Spatial Distribution of Fine Roots in *Quercus mongolica* and *Quercus acutissima* Stands

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신갈나무와 상수리나무 숲에서 細根의 空間分布

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ABSTRACT

Vertical and horizontal distribution and seasonal changes of fine roots as well as inorganic nitrogen content in soil were determined in *Quercus mongolica* and *Quercus acutissima* stands in Mt. Taemosan, Seoul. The vertical distribution of fine root phytomass showed a power-functional decrease as descending soil depth. Fine root phytomass was 170 g DM /m^2 (46%) and 225 g DM /m^2 (47%) in top soil of 5 cm depth, and 370 g DM /m^2 and 480 g DM /m^2 from soil surface to 50 cm depth in *Q. mongolica* and *Q. acutissima* stands, respectively. Fine roots in relation to the distance from the nearest tree were evenly distributed horizontally in both stands. Fine roots phytomass in top soil of 5 cm depth reached a peak in June, and thereafter decreased gradually in both stands. Patterns of seasonal changes in fine root phytomass were closely related to inorganic nitrogen and moisture content.

Key words : Fine roots, Phytomass, Power-function, Vertical distribution, *Quercus mongolica, Quercus acutissima*

INTRODUCTION

The root system of forest trees is divided into coarse roots (diam.> 2mm) and fine roots (diam. ≤ 2mm) (Hermann 1977). In particular, the quantity of fine roots in the root systems represents a large and dynamic portion of the belowground biomass and a prime significance in regard to water and nutrient supply in temperate forests (Persson 1978, Smucker *et al.* 1991, Vogt *et al.* 1987).

The purpose of this study is to determine the spatial distribution and the seasonal changes of fine roots, in order to understand the importance of fine roots as maintaining stocks of soil organic matter in *Q. mongolica* and *Q. acutissima* stands.

STUDY SITES

This study was carried out in *Q. mongolica* and *Q. acutissima* stands which had developed on the west of Mt. Taemosan, Kangnam-ku, Seoul (Fig. 1). The sites have been preserved as a royal tomb, Huninnung, for a long time. Soil texture is sandy loam (sand 62~72%, silt 20~25%, clay 8~13%) and loamy sand (sand 75~85%, silt 15~20%, clay 5~10%), soil pH ranges from 4.5 to 5.0 and from 4.6 to 4.9, and tree age is approximately 30 and 35 years old in *Q. mongolica* and *Q. acutissima* stands, respectively. Understory of both stands, though the abundance was scant, mainly consisted of *Rhododendron mucronulatum, Styrax japonica, Artemisia keiskeana, Carex lanceolata, Pueraria thunbergiana*, etc.

METHODS

The soil cores for the root sample were extracted from the permanent quadrat (10 × 20 m) with a 5° south facing slope in each stand using a soil sleeve (4.5 cm diam.). For the examination of vertical and horizontal distribution of fine roots, cores were excavated to the depth of 50 cm into the ground at intervals of 5 cm of *Q. mongolica* and *Q. acutissima* stands in relation to the distance from the nearest tree. For the examination of seasonal

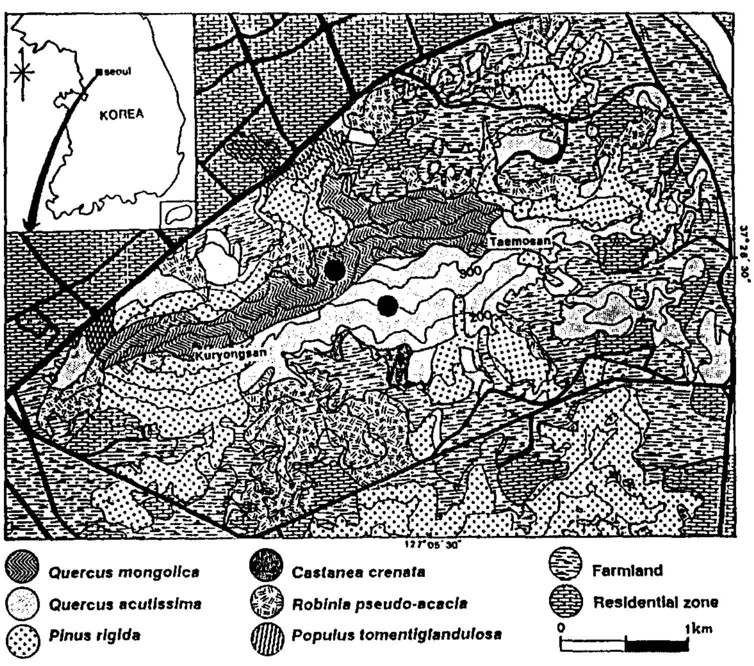

Fig. 1. Vegetation map showing the study sites (closed circles)

changes of fine root phytomass in the upper 5 cm layer, three cores were collected from each of six randomly chosen points on the permanent quadrat, i.e. 18 cores per month from each stand at monthly intervals from March to October 1989. Fine roots (diam. ≤ 2mm) were separated from soil by flotation and the residue was carefully checked for root fragments. Roots sorted from the aliquots were oven-dried at 70℃ for 48 hr. All roots were weighed after drying and converted to area basis (m^{-2}).

The inorganic nitrogen content of forest soil was measured using ion exchange resin (IER) bag method under field condition (Binkley and Matson 1983). Bag with approximately 100 cm^2 in area was placed at 5 cm depth of the soil in the stands on every month. Placement of the resin bag had 18 replicates.

RESULTS AND DISCUSSION

Vertical distribution of fine roots

In the vertical distribution of fine root phytomass for the two oak stands, the phytomass typically decreased with increasing soil depth (Fig. 2). Fine root phytomass of top soil of 5 cm depth was 170 g DM /m^2 (46%) and 225 g DM /m^2 (47%), that from soil surface to 20 cm depth was 270 g DM /m^2 (73%) and 313 g DM /m^2 (55%), and that from surface to 40 cm depth was 370 g DM /m^2 and 480 g DM /m^2 in *Q. mongolica* and *Q. acutissima* stands, respectively. Powers (1984) found that about a half of the fine roots in a mixed-conifer forest existed within the top 20 cm of soil, the result of which was deeper than our data. Many studies have shown that the majority of forest tree roots are distributed in the upper 50 cm of a soil profile with most of the absorbing roots in the top 20 cm (Hermann 1977, Santantonio and Hermann 1985, Kwak 1993). In addition, fine roots of *Q. acutissima* stands was more evenly distributed along the soil depth than that of *Q. mongolica* stands (Fig. 2).

Relationship between the fine root phytomass (FRP) and soil depth (D) appeared to be a power function equation as follows (Fig. 2)

$$FRP = 423.7 \times D^{-1.26}$$ for *Quercus mongolica*

$$FRP = 721.2 \times D^{-0.89}$$ for *Quercus acutissima*

Applying these equations, the fine root phytomass was calculated as much as 447 g DM /m^2 and 654 g DM /m^2 from the surface to 2 m depth, and 75 g DM /m^2 (17%) and 176 g DM /m^2 (27%) from 50 cm to 2 m depth in *Q. mongolica* and *Q. acutissima* stands, respectively.

Existence of a large proportion of fine roots within the top soil suggests that conditions of nutrient, moisture and aeration are most favorable in the upper part of the mineral soil. However, these fine roots in the top soil may be vulnerable by the stresses such as drought and coldness.

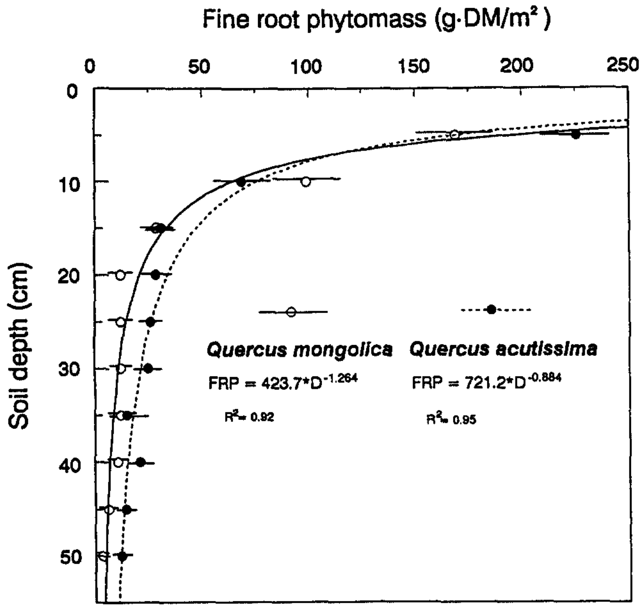

Fig. 2. Vertical distribution of fine roots from surface to 50 cm soil depth of *Quercus mongolica* and *Q. acutissima* stands, in July, 1989. Estimates are given as the mean phytomass ± a standard error

Horizontal distribution of fine roots

Fluctuation of fine root phytomass with distance from a given stump to next stump was slight with mean values of 360 g DM / m^2 in *Q. mongolica* stand and 470 g DM / m^2 in *Q. acutissima* stand. The largest amount of fine roots was found in 50 cm from the tree stump at both stands. No significant difference was found in the phytomass with distance from the nearest tree. The distribution of fine roots in forests seems to be fairly independent of the proximity of tree stems (Makay and Malcolm 1988, Kwak 1993). We may certainly infer that fine roots have the strategy of efficient uptake of water and nutrients from whole area of soils, forming an integrated network of expanding root systems.

Seasonal changes of fine root phytomass and inorganic nitrogen content

Fine root phytomass within 5 cm of top soil increased in June, thereafter, decreased gradually in both stands, which showed that fine root growth most flourished in June (Fig. 4A). Inorganic nitrogen content within 5 cm top soil exhibited similar monthly changes in both stands (Fig. 4B). Seasonal changes of fine root phytomass and of inorganic nitrogen content showed similar trends in both stands. Our results correspond with the hypothesis that fine roots grow vigorously in nitrogen rich soil (Vogt *et al.* 1987, Powell and Day 1991), but contradict the hypothesis that fine roots in nitrogen rich soil grow less than that in nitrogen poor soil (Wareing and Patrick 1975).

Seasonal changes of soil moisture content in the top soil (5 cm) were closely related to those of fine root phytomass and of inorganic nitrogen content in both stands (Fig. 4 and 5). McMichael and Quisenberry (1991) has shown that fine root phytomass altered as a result of decreasing soil moisture. They showed that the rooting density decreased as

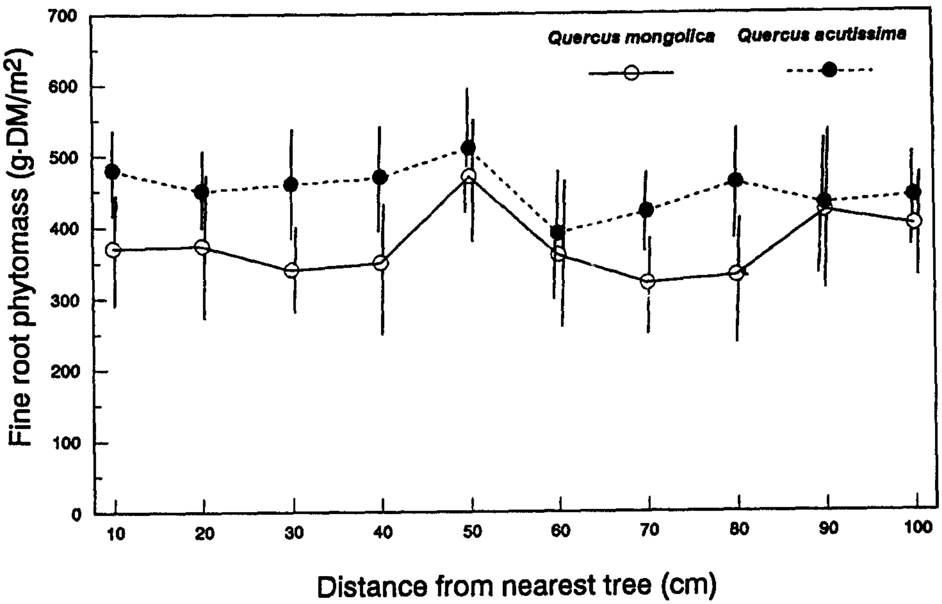

Fig. 3. Horizontal distribution of fine roots from surface to 50 cm soil depth in *Quercus mongolica* and *Q. acutissima* stands in relation to the distance from the nearest tree, in July, 1989. Estimates are given as the mean phytomass ± a standard error (g DM /m^2)

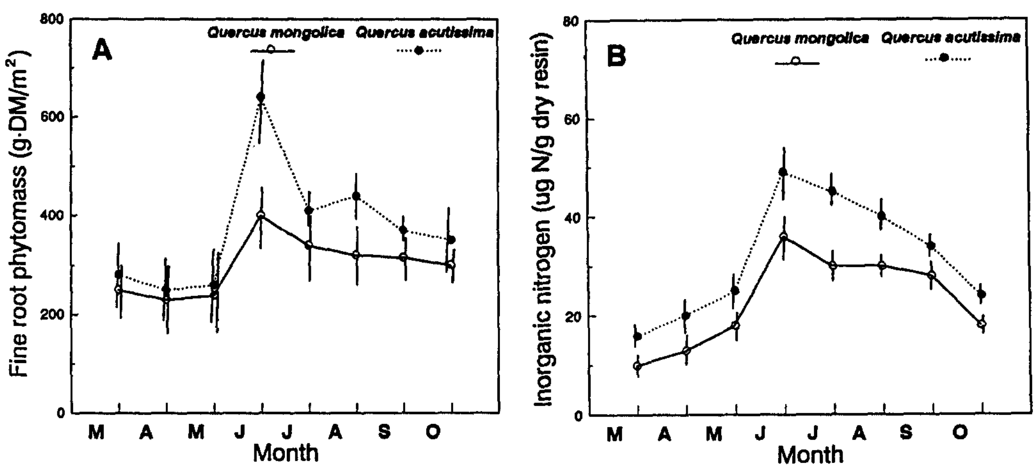

Fig. 4. Seasonal changes of fine root phytomass (A) and inorganic nitrogen content (B) in top soil of 5 cm layer in *Quercus mongolica* (open circle) and *Q. acutissima* (solid circle) stands.

rooting depth increased, especially in the upper soil layers. It is assumed that drying in the upper soil affects significantly on the growth and function of fine roots.

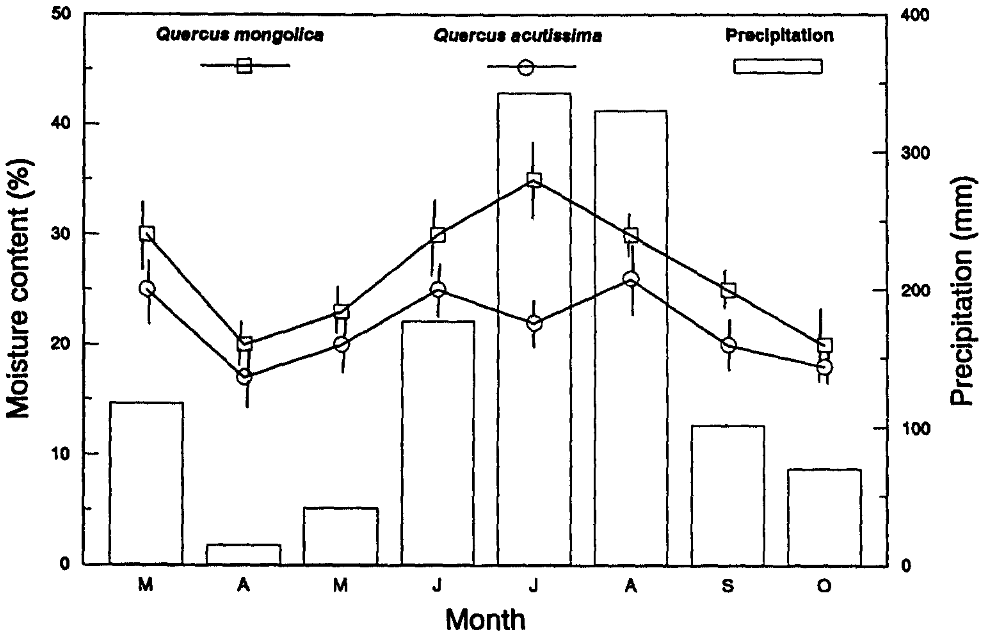

Fig. 5. Soil moisture content in the top 5 cm layer and precipitation of *Quercus mongolica* and *Q. acutissima* stands from March to October, 1989.

摘 要

서울 대모산에서 신갈나무와 상수리나무숲의 세근의 수직분포, 수평분포 및 세근량의 계절변화를 조사하였다. 세근량의 수직분포는 토양이 깊어짐에 따라 멱함수적으로 감소하였고, 신갈나무와 상수리나무숲에서 표토 5 cm 깊이에 각각 170 (46%)과 225 g DM /m^2 (47%), 표면으로부터 50 cm 깊이 사이에 각각 370 과 480 g DM /m^{2}이 분포하였다. 수간으로부터 거리에 따른 세근량은 수평적으로 균일하게 분포하였다. 두 숲의 5 cm 깊이 토양에서 세근량은 6월에 최고치를 보인 후 감소하였고, 이러한 경향은 토양속의 무기질소량과 함수량의 변화와 밀접한 관계가 있었다.

LITERATURES CITED

Binkley, D. and P. Matson. 1983. Ion exchage resin bag method for assessing forest soil nitrogen availability. Soil Sci. Soc. Am. J. 47:1050-1052.

Hermann, R.K. 1977. Growth and production of tree roots; a review. *In* J.K. Marshall (ed.). The belowground ecosystems: a synthesis of plant associated processes. Science Series No. 26, Colorado Univ., pp. 7-28.

Kwak, Y.S. 1993. Productivity of plant communities and grouping of calcicoles and calcifuges in Tanyang limestone area. Ph. D. thesis, Seoul National University. 142p.

Mckay, H.M. and D.C. Malcolm. 1988. A comparison of the fine root component of a pure and a mixed coniferous stand. Can. J. For. Res. 18:1416-1426.

McMichael, B.L. and J.E. Quisenberry. 1991. Genetic variation for root-shoot relationships among cotton germplasm. Environmental and Experimental Botany 31:461-470.

Persson, H. 1978. Root dynamics in a young scots pine stands in central Sweden. Oikos 30:508-519.

Powell, S.W. and F.P. Day, JR. 1991. Root production in four communities in the great dismal swamp. *American J. of Bot.* 78: 288-297.

Powers, R.F. 1984. Sources of variation in mineralizable soil nitrogen. *In* Nitrogen assessment workshop 1984, RFNRP Report No. 2, College of Forest Resources, University of Washington, Seattle, pp. 25-31.

Santantronio, D. and R.K. Hermann. 1985. Standing crop, production and turnover of fine roots on dry, moderate and wet soils of mature Douglas-fir in Western Oregon. Ann. Sci. For. 42:113-142.

Smucker, A.J.M, A. Nunez-Barrios and J.T. Richle. 1991. Root dynamics in drying soil environements. Belowground Ecology 2:4-5.

Vogt, K.A., D.A. Publicover, J. Bloomfield, J.M. Perez, D. J. Vogt and W.L. Silver. 1993. Belowground responses as indicators of environmental change. Environmental and Experimental Botany 33:189-205.

Vogt, K.A., D.J. Vogt, E.E. Moore, D.A. Fatuga, M.R. Redlin and R.E. Edmonds. 1987. Conifer and angiosperm fine root biomass in relation to stand age and site productivity in Douglas-fir forests. J. Ecol. 75:857-876.

Wareing, P.F. and J. Patrick. 1975. Source-sink relations and the partition of assimilates in plant. *In* J.P. Copper (ed.). Photosynthesis and productivity in different environments. Cambridge, England. pp. 481-500

(*Received* 4, *March* 1994)