7	-	1.9	7.4	5.7	-	2	4.9
Stephanandra incisa (Thunb.) Zabel	-	-	6.2	2.2	1.5	-	-	-	-	-	-	-	9.3	8	2.7
Acer pseudosieboldianum (Pax) Kom.	-	24.3	-	-	7.3	-	-	8.1	-	2.7	-	-	-	2	0.2
Oplismenus undulatifolius (Ard.) P.Beauv.	-	-	-	22.2	2.2	-	-	-	3.7	0.6	-	-	-	5.8	0.6
Stewartia pseudocamellia Maxim.	-	34.3	-	-	10.3	-	-	-	-	-	7.4	8.1	-	-	5.4
Sapium japonicum (Siebold & Zucc.) Pax & Hoffm.	-	-	0.6	-	0.1	-	-	-	-	-	-	11	-	2	3.5
Morus bombycis Koidz.	-	-	-	-	-	-	-	5.7	2.5	2.3	-	8.1	-	-	2.4
Quercus serrata Thunb.	-	-	-	-	-	-	-	-	-	-	18.4	-	-	2	7.6
Hydrangea serrata for. *acuminata* (Siebold & Zucc.) E. H. Wilson	-	-	-	-	-	-	-	4.1	-	1.4	-	-	12.8	2.7	2.8
Platycarya strobilacea Siebold & Zucc.	70.8	-	-	-	28.3	-	-	-	-	-	-	-	-	-	-
Cornus walteri F. T. Wangerin	-	-	-	-	-	17.5	-	-	-	8.8	-	-	-	-	-
Ligustrum obtusifolium Siebold & Zucc.	-	-	-	-	-	-	-	4.1	-	1.4	-	8.1	6.4	-	3.7
Styrax obassia Siebold & Zucc.	-	-	-	-	-	-	-	4.1	2.5	1.8	9.3	-	-	-	3.7
Actinidia arguta (Siebold & Zucc.) Planch. ex Miq.	-	-	-	-	-	-	-	-	3.7	0.6	-	-	-	-	-
Cornus controversa Hemsl.	-	-	-	-	-	15.3	-	-	-	7.7	-	2.9	-	2	1.1
Quercus aliena Blume	29.2	-	-	-	11.7	-	-	-	-	-	7.4	-	-	-	3
Athyrium niponicum (Mett.) Hance	-	-	-	-	-	-	-	-	1.3	0.2	-	-	-	2	0.2
Boehmeria tricuspis (Hance) Makino	-	-	-	-	-	-	-	-	7.6	1.3	-	-	-	2	0.2
Philadelphus schrenkii Rupr.	-	-	-	-	-	-	-	8.1	-	2.7	-	-	12.8	-	2.6
Sorbus alnifolia (Siebold & Zucc.) C. Koch	-	-	6.2	-	1.2	-	-	5.7	-	1.9	-	-	-	-	-
Securinega suffruticosa (Pall.) Rehder	-	-	6.2	-	1.2	-	-	-	-	-	-	5.7	-	-	1.7
Disporum smilacinum A. Gray	-	-	-	22.2	2.2	-	-	-	2.5	0.4	-	-	-	-	-
Ainsliaea acerifolia Sch. Bip.	-	-	-	2.2	0.2	-	-	-	-	-	-	-	-	2	0.2
Parthenocissus tricuspidata (Siebold & Zucc.) Planch.	-	-	-	-	-	-	-	-	-	-	-	11.4	-	-	3.4
Viburnum erosum Thunb.	-	-	-	-	-	-	-	-	3.7	0.6	-	-	-	5.8	0.6
Rhus trichocarpa Miq.	-	-	6.2	-	1.2	-	-	5.7	-	1.9	-	-	-	-	-
Polygonatum odoratum var. *pluriflorum* (Miq.) Ohwi	-	-	-	-	-	-	-	-	2.5	0.4	-	-	-	2	0.2
Weigela subsessilis (Nakai) L. H. Bailey	-	-	-	-	-	-	-	-	-	-	-	8.1	7.4	-	3.9
Alnus sibirica Fisch. ex Turcz.	-	-	-	-	-	-	-	-	-	-	12.9	-	-	-	5.2
Carex humilis var. *nana* (H. Lév. & Vaniot) Ohwi	-	-	-	44.4	4.4	-	-	-	-	-	-	-	-	-	-
Styrax japonicus Siebold & Zucc.	-	24.3	-	-	7.3	-	-	-	-	-	-	11.4	-	-	3.4
Fraxinus rhynchophylla Hance	-	-	6.2	-	1.2	-	-	-	0.3	0.04	-	-	-	-	-
Potentilla freyniana Bornm.	-	-	-	-	-	-	-	-	2.5	0.4	-	-	-	4	0.4
Quercus mongolica Fisch. ex Ledeb.	-	-	-	-	-	12.4	-	-	-	6.2	7.4	-	-	-	3
Morus alba L.	-	-	-	-	-	17.5	-	-	-	8.8	-	-	-	-	-

*Community I: Platycarya strobilacea-Stewartia pseudocamellia, Community II: *Cornus walteri-Morus alba*, Community III: Quercus serrata.

C, importance percentage in canopy layer; U, importance percentage in understory layer; S, importance percentage in the shurb layer; H, importance percentage in the herbaceous layer; M, mean importance percentage.

nation of the community heterogeneity. In addition, queritron, which had a high importance value, commonly emerged in study quadrats 1, 2, 4 and 8 which were clustered in proximity. Thus, relationships of communities in natural habitats of *D. paniculata* were determined based on the difference of dominant species rather than numbers of the commonly identified species.

Analyses of importance values

An importance value analysis by community found that study quadrat 3 belonged to Cluster Ⅰ (cone-fruit platycarya-Korean stewartia). In the tree layer, cone-fruit platycarya was the dominant species (70.8%), while white oak also emerged (29.2%). In the sub-tree layer, Korean stewartia was the dominant species (34.3%), while Korean maple (24.3%), snowbell (24.3%), and loose-flower hornbeam (17.1%) were also present. In the shrub layer, *D. paniculata* (21.6%) and red-fruit spicebush (12.5%) were dominant, while ginger plant (9.2%), laceshrub (6.2%) andAsian bushweeds (6.2%) also appeared. In the herbaceous layer, low sedge was dominant (44.4%), while fairy-bells (22.2%) and wavy-leaf basketgrass (22.2%) also occupied significant proportions. Cluster I was a community of cone-fruit platycarya-Korean stewartia, in which there were many *D. paniculata* plants in the shrub layer and it was predicted that the current community was stable for the time being.

Study quadrats 5, 6 and 7 belonged to Cluster II (Walter's dogwood-mulberry). In the tree layer, Walter's dogwood (17.5%) and mulberry (17.5%) were dominant, while dogwood (15.3%), Mongolian oak (12.4%) and red-fruit spicebush (10.2%) also appeared. There was no sub-tree layer in Cluster II. In the shrub layer, *D. paniculata* was dominant (12.5%), while mock orange (8.1%) and Korean maple (8.1%) also accounted for high proportions. In the herbaceous layer, spidate falsenettle was a dominant species (7.6%), while *D. paniculata* (3.7%), Siberian gooseberry (3.7%), and Solomon's seal (2.5%) were also observed. Cluster II was the community of Walter's dogwood-mulberry, where Walter's dogwood and mulberry in the tree layer were competing against each other in similar proportions. It was predicted that the current community would remain stable for the time being.

Study quadrats 1, 2, 4 and 8 belonged to Cluster III (queritron). In the tree layer, queritron (18.4%) was dominant, while Siberian alder (12.9%), red-fruit spicebush (9.3%), and fragrant snowbell (9.3%) also emerged. In the sub-tree layer, snowbell (11.4%) and bristly fruit sumac (11.4%) were dominant species, while tallow tree (11.0%), Korean weigela (8.1%), ginger plant (8.1%), and mono maple (5.7%) also appeared. In the shrub layer, *D. paniculata* (17.3%) was dominant, while hydrangea (12.8%) and mock orange (12.8%) also occupied high proportions. In the herbaceous layer, laceshrub was a dominant species (8.0%), while ivy (5.8%), *D. paniculata* (3.3%), and Freyn's cinquefoil (4.0%) appeared. Cluster Ⅲ was the community of queritron, which was again expected to remain stable for the time being. In addition, it seemed that queritron would prevail in the tree layer as it becomes dominant through the succession process (Table 4).

Species diversity analysis

Species number was calculated for each layer as well as Shannon & Weaver's species diversity index (H'), the maximum species diversity (H'max), evenness (J') and dominance (D'). Analyses showed that Cluster Ⅱ had the highest species diversity index (1.7502), whereas Cluster Ⅰ had the lowest value (1.2954). As for the maximum species diversity (H' max) (calculated by species number), Cluster Ⅲ had the highest value (1.8808). Evenness (J') represents the degree of distribution for the number of individuals for each species. A value which is closer to 1 indicates a more equal number of individuals among many species. Evenness by study quadrat in the present study was between 0.8010-0.9518, suggesting that there was relatively equal numbers of plants for each species in the vegetation.

Dominance (D') is the opposite of evenness. When dominance is 0.9 or higher, 1 species is dominant, whereas values of 0.3-0.7 and 0.3 or lower mean that there is dominance by 2-3 species or multiple species, respectively. Cluster Ⅲ had the highest value (0.1990), while Cluster Ⅱ had the lowest value (0.0482) (Table 5). In the present study, the total dominance of all study quadrats was, on average (Whittaker 1956), 0.1141, suggesting that multiple species rather than a single species were dominant in these communities.

Table 5. Species diversity indices of woody and herb plant species in the investigated plots

Sites	No. of species	Species diversity (H')	Maximum H' (H'max)	Evenness (J')	Dominance (1-J')
Community I	27	1.2954	1.4314	0.905	0.095
Community II	69	1.7502	1.8388	0.9518	0.0482
Community III	76	1.5065	1.8808	0.801	0.199
Average	57	1.5174	1.717	0.8859	0.1141

Table 6. Species diversity indices of woody and herb plant species in the investigated plots

	AT	SD	DV	BR	LL	NS	DIV	EVE	DOM	PH	OM	AV	EC	CEC	EK	ECA	EMG
AT	1																
SD	-0.112	1															
DV	-0.541	0.31	1														
BR	-0.185	0.869**	0.135	1													
LL	-0.171	-0.36	0.014	-0.432	1												
NS	0.343	-0.622	-0.653	-0.605	0.368	1											
DIV	0.245	-0.63	-0.656	-0.6	0.47	0.986**	1										
EVE	-0.125	0.063	-0.108	-0.11	0.847**	0.269	0.377	1									
DOM	0.125	-0.063	0.108	0.11	-0.847**	-0.269	-0.377	-1.000**	1								
PH	0.124	-0.088	-0.678	0.196	0.022	0.092	0.179	0.121	-0.121	1							
OM	-0.178	0.107	-0.23	0.367	-0.717*	-0.266	-0.286	-0.601	0.601	0.27	1						
AV	0.193	0.299	-0.638	0.505	-0.588	-0.063	-0.06	-0.263	0.263	0.688	0.729*	1					
EC	-0.074	0.352	-0.128	0.716*	-0.586	-0.287	-0.33	-0.511	0.511	0.195	0.706	0.566	1				
CEC	-0.083	0.206	-0.195	0.607	-0.476	-0.459	-0.448	-0.443	0.443	0.537	0.749*	0.658	0.832*	1			
EK	0.065	0.37	-0.277	0.728*	-0.665	-0.366	-0.387	-0.534	0.534	0.537	0.703	0.782*	0.874**	0.905**	1		
ECA	-0.1	0.058	-0.499	0.505	-0.245	-0.089	-0.038	-0.187	0.187	0.793*	0.622	0.742*	0.724*	0.872**	0.843**	1	
EMG	-0.271	0.01	-0.41	0.468	-0.145	-0.085	-0.02	-0.124	0.124	0.706	0.63	0.639	0.719*	0.847**	0.757*	0.975**	1

*indicate significance at 5% level, **indicate significance at 1% level.

AT, altitude; SD, slop degree; DV, distance from the valley; BR, bare rock; LL, litter layer; NS, no. of species; DIV, species diversity; EVE, evenness; DOM, dominance; PH, pH; OM, oaganic matter; AP, available phosphate; EC, electric conductivity; CEC, cation exchange capacity; EK, exchangeable cation K^+; ECA, exchangeable cation Ca^{2+}; EMG, exchangeable cation Mg^{2+}.

Correlation analysis

Correlation analyses between environmental characteristics of the natural habitats of *D. paniculata* and soil analyses results demonstrated a positive correlation between slope and rock rate, which indicates that a rapid slope of natural habitats for *D. paniculata* should be associated with a higher rock rate. Thus, these results suggest that *D. paniculata* should grow best in a region with a high rock rate. Forest floor showed a negative correlation with evenness and a positive correlation with dominance. Thus, these results suggest that a deeper forest floor in the natural habitats of *D. paniculata* should be associated with a relatively less equal number of individuals for each species, and with various dominant species rather than a single dominant species. Species number and species diversity were positively correlated. In addition, evenness and dominance were negatively correlated. In general, dominance has an inverse relationship with species diversity, so that dominance is known to be represented by a few species with high values. The natural habitats for *D. paniculata* also displayed this tendency (Ellenberg 1956; Yoo et al. 2012; Yoon et al. 2014).

There was a positive correlation between electrical conductivity (EC) and exchangeable cation content (K^+). Cation exchange capacity (CEC) had a positive correlation with exchangeable cation contents (K^+, Ca^{2+}, and Mg^{2+}).

In addition, exchangeable cation content (Ca^{2+}) demonstrated a positive correlation with exchangeable cation contents (K^+ and Mg^{2+}, Table 6).

Principal component analysis was performed on the relationships between environmental factors and vegetation community. This analysis found no correlation between the community of cone-fruit platycarya-Korean stewartia (I) and environmental factors. In the Walter's dogwood-mulberry community (II), PCA analysis found a correlation between relatively high soil acidity (pH) and the presence of this community. In contrast, the presence of the queritron community (III) demonstrated a correlation with regions which were relatively far from the valley and had a relatively high slope and rock rate.

Comprehensive discussion

Fundamentally, plants have a narrow ecological niche. Rare plants tend to have an even narrower ecological niche due to their sensitivity to specific environments. With regards to rare plants, it is vital that we have information on the optimum environmental conditions for growth and vitality.

In the present study, Most of the natural habitats of *D. paniculata* were rock layers located at the edge of forest valleys. The vegetation was distributed to regions with a high density of mountainous stream vegetation including Korean stewartia, mulberry, Korean maple, and red-fruit spicebush, while species diversity was relatively low in the herbaceous layer due to many rocks. These results suggest that these species prefer locations where the upper layer crown density is more closed as deciduous trees become dominant due to the succession to various deciduous broad-leaved species, and where humidity remains high due to the close proximity to a valley (within 0.5 m-30 m). These findings are similar to the results of the study targeting Gunwi, Miryang, Yangsan, Ulsan, Gyeongju, and Busan study areas (Jung et al. 2016). Taken together, these findings suggest that the natural habitats of *D. paniculata* in South Korea are stony slopes of forests at 250-960 m in altitude, at the edges of a valley or rock layers, where deciduous trees are dominant and higher humidity is maintained.

Of all of the vegetation in the natural habitats, the community with *Platycarya strobilacea-Stewartia koreana* showed the least correlation with any of the environmental factors. However, the *Cornus walteri-Morus alba* community demonstrated a correlation with soil acidity (pH) and the queritron community showed a correlation with distance from the valley, rock rate and slope. While limited in its distribution, it seems that *D. paniculata* grows in various environments around forest valleys, rather than a specific environment.

The natural habitat of the Palgongsan Mountain in Daegu is known to have a high genetic diversity. There were eight *D. paniculata* individuals present in this location from 2014 to 2019. However, in 2018, grass mowing works made a space in the herbaceous layer, resulting in 12 individuals being identified in 2019, showing that it continuously maintained a certain number of individuals. Although the emergence of seedlings was unable to be identified in 2018, four individual seedlings were identified in 2019 as a result of artificial thinning. It seems that the light intensity was previously insufficient within the herbaceous layer, as up until 2018 the degree of deciduous tree coverage had increased. If regular artificial thinning or control of the appropriate stand density within the natural habitats is performed in the future, in parallel with a study on the environment of seedlings and mature individuals the success of such methods in promoting *D. paniculate* conservation in the field could be assessed..

In a previous study (Jung et al. 2016), *D. paniculata* was found in discontinuous patches in natural habitats instead of in successive colonies. Similarly, in the present study we also found discontinuous patches of *D. paniculata* in Ulsan and Gyeongju, but not in Cheongdo and Daegu. In the present surveys, all communities showed asexual reproduction that produced new branches through rhizomes, which is consistent with all of the preceding studies (Coates and Sokolowski 1992; Jung et al. 2016; Wagenius et al. 2010; Chang and Kim 2014). In particular, the natural habitat of Dareumsan Mountain in Busan could even be considered as a single propagule (clone) community, which had a limited community size and occupied a small area, leading to a vulnerable clone community without genetic diversity. These factors may result in inbreeding due to the decline of effective community size caused by the isolation of genetically similar individuals, resulting in a loss of genetic diversity. A preceding study determined that an effective community size for *D. paniculata* would be 42 individuals (Hamrick and Godt 1989; Chang and Kim 2014). To maintain this, genetic diversity would have to be increased. This could be achieved by transplanting individuals from the Palgongsan Mountain community, as they had the highest level of genetic diversity. Cross-fertilizations between individuals with different genotypes in different communities in the field (termed intercommunity-crossing) would further promote this.

In addition, most of the natural habitats were localized close to either hiking trails or forest roads, meaning that the habitats could be potential destroyed and the number of individuals reduced due to damage and overexploitation by mountain hikers. These factors could potentially be controlled through institutional interventions. For example, the natural habitat of Gyeongju is located close to the Rock-carved Buddhas of Sinseonsa in the Danseoksan Mountain. Current repair works to the site have caused both direct and indirect damages, so that it is required to have prearrangement with those in charge of the construction and set up a notice board.

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