JFES

Journal of Forest and Environmental Science

Ecological Niche Overlap and Competition between *Quercus mongolica* and *Quercus dentata* Under Soil Water Gradient

Yeon-ok Seo[1], Se-Hee Kim[2], Eui-Joo Kim[2], Yoon-Seo Kim[2], Kyeong-Mi Cho[2], Jae-Hoon Park[2], Ji-Won Park[2], JungMin Lee[2], Jin Hee Park[3], Byoung-Ki Choi[1] and Young-Han You[2],*

[1]*Warm Temperate and Subtropical Forest Research Center, Jeju 63582, Republic of Korea*
[2]*Department of Biological Sciences, Kongju National University, Gongju 32587, Republic of Korea*
[3]*Department of Animal and Plant Research, Nakdonggang National Institute of Biological Resources, Sangju 37242, Republic of Korea*

Abstract

Q. mongolica and *Q. dentata* are representative species of deciduous forest communities in Korea and are known to be relatively resistant to soil drying condition among Korean oaks. This study attempted to elucidate the degree of competition and ecological niche characteristics of the two species by comparing the ecological responses of the two species according to soil moisture. Competition between *Q. mongolica* and *Q. dentata* was shown to be more intense under the conditions where moisture content was low than under the conditions where moisture content was high. As for the ecological niche overlaps of the two species for soil moisture, the structural traits of plant such as stem diameter overlapped the most, the traits of biomass such as petiole weight overlapped the least, and photosynthetic organ-related traits such as leaf width and length overlapped intermediately. When looking at the competition for soil moisture between the two species, it can be seen that *Q. mongolica* won in nine traits (leaf width length, leaf lamina length, leaf lamina weight, leaf petiole weight, leaf area, leaves weight, shoot weight, root weight, and plant weight) and *Q. dentata* won in the remaining seven traits (leaf petiole length, leaves number, stem length, stem diameter, stem weight, shoot length, and root length). Competition between the two species for the moisture environment of the soil was shown to be intense under the conditions where moisture content was low. The degree of competition between *Q. dentata* and *Q. mongolica* for soil moisture is high under the conditions where soil moisture content is low, and it is judged that *Q. mongolica* is more competitive for soil moisture than *Q. dentata*.

Key Words: ecological, morphological, traits, growth response

Introduction

Mountainous areas in the Korean Peninsula account for 42% of the national land area. As of 2020, the forest area in Korea is about 6,000,000 ha comprising the area of coniferous forests, which is about 2,320,000 ha (37% of the total forest area), the area of mixed forests, which is about 1,660,000 ha (about 27% of the total forest area), and the area of broad-leaved forests, which is about 2,000,000 ha (32% of the total forest area). It is known that coniferous forests occupy the largest area thus far, but it is found that the area is gradually decreasing, and the area of broad-leaved forests is gradually increasing (Korea Forest Service 2020).

Representative broad-leaved trees distributed throughout Korea comprise six species; *Q. acutissima*, *Q. variabilis*, *Q. mongolica*, *Q. aliena*, *Q. serrata*, and *Q. dentata* of the deciduous oaks (Lee 2003; Chung and Lee 2021). Among them, *Q. mongolica* is a representative dominant species in temperate deciduous forests (Chung and Lee 1965; Lee et al 2016; Kim et al 2018). It inhabits areas with altitudes of about 150 to 1400 m above sea level and annual precipitation of about 1100 to 1,800 mm and is known to have the widest distribution area among the six species (You et al. 2019; Lee et al. 2020). In particular, it inhabits moist slopes of mountainous area in the central and northern parts in Korea with altitudes of at least 900 m above sea level (Kim and Gil 2000; Song et al. 2003) and is reported to form a representative forest type in Korea (Jang 2007). *Q. dentata*, which is another species of the genus *Quercus*, inhabits areas with altitudes of about 600 m above sea level and an annual precipitation of about 1400 mm, and is known to have the narrowest distribution area among the six species (You et al. 2019; Lee et al. 2020). In addition, it has been reported to mainly inhabit in the lowlands and dry limestone areas of mountainous area in Korea and form broad-leaved forests in plains and coastal stationary sand dunes in Japan, an East Asian region (Chung and Lee 1965; Kim et al. 1990; Kim et al. 1991; Menitsky 2005). As such, *Q. mongolica* and *Q. dentata* are the main dominant species in broadleaf forests in the central and northern parts and lowlands of the Korean Peninsula, and the results of their material production (formation of crown layers and forest floors, seed production, etc.) are directly and indirectly used for the inhabitation of many living organisms and play ecologically important roles (Song et al. 1996; Kim and Gil 2000).

Organisms living in nature are often assumed to be randomly distributed within their habitats, but in reality, they may exhibit a regular distribution or a central distribution type due to abiotic environmental factors. Therefore, in order to know the characteristics of a certain population, it is necessary to understand the type of spatial distribution as well as the population density (Yeochon Association for Ecological Research 2005). Among the abiotic environmental factors, soil moisture is an essential element for the survival of plants. The adaptation of most plants to the environment is closely related to the temporal and spatial distribution of moisture, and the growth types are determined by their adaptation to moisture (Barbour et al. 2015). According to previous studies, it can be seen that the distribution of plants in nature is closely related to moisture (Kim 2010), and the distribution of oak species such as *Q. mongolica* and *Q. dentata* mentioned above is also related to the soil moisture content in their natural habitats. (Lee and Lee 2003).

As such, when evaluating the influence of environmental factors on a species in actual nature, the concept of ecological niche is mainly used. Ecological niche refers to the spatial location and functional role of an organism in a community (Grinnell 1917). Within an ecosystem, each species has a unique ecological niche, which can be quantified through mathematical methods. To know the ecological niche of a species, the ecological niche breadth and the ecological niche overlap are investigated. Ecological niche breadth refers to the range of tolerance of an organism to environmental factors in its habitat and means the breadth between the lowest tolerance limit and the highest tolerance limit (Pianka 1983). Ecological niche breadth is generally calculated using the method created by Levin (1968). When the ecological niche breadths as such overlap within or between species, the state is called ecological niche overlap, and ecological niche overlap occurs when the use of environmental factors or resources is the same or similar (Yeochon Association for Ecological Research 2005). The ecological niche breadth is measured through the responses of each individual to know the living characteristics of a certain community or species, and the ecological niche overlap is calculated by calculating the parts where the ecological niche breadths overlap to know the degree of interspecies competition (Schoener 1970). The ecological niche overlap is expressed as two types of proportional similarity. When two ecological niches are the same, the ecological niches overlap completely and the proportional similarity becomes 1, and when the ecological niches are completely different, the proportional similarity becomes 0 (Yeochon Association for Ecological Research 2005). In an ecosystem, when the ecological niche overlaps, competition for resources between species is avoided, but in some cases, one species is culled due to the intensification of resource competition (Kim 1995). In the latter case, the ecological niche overlap as such can be used as a measure to assess the degree of

competition between species for resources (Abrams 1980; Park 2003).

To date, studies have been conducted on the distribution patterns of *Q. mongolica* and *Q. dentata* communities in Korea (Hong 2020), and growth and ecological responses to environmental factors of the two species, respectively (Lee and You 2009; Jeong 2019; Kim et al. 2020), but research on ecological niche overlap that can identify the competitive relationship between two species have not been conducted.

Therefore, this study was conducted to identify the competitive relationship between *Q. mongolica* and *Q. dentata*, which are representative tree species in broad-leaved forests in Korea, for moisture by analyzing the ecological niche breadths and ecological niche overlap of the two species through their ecological responses according to soil moisture contents in order to provide basic data on major broad-leaved tree species in Korea.

Materials and Methods

Gradient of environmental factors

The water gradients were divided into a total of four gradients based on 800 mL (M4), which is the carrying water capacity of the pot used in the experiment, to comprise 700 mL (M3), 600 mL (M2), and 400 mL (M1). Water was supplied basically at intervals of 4 days, and in summer, when evaporation was rapid, after checking the soil condition, water was supplied at intervals of 2-3 days. The soil used in the experiment was sand (not exceeding 2 mm in diameter) similar to the habitat environment. In addition, the experiment was conducted with the same conditions of the amount of light (all sunlight incident on the greenhouse) and organic matter content (5%).

Seed selection and sowing

The *Q. mongolica* seeds used in the experiment were collected in October from Gwanaksan near Seoul National University, and *Q. dentata* seeds were collected in October from Joryeongsan Mountain in Goesan-gun, Chungcheongnam-do. Thereafter, the seeds were refrigerated at 4°C and sown in March of the following year, respectively. In order to minimize the influence between individuals, seeds of similar sizes that were free from damage by pests and fungi

were selected and sown. Pots were of a diameter of 24 cm and a height of 23.5 cm, and after sowing in March, the tree species were grown in a glass greenhouse at the Department of Life Sciences of Kongju National University for 8 months and were harvested thereafter.

Measurement of growth response

The measured ecological and morphological traits were a total of 16 items comprising the leaves number (ea), leaf width length (cm), leaf lamina length (cm), leaf petiole length (cm), leaf area (cm^2), stem length (cm), and stem diameter (mm), shoot length (cm), root length (cm), leaf lamina weight (g), leaf petiole weight (g), leaves weight (g), shoot weight (g), stem weight (g), root weight (g), and plant weight (g) (Table 1). According to previous studies, the calculations of ecological niche overlaps can be selected and compared according to the overlap of ecological niches to be obtained, such as productivity, growth rate, and shape (Kim 1995). Therefore, in this study, the ecological niche breadths of the 16 traits according to changes in moisture contents were divided according to their characteristics into a total of three groups, which are photosynthetic organs (leaves number, leaf lamina length, leaf width length, leaf

Table 1. Correlation matrix of 16 variables with the first and two principal component scores of principle component analysis (PCA)

	Factor1	Factor2
Leaf width length	0.85*	0.36
Leaf lamina length	0.90*	0.17
Leaf petiole length	0.37	0.50*
Leaf lamina weight	0.86*	0.44
Leaf petiole weight	0.52*	0.53*
Leaf area	0.89*	0.38
Leaves number	0.28	0.83*
Leaves weight	0.95*	0.10
Stem length	0.22	0.48
Stem diameter	0.72*	0.52*
Stem weight	0.47	0.84*
Shoot length	0.29	0.71*
Shoot weight	0.86*	0.48
Root length	0.62*	0.26
Root weight	0.95*	0.11
Plant weight	0.98*	0.07
Variance explained (%)	51.98	23.43

*Statistically significant factors with values greater than 0.5.

petiole length, leaf area), plant architecture (root length, shoot length, stem diameter, stem length), and biomass (plant weight, root weight, shoot weight, leaves weight, stem weight, leaf lamina weight, leaf petiole weight) (Kim 1995) (Table 1).

Photosynthetic organ

The photosynthetic organs were measured with a total of five measurement items comprising the leaves number (ea), leaf width length (cm), leaf lamina length (cm), leaf petiole length (cm), and leaf area (cm^2) (Table 1). When harvesting the seedlings, the total number of leaves of each individual was counted, three leaves at the top of each individual were collected, and after removing the petiole from each leaf, the leaf width length, leaf lamina length, and leaf area were measured using a leaf area meter (SI700, Skye). The leaf petiole length was measured using Vernier calipers (CD-15CPX, Mitutoyo Co.) (Fig. 1).

Plant architecture

Plant architecture was measured with a total of four measurement items comprising stem length (cm), stem diameter (cm), shoot length (cm), and root length (cm) (Table 1). The stem length and stem diameter were meas-

ured using Vernier calipers (CD-15CPX, Mitutoyo Co.), and the shoot length and root length were measured using a 50cm ruler. In this case, the stem diameter was measured after cutting based on the boundary between the shoot and the root that is, the remaining cotyledons or traces of attached cotyledons, and the stem length was measured by measuring the length between two nodes. In addition, the shoot was measured by measuring the length from the boundary to the apex of the stem, and the root was measured by measuring the length from the boundary to the distal end of the root (Fig. 1).

Biomass

The biomass was measured with a total of seven measurement items comprising the leaf lamina weight (g), petiole weight (g), leaves weight (g), shoot weight (g), stem weight (g), root weight (g), and plant weight (g) (Table 1). When harvesting the seedlings, the soil was completely removed by washing with water, and the dry weight of the seedlings was measured using an electronic scale (UX400H) after drying the seedlings at 70°C for 48 hours. In this case, the shoot weight (leaves weight+stem weight+branch weight) and the plant weight (shoot weight+root weight) were calculated using the measured values (Fig. 1).

Calculation of ecological niche breadth and ecological niche overlap

The ecological niche breadth was calculated by applying the average value of individual response values to the 16 traits in each water gradient to the equation of Levins (1968).
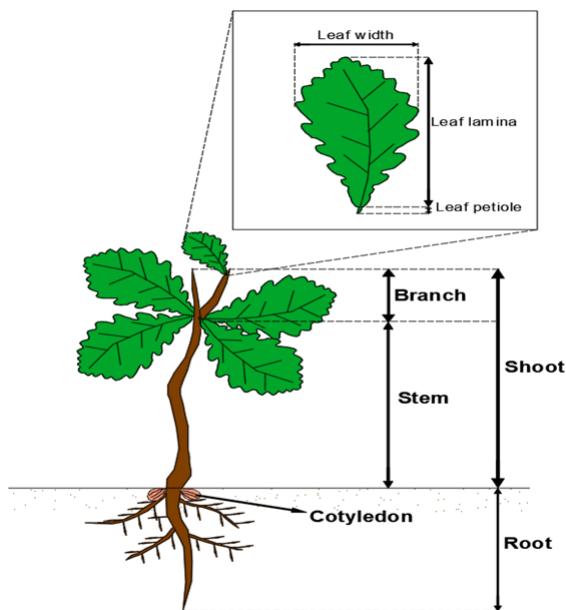
B=1/∑(Pi2) S
B=niche breadth (Levins' B)
Pi=relative response of a given species to the whole
    gradients that is realized in gradient i
S=total number of gradients

For the ecological niche overlaps of the two species, proportional similarities were calculated according to the method of Schoener (1970) using the average value of each trait by environmental gradient.

Fig. 1. Schematic diagram of seedling for ecological and morphological traits of *Quercus* seedling.

$$PS = 1 - 1/2 \sum |Pij - Pih|$$

PS = proportional similarity (niche overlap)

Pij = relative response of species j in the i th gradient

Pih = relative response of species h in the i th gradient

The values of ecological niche breadth and ecological niche overlap exceeding 0.9 were interpreted as indicating wide breadths and the values not exceeding 0.9 were interpreted as meaning narrow breadths (Lee and You 2009; Jeong 2019). In addition, the value of the ecological niche breadth (NB) minus the value of the ecological niche overlap (NO) of each trait was calculated to explain the degree of competition between the two species. The larger the difference (NB-NO) between these two values, the greater the competition.

Statistical processing

To understand the overall degree of competition between the two species according to the moisture gradient, principal component analysis (PCA) was conducted using the individual response values of each gradient. The principal component analysis was conducted using the correlation values of the measured variables. The above statistical analysis was conducted using Statistica 7 (Statsoft INC 2004).
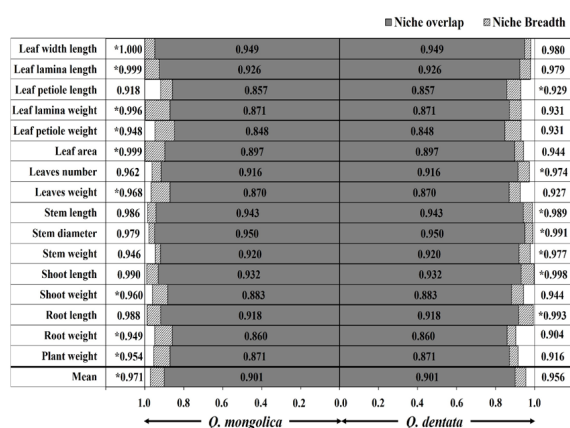
Results

Comparison of ecological niche breadths by tree species according to trait

Ecological niche breadths were measured for the 16 traits according to soil moisture gradients in *Q. mongolica* and *Q. dentata*. As a result, ecological niche breadths were shown to be wide since they were at least 0.90 in the 16 traits measured in both species. This finding was similar to that of the previous studies indicating that both species had wide ecological niche breadths for moisture (Lee and You 2009; Jeong 2019). Given the foregoing, it is judged that in cases where the ecological niches of the two species for moisture in the same environmental condition overlap slightly, both species will adapt well to changes in soil moisture, respectively. The ecological niche breadths of the two species, *Q. dentata* and *Q. mongolica* were 0.956±0.031 and 0.971±0.024, respectively. Therefore, the niche breadth of the latter species was slightly wider (Fig. 2). The ecological niche breadths of the 16 traits were divided into groups according to their characteristics and according to the results, the niche breadths in *Q. mongolica* were wide in traits related to plant architecture and narrow in biomass-related traits as the values were plant architecture (0.986) ＞ photosynthetic organ (0.976) ＞ biomass (0.960) (Fig. 3). The niche breadths in *Q. dentata* were also wide in traits related to plant architecture and narrow in biomass-related traits as the values were plant architecture (0.993) ＞ photosynthetic organ (0.961) ＞ biomass (0.933) (Fig. 3).

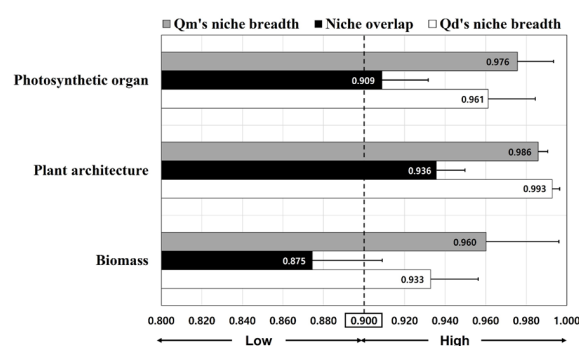|			Niche overlap	Niche Breadth	
Leaf width length	*1.000	0.949	0.949		0.980
Leaf lamina length	*0.999	0.926	0.926		0.979
Leaf petiole length	0.918	0.857	0.857		*0.929
Leaf lamina weight	*0.996	0.871	0.871		0.931
Leaf petiole weight	*0.948	0.848	0.848		0.931
Leaf area	*0.999	0.897	0.897		0.944
Leaves number	0.962	0.916	0.916		*0.974
Leaves weight	*0.968	0.870	0.870		0.927
Stem length	0.986	0.943	0.943		*0.989
Stem diameter	0.979	0.950	0.950		*0.991
Stem weight	0.946	0.920	0.920		*0.977
Shoot length	0.990	0.932	0.932		*0.998
Shoot weight	*0.960	0.883	0.883		0.944
Root length	0.988	0.918	0.918		*0.993
Root weight	*0.949	0.860	0.860		0.904
Plant weight	*0.954	0.871	0.871		0.916
Mean	*0.971	0.901	0.901		0.956

Fig. 2. Comparison of ecological niche breadth and ecological niche overlap for 16 ecological and morphological traits according to soil moisture changes in *Q. mongolica* (Qm) and *Q. dentata* (Qd) (*; larger values when comparing niche breadth between two species).

Fig. 3. Comparison of ecological niche breadth and ecological niche overlap by grouping 16 ecological and morphological traits of soil moisture changes in *Q. mongolica* (Qm) and *Q. dentata* (Qd).

Comparison of ecological niche overlaps for soil moisture between the two species

The ecological niche overlaps of *Q. mongolica* and *Q. dentata* were calculated and the result was found to be high as 0.90 ± 0.035. The ecological niche overlaps of 16 traits can be divided into those not exceeding 0.9 and those exceeding 0.9 and explained as follows. The overlaps were shown to be relatively wide in eight traits (0.916-0.950) comprising the leaves number (0.916), root length (0.918), stem weight (0.920), leaf lamina length (0.926), stem length (0.943), shoot length (0.932), leaf width length (0.949), stem diameter (0.950), and relatively narrow in eight traits (0.857-0.897) comprising the petiole weight (0.848), petiole length (0.857), root weight (0.860), leaves weight (0.870), plant weight (0.871), leaf lamina weight (0.871), shoot weight (0.883), and leaf area (0.897). Among the above 16 traits, stem diameter showed the widest ecological niche overlap at 0.950 and petiole weight showed the narrowest ecological niche overlap at 0.848 (Fig. 2). In the results of dividing the 16 traits into groups according to their characteristics, the ecological niche overlaps were shown to be wide in the traits related to plant architecture, intermediate in the traits related to photosynthetic organs, and narrow in the traits related to biomass as the values were plant architecture (0.936) > photosynthetic organ (0.909) > biomass (0.875).

Comparison of the degree of competition for soil moisture between the two species

To identify the degree of competition for soil moisture between the two species, the ecological niche overlap of each trait was subtracted from the ecological niche breadth of each trait (NB-NO) and according to the results, *Q. mongolica* was superior to *Q. dentata* in nine traits (leaf width length, leaf lamina length, leaf lamina weight, leaf petiole weight, leaf area, leaves weight, shoot weight, root weight, plant weight) out of 16 traits for competition for soil moisture, and in particular, the trait of leaf lamina weight (0.125) was shown to be the most competitive in *Q. mongolica* compared to *Q. dentata*. *Quercus dentata* was more competitive than *Q. mongolica* for competition for moisture in seven traits (leaf petiole length, leaves number, stem length, stem diameter, stem weight, shoot length, root

length), and was the most superior in stem weight (0.032) (Fig. 2). In addition, the ecological niche breadths of the two species were compared for all traits to find out differences with a view to identifying the most superior trait in each species in the event of competition. According to the results, in *Q. mongolica*, among the 16 traits, the leaf lamina weight was found to be the most superior trait as the ecological niche breadth difference between the two species in leaf lamina weight was the largest at 0.065. In *Q. dentata*, the stem weight was found to be the most superior trait as the ecological niche breadth difference between the two species in stem weight was the largest at 0.032 (Fig. 2). Also, with regard to the degree of competition between the two species (difference between ecological niche overlap and ecological niche breadth), *Q. dentata* (0.04) beat *Q. mongolica* (0.029) in stem diameter (0.950) that had the widest ecological niche overlap among 16 traits and *Q. mongolica* (0.1) beat *Q. dentata* (0.083) in petiole weight (0.848) that had the narrowest ecological niche overlap (Fig. 2). With regard to the degree of competition (NB-NO) in each group, *Q. mongolica* (0.083/0.067) beat *Q. dentata* (0.058/0.052) in photosynthetic organ or biomass-related traits, respectively, and in particular, *Q. mongolica* won big in the biomass-related traits. However, in the traits related to plant architecture, *Q. dentata* (0.057) slightly beat *Q. mongolica* (0.050).

Analysis of the correlations between soil moisture gradient and traits

According to the results of principal component analysis of the 16 traits of *Q. mongolica* and *Q. dentata* according to water gradient, in the one-dimensional spatial arrangement based on the axis of factor 1, the two species were arranged closely in general so that little differences were shown, but in the space defined as the fourth quadrants by factor 1 and factor 2, *Q. dentata* was arranged from the upper left to the upper right of the axis, and *Q. mongolica* was arranged relatively widely from the upper right to the lower left of the axis so that the arrangements of the two species were clearly distinguished (Fig. 4). *Q. mongolica* and *Q. dentata* have been reported as submersion-sensitive plants whose growth is reduced in a humid environment (Han et al. 2009), and both species are woody trees tolerant of drought and are known to prefer environments with low moisture content
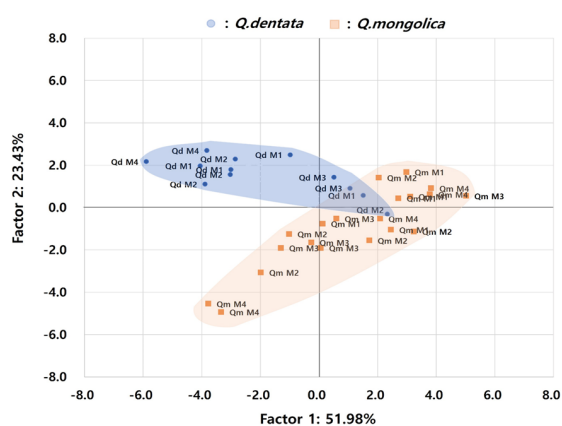
Fig. 4. Principal component analysis (PCA) of 16 characteristics of 32 individuals of *Q. mongolica* (Qm) and *Q. dentata* (Qd) along with soil moisture gradients (M1-M4).

such as sandy soils and limestone (Menitsky 2005). In this study, *Q. mongolica* and *Q. dentata* were arranged closely to low-moisture conditions (M1, M2) rather than the medium or high-moisture conditions (M3, M4) (Fig. 4). This is similar to the tendency of the two species that prefer low-moisture environments. Consequently, the foregoing can be interpreted as indicating that competition between the two species is intense when the soil moisture content is low. In addition, among the measured traits affecting the distribution of the two species in two dimensions (Table 1), petiole weight and stem diameter showed high correlations with the two axes and the remaining 15 traits except for stem length were correlated with one of axis 1 and axis 2 ($r > 0.5$). In particular, the stem length, which showed a low correlation compared to other traits, was similar to the finding of the previous study indicating that six species of oak trees showed low correlations in ecological responses to submergence of water (Han et al. 2009). In addition, 11 traits were highly correlated with axis 1 and six of which were related to biomass. Given the foregoing, it can be said that rather than a small number of traits, multiple traits are simultaneously involved in the ecological responses of the two species to moisture. In this case, it is thought that stem length is less correlated with soil moisture compared to other traits and traits related biomass are highly correlated with soil moisture.

Discussion

In an ecosystem, soil moisture content is closely related to the temporal and spatial distribution of precipitation, and factors affecting soil moisture distribution in forest vegetation include topographical and seasonal factors (Barbour et al. 2015). In the case of Korea, climates of four seasons appear, and annual precipitation is about 1,300 mm, which is relatively large, but it is known that most of the precipitation is concentrated in summer (June to September), and a phenomenon of severe dryness appears in winter (November to February) and early plant growth period (March to May) (Lee and Lee 2003). Accordingly, Byun and Han (1994) explained the seasonal droughts in the Korean Peninsula, and indicated that among them, the winter drought was the longest, lasting from the end of November to the end of March. Although precipitation is remarkably low during the winter drought period as such, it is known that the soil moisture potential is maintained at a constant level thanks to the low temperature and snow cover along with the decrease in evapotranspiration in winter (Bell and Bliss 1979; Ryoo and Kim 2000). In particular, winter snow is known to supply water usable by plants to soil as it melts, protect seeds and plants from the cold by providing heat insulation and windbreaking effects, and have ecologically important influence (Billings and Bliss 1959; Barbour et al. 2015). In North America, it is known that when the moisture content of Fagaceae fruits is reduced to 30% or less, the survival rate decreases sharply, and that the fruits of species belonging to Red oak must be stored for 1 to 3 months at 0-5°C before germination (Young and Young 1992). Therefore, the maintenance of moisture content in Fagaceae seeds and the pre-germination process in winter is expected to affect the settlement of Fagaceae seedlings.

Fagaceae fruits are divided according to their characteristics into white oak fruits, which mature for one year, and red oak fruits, which mature for two years (Young and Young 1992). Matsuda and Mcbride (1989) divided species belonging to white oak into fast germination types (Germinating in October-November) and species belonging to red oak into slow germination types (Germinating in January-February). In Korea too, a study on the germination of six oak species was conducted by Jeong et al. (2021),

and according to this study, the root germination period of *Q. mongolica*, the target species of this study, was found to be from September to October, and that of *Q. dentata* was shown to be January the next year. Looking at this with the classification method of Matsuda and Mcbride (1989), *Q. mongolica* was similar to the fast germination type and *Q. dentata* was similar to the slow germination type. Due to the difference in germination periods as such, if both types of fruits germinate in the same space, it can be interpreted to be advantageous for *Q. mongolica* to use moisture.

Q. mongolica and *Q. dentata* were known by Kim and Kim (1994a, 1994b) as dry habitat species resistant to dryness, and although their forms of adaptation to a dry environment were similar, Park et al. (1996) reported that the moisture absorption coefficient of the soil was higher in the *Q. dentata* stands compared to the *Q. mongolica* stands. Higher moisture absorption coefficients refer to soils with more clay and humus and larger surface areas, and lower moisture absorption coefficients refer to soils with more coarse sand components and smaller surface areas (Kwon and Park 2007). Moisture absorption coefficients can be interpreted as an indicator that indirectly represents the water retention capacity of soils. In addition, according to Jeong et al. (2009) reported that *Q. mongolica* seedlings showed a tendency to have a larger biomass of the shoot, root, and plant under conditions with low soil moisture than under conditions with high soil moisture and that in this case, the biomass of the root was larger compared to that of the shoot, and according to Kim et al. (2020), *Q. dentata* seedlings tended to have large biomass of the shoot, root, and plant under high soil moisture conditions and in such case, the biomass of the root was larger compared to that of the shoot. Through previous studies, it can be interpreted that of the two species, *Q. mongolica* showed a good growth tendency in soil with a high content of sand, which retains relatively little moisture, and *Q. dentata* showed a good growth tendency in soil with a high content of clay, which retains relatively much moisture. However, since these results were obtained when only soil moisture was set as an independent variable excluding other environmental factors, additional studies are considered necessary to determine the effect of the interaction of various environments on competition for soil moisture between two species in actual nature.

According to the results of comparing the ecological niche overlaps by group, it was shown that the traits related to plant architecture had relatively intense competition, and the traits related to biomass had relatively weak competition. Each ecological niche overlap was subtracted from each ecological niche breadth (NB-NO) to identify the degree of competition between the two species and according to the *Q. mongolica* won in 9 out of 16 traits, and *Q. dentata* in 7 out of 16 traits. In addition, NB-NO was compared by group and according to the results, *Q. mongolica* won in the photosynthetic organ-related traits and biomass-related traits, and *Q. dentata* was slightly superior in the plant architecture-related traits. Lastly, according to the results of the PCA arrangements of the two species, it is judged that competition between the two species will be intense in low-moisture environments because the arrangements of the two species are close in low-moisture conditions and according to the results of previous studies, the foregoing is considered to be related to the fact that the forms of adaptation of both species to dry environments are similar. Consequently, when the degrees of competition between the two species for soil moisture were compared, *Q. mongolica* is expected to win the competition over *Q. dentata*. However, since the results of this study were obtained when only soil moisture was set as an independent variable, additional studies are considered necessary on the responses of the two species to moisture in relation to various actions in the actual ecosystem.

Acknowledgements

References

Abrams P. 1980. Some comments on measuring niche overlap. Ecology 61: 44-49.

Barbour MG, Burk JH, Pitts WD, Gilliam FS, Schwartz MW. 2015. Terrestrial Plant Ecology. 3rd ed. Mun HT, Jeong YS, You YH, translator. Hongreung Publishing Company, Seoul, 614 pp.

Bell KL, Bliss LC. 1979. Autecology of Kobresia bellardii: why winter snow accumulation limits local distribution. Ecol Monogr

49: 377-402.

Billings WD, Bliss LC. 1959. An alpine snowbank environment and its effects on vegetation, plant development, and productivity. Ecology 40: 388-397.

Byun HR, Han YH. 1994. On the existence of the seasonal drought in the Korean Peninsula. Asia Pac J Atmos Sci 30: 457-467.

Chung SH, Lee ST. 2021. Classification of forest cover types in the Baekdudaegan, South Korea. J For Environ Sci 37: 269-279.

Chung TH, Lee WC. 1965. A study of the Korean woody plant zone and favorable region for the growth and proper species. J Sunkyunkwan Univ 10: 329-366.

Grinnell J. 1917. The niche-relationships of the California Thrasher. The Auk 34: 427-433.

Han SJ, Kim HJ, You YH. 2009. Selection on tolerant oak species to water flooding for flood plain restoration. J Wetl Res 11: 1-7.

Jang GJ. 2007. Phytosociological studies on the *Quercus mongolica* forest in Korea. PhD thesis. Kangwon National University, Chuncheon, Korea. (in Korean)

Jeong HM, Kim HR, You YH. 2009. Growth difference among saplings of Quercus acutissima, *Q. variabilis* and *Q. mongolica* under the environmental gradients treatment. Korean J Environ Biol 27: 82-87.

Jeong HM, Kim HR, You YH. 2021. Impact of germination and initial growth of deciduous six oak species under climate change environment condition. Korean J Ecol Environ 54: 334-345.

Jung YH. 2019. Growth response and ecological niche breadth of Quercus dentata, according to environmental conditions under climate change. MS thesis. Kongju National University, Gongju, Korea. (in Korean)

Kim EJ, Jeong YH, Park JH, Lee EP, Lee SY, Lee SI, Hong YS, Jang RH, Ceung SH, Lee YK, You YH, Cho KT. 2020. Growth Response and Ecological Niche of Quercus dentata Thunb. Sapling under the Light, Moisture Content, Soil Texture and Nutrient Treatment. Korean J Ecol Environ 53: 102-108.

Kim HD. 2010. Studies on community dynamics of forest vegetation in Bukhansan National Park. PhD thesis. Changwon National University, Changwon, Korea. (in Korean)

Kim JE, Gil BS. 2000. The Mongolian Oak Forest in Korea. Wonkwang University Press, Iksan, 511 pp.

Kim JH. 1995. The Stepping-stones for Ecology in Korea. Yeocheon Kim Jun-ho Professor Retirement Commemoration Association Thesis Publication Committee, Seoul, pp 317-350.

Kim JH, Mun HT, Kwak YS. 1990. Community structure and soil properties of the Pinus densiflora forests in limestone areas. Korean J Ecol 13: 285-295.

Kim JH, Mun HT, Kwak YS. 1991. Community structure and soil properties of Chinese Cork oak (*Quercus variabilis*) forests in limestone area. Korean J Ecol 14: 159-169.

Kim JW, Kim JH. 1994a. Stomatal Control and Strategy Segregation to Drought Stress in Young Trees of Several Oak Species.

Korean J Ecol 17: 241-249.

Kim JW, Kim JH. 1994b. Comparison of Adjustments to Drought Stress Among Seedlings of Several Oak Species. J Plant Biol 37: 343-347.

Kim SG, Kwon B, Son Y, Yi MJ. 2018. Carbon storage in an age-sequence of temperate *Quercus mongolica* stands in central Korea. J For Environ Sci 34: 472-480.

Korea Forest Service. 2020. Forest Basic Statistics. https://kfss.forest.go.kr/stat/ptl/main/main.do. Accessed 18 Oct 2021.

Kwon DH, Park HD. 2007. Soil Geography. Hanulbooks, Paju, pp 56-60.

Lee CS, Lee AN. 2003. Ecological Importance of Water Budget and Synergistic Effects of Water Stress of Plants due to Air Pollution and Soil Acidification in Korea. Korean J Ecol 26: 143-150.

Lee H, An C, Han S, Lee W, Jang K. 2016. Component Analysis of Acorns of *Quercus mongolica* and *Quercus Variabilis*. J For Environ Sci 32: 103-112.

Lee HJ, You YH. 2009. Ecological Niche Breadth of *Q. mongolica* and Overlap with *Q. acutissima* and *Q. variabilis* along with Three Environment Gradients. Korean J Environ Biol 27: 191-197.

Lee SY, Kim EJ, Lee EP, Cho KT, Park JH, Lee YK, Chung SH, Hong YS, Park JH, Choi SS, Kim HR, You YH. 2020. Analysis of Climate and Topographical Factors of Economical Forests in Korea to Select the Restoration Safe Site of 5 Dominant Oak Species. Korean J Ecol Environ 53: 427-435.

Lee TB. 2003. Coloured Flora of Korea. Hyangmunsa, Seoul, pp 200-208.

Levins R. 1968. Evolution in Changing Environments: Some Theoretical Explorations. Princeton University Press, Princeton, NJ.

Matsuda K, Mcbride JR. 1989. Germination Characteristics of Selected California Oak Species. Am Midl Nat 122: 66-76.

Menitsky YL. 2005. Oaks of Asia. Science Publishers, Enfield, NH.

Noh HJ, Jeong HY. 2002. Easy-to-understand Statistical Analysis by STATISTICA. Hyungseul Publisher, Seoul, pp 535-556.

Park BH. 2003. Studies on the Niche of four herbal species along the Environmental Gradient. MS thesis. Seowon University, Cheongju, Korea. (in Korean)

Park IH, Lee DK, Lee KJ, Moon GS. 1996. Growth, biomass and net production of Quercus species (I) - with reference to natural stands of *Quercus variabilis*, *Q. acutissima*, *Q. dentata*, and *Q. mongolica* in Kwangju, Kyonggi-Do. J Korean For Soc 85: 76-83.

Pianka ER. 1983. Evolutionary Ecology. 3rd ed. Harper & Row, New York, NY.

Ryoo SB, Kim YA. 2000. Variation of Evapotranspiration over Forest Site at Kwangneung: from Fall to Early Winter. Asia Pac J Atmos Sci 36: 43-50.

Schoener TW. 1970. Nonsynchronous spatial overlap of lizards in

patchy habitats. Ecology 51: 408-418.

Song CY, Lee SW. 1996. Biomass and Net Primary Productivity in Natural Forests of *Quercus mongolica* and *Quercus variabilis*. J Korean For Soc 85: 443-452.

Song HK, Lee MJ, Yee S, Kim HJ, Ji YU, Kwon OW. 2003. Vegetation Structures and Ecological Niche of *Quercus mongolica* Forests. J Korean For Soc 92: 409-420.

Statsoft INC. 2004. STATISTICA (data analysis software system). Version 7.

Yeochon Association for Ecological Research. 2005. Modern Ecology Experiment. Kyomunsa, Seoul.

You YH, Lee SY, Lee EP, Kim JE, Kim EJ, Park JW, Roh JY, Lee JM, Kim MJ, Song SH, Kim YS, Cho KM. 2019. Development of High-value Use of Broadleaf Forests and Management Technology by Type: Distribution Status and Type Classification for Broadleaf Forest Operations. National Institute of Forest Science, Seoul, 171 pp. (in Korean).

Young JA, Young CG. 1992. Seeds of Woody Plants in North America. Dioscorides Press, Portland, OR, pp 289-294.