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Weight Loss and Nutrients Dynamics during the Decomposition of Fine Roots

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ABSTRACT : Weight loss, N and P dynamics during decomposition of fine roots (<2mm) of alder(*Alnus japonica*), oak (*Quercus acutissima*) and pitch pine(*Pinus rigida*) were studied for 33 months in Kongju, Korea. After 33 months, remaining weight of fine roots of alder, oak and pitch pine was 29.2%, 47.7% and 53.4% of the initial weight, respectively. The decomposition rate constant (*k*) for alder, oak and pitch pine was 0.448 yr^{-1}, 0.269 yr^{-1}, 0.228 yr^{-1}, respectively. Initial concentration of N and P in fine roots was 10.32mg/g and 0.69mg/g for alder, 6.20mg/g and 0.37mg/g for oak and 7.26mg/g and 0.44mg/g for pitch pine, respectively. Initial concentration of N and P in alder were higher than those in oak and pitch pine. After 33 months, remaining N and P in fine roots was 39.5% and 31.8% for alder, 59.4% and 57.8% for oak, 63.0% and 83.4% for pitch pine, respectively. Decomposition rate and the rate of N released from decomposing fine roots was positively correlated with the initial N concentration of the fine roots.

Key words: *Alnus japonica*, Decomposition rate, Fine roots, Nutrients dynamics, *Pinus rigida, Quercus acutissima*

INTRODUCTION

Fine roots are important structural and functional components of forest ecosystems (Persson 1980, Chen *et al.* 2002). Much of the carbon assimilated by plants is allocated to fine roots production, resulting in a large flux of organic matter and nutrients into the soil system (Vogt *et al.* 1986, Hendrick and Pregitzer 1993, Kurz *et al.* 1996, Cairns *et al.* 1997). Carbon and nutrients returned to the soil from fine roots decomposition equals or surpasses that returned through leaf litter in many forests (Hendrick and Pregitzer 1992). Although tree root systems store large amounts of organic matter and nutrients in forest ecosystems, information on the decay rates of fine roots and nutrients dynamics during fine-root decomposition is not much, especially compared with the wealth of data on aboveground litter decomposition (Gosz *et al.* 1973, Fogel and Cromack 1977, Harmom *et al.* 1990). Thus it needs more fine-roots decomposition studies to understand the nutrient cycling of forest ecosystems.

The major biotic factors which affect root decomposition include nitrogen and lignin content in roots as well as decomposer community present in the soil (Berg 1984, Hobbie 1996, Chen *et al.* 2001). Among the biotic factors, the initial lignin/N ratio in roots seems to be the best predictor of root decomposition (McClaugherty *et al.* 1984, Aber *et al.* 1990, Hobbie 1996). A variety of abiotic factors also affect root decomposition. Among the abiotic factors, soil temperature and moisture content of roots are considered as the main factors affecting root decomposition (Vogt *et al.* 1986, Hobbie 1996, Chen *et al.* 2000).

This paper presents the 33 months data of fine-root decomposition. The purpose of this study is to investigate the decay rates of fine roots of some tree species and nutrients dynamics during decomposition in a temperate forest.

MATERIALS AND METHODS

Study area

This study was conducted in an oak forest which is distributed 100 to 230m altitude on east facing slope with 20° inclination in Kongju, Korea. Oak forest in this study area has preserved well because the general public are not permitted to enter in this area since around 1920. *Quercus acutissima* is the dominant tree species and some *Q. variabilis* occurred in tree layer. Height of tree layer was about 20m, and average DBH was 21.2cm. In shrub layer, *Lindera obtusiloba, Stephanandra incisa, Rhus trichocarpa, Rosa multiflora, Prunus sargentii, Lindera erythrocarpa, Viburnum burejaeticum* are occurred.

Monthly precipitation, mean temperature and mean soil temperature during the study period was depicted in Fig. 1 and Fig. 2. Climatic data was obtained from Buyo meteorological station 32km distance from the study area. Annual precipitation in 1999 and 2000 was 1,530 and 1,521mm, respectively. However,

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annual precipitation in 2001 was much lower than previous years with the value of 753mm. Soil temperature was measured at 1 hr intervals with Thermo Recorder (TR-72S) at 5cm and 10cm soil depth.

Root preparation

Fine roots of alder, oak and pitch pine were obtained from each stand in Kongju in October 1998. Pitch pine is coniferous and alder and oak are deciduous. We followed lateral roots originating from woody roots of each species, because it was not easy to distinguish fine roots from other species. The fine root system was defined as roots <2 mm in diameter and their associated root tips. Collected fine roots were cleaned by rinsing with tap water in laboratory, and dried at 60℃ to a constant weight.

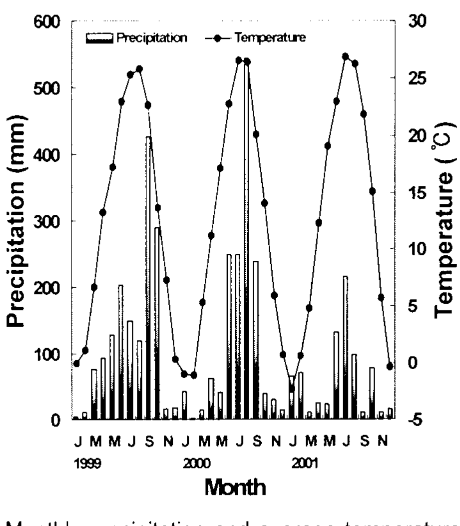

Fig. 1. Monthly precipitation and average temperature at Buyo meteorological station about 32km distance from the study site.

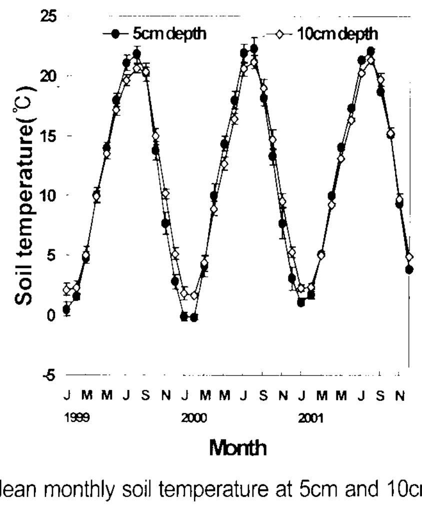

Fig. 2. Mean monthly soil temperature at 5cm and 10cm soil depth at the study site.

Root litter-bag preparation

Root litter-bags, 15 x 15 cm, were made of nylon mesh with 2-mm^2 holes. We prepared 50 litter-bags in each species. Each root litter-bag enclosed about 5 g of root and an aluminum tag which giving the exact weight of the root. The root litter-bag openings were sealed with impulse sealer (monel staples). Root litter-bags were buried at 10-15cm depth in the forest floor in December 1998.

Root litter-bag retrieval and treatment

The first retrieval of root litter-bags was done on January 1999, 1-month after installation, and then retrieved every 3-months till March 2000, and then 6-months intervals till September 2001. Five root litter-bags of each species was retrieved on each sampling. Adhering material on the outside of the root litter-bags were removed with tap water. Remaining roots in each root litter-bag was weighed individually after drying for 72 hr at 60℃. Dried root samples were ground in mill and passed through 1mm screen. Samples were stored in air-tight container to prevent moisture changes prior to analyses for N and P content.

Weight loss and changes of nutrients during decomposition were determined by measuring the remaining weight and nutrient concentration of roots in the root litter-bags. Weight loss of the root was expressed as % of the initial sample weight. The decomposition rate constant (k) is derived from the exponential decay formula,

$$X_t = X_0\, e^{-kt}$$

where X_0 is the percentage of initial mass of fine roots, X_t is the percentage of initial mass remaining at time t, and t in years (Brinson *et al.* 1981, Chen *et al.* 2002). Comparisons of mean weight loss among the three species were carried out using Student' s *t* test with SPSS 8.0 program for Windows.

Chemical analysis

Total N and total P was determined by Autoanalyzer(Lachat: QuickChem 8000) after wet digestion. Remaining nutrients in the root litter-bags at each sampling date was calculated using the concentration of nutrient in the roots and the weight of the remaining roots in the litter-bags. Each remaining nutrients was expressed as a percentage of the amount contained in the initial root litter-bags.

RESULTS AND DISCUSSION

Weight loss

Fine roots showed a rapid weight loss during the first 12 months, followed by a slowing of the decomposition rate except for alder (Fig. 3). Weight loss of *A. japonica* was significantly greater than those of *Q. acutissima* and *P. rigida* (p<0.01). After

33-months, remaining weight of alder, oak and pitch pine was 29.2, 47.7 and 53.4% of the initial weight, respectively. The decomposition rate constant (*k*) for alder, oak and pitch pine was 0.448 yr^{-1}, 0.269 yr^{-1}, 0.228 yr^{-1}, respectively. Chen *et al.* (2002) reported that the decomposition rate constant for 15 species examined ranged from 0.172 yr^{-1} for *Picea engelmanni* to 0.386 yr^{-1} for *Fraxinus latifolia*. They reported that red alder lost about 55% of its initial mass during the 2 year decomposition. In our study, however, alder lost about 65% of its initial mass during the 2 years decomposition. Pitch pine and oak lost about 43% and 38% of its initial mass during the 2 years decomposition. During the first 21 months decomposition, fine roots of pitch pine lost more than that of oak. Thereafter, oak lost more rapidly than pitch pine.

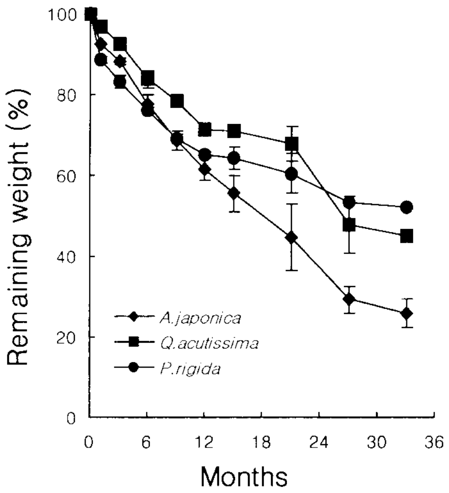

Fig. 3. Mean percent remaining weight in the decomposing fine roots of alder, oak and pitch pine. Bars indicate standard deviation.

N and P dynamics

Initial N concentration of fine roots of alder, oak and pitch pine was 10.32 mg/g, 6.20 mg/g, 7.26 mg/g, respectively. The nitrogen content of the decomposing fine roots of the three species exhibited a decrease in first month and then showed a increasing trend over time (Fig. 4A). Increasing trend was more obvious in alder than other species. Nitrogen content of oak consistently lower than the other two species during decomposition. After 33 months decomposition, nitrogen concentration of alder, oak and pitich pine was 15.7 mg/g, 8.2 mg/g and 8.8 mg/g, respectively.

Nitrogen was released from all three species during the 33 months of decomposition (Fig. 4B). After 1 year of decomposi-

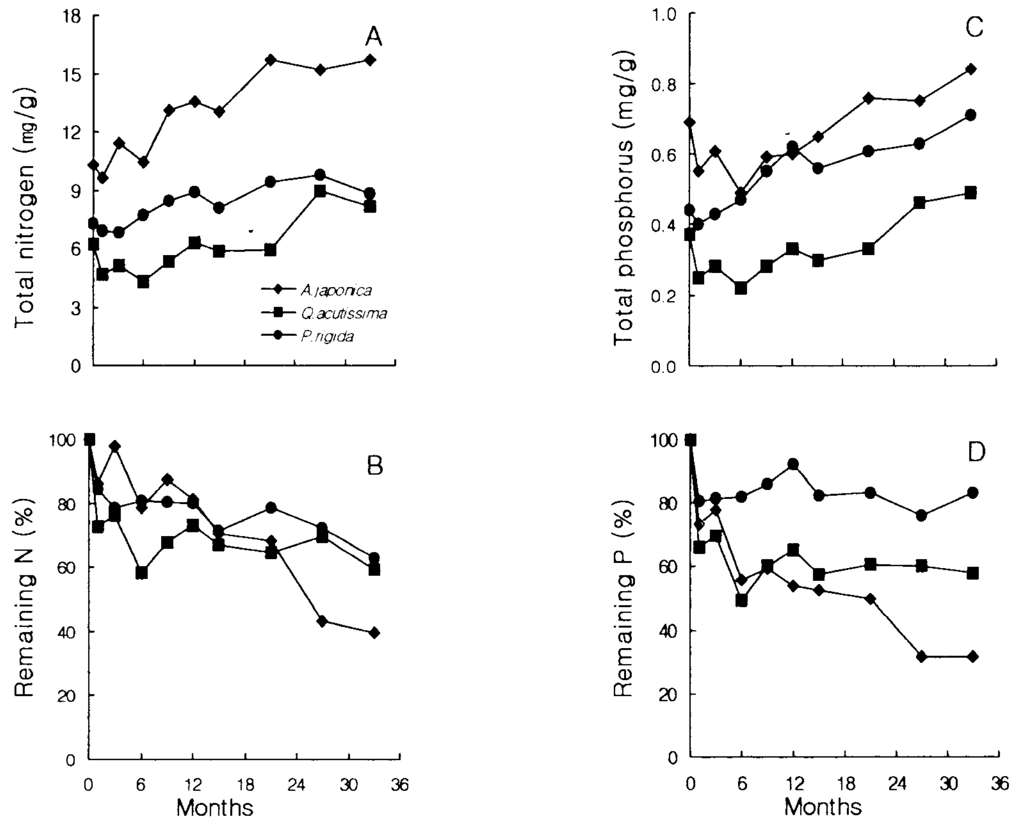

Fig. 4. Changes of N content (A), % of remaining N (B), P content (C) and % of remaining P (D) in the decomposing fine roots of alder, oak and pitch pine.

tion, the decomposing fine roots of alder, oak and pitch pine released 19.9, 27.1 and 20.1% of initial nitrogen content. After 33 months of decomposition, however, the fine roots of alder released about 60% of initial nitrogen content (Fig. 4B). During the same period, decomposing fine roots of oak and pitch pine released about 40% and 37%, respectively, of their initial nitrogen content.

Chen *et al.* (2002) reported that the initial N concentration of fine roots accounted for 80% of the variation in the rate of N release. They suggested that the mean threshold value of initial N concentration is 0.4% of the dry mass. That is, as long as the initial N concentration of fine roots was higher than 0.4%, roots would release N during 2 years of decomposition. The initial N concentration of fine roots in this study, ranging from 0.62 to 1.03%, was much higher than 0.4%.

Initial P concentration of fine roots of alder, oak and pitch pine was 0.69 mg/g, 0.37 mg/g, 0.44 mg/g, respectively. The phosphorus content of the decomposing fine roots of the three species also exhibited a decrease in first 1 month and then showed a increasing trend over time (Fig. 4C). Phosphorus content of oak consistently lower than the other two species during decomposition. After 33 months decomposition, phosphorus concentration of alder, oak and pitch pine was 0.84 mg/g, 0.47 mg/g and 0.71 mg/g, respectively.

Phosphorus was also released from three species during the 33 months of decomposition (Fig. 4D). After 1 year of decomposition, the decomposing fine roots of alder, oak and pitch pine released 46.4, 35.0 and 7.7% of initial phosphorus content. After 33 months of decomposition, however, the fine roots of alder released about 68% of initial phosphorus content (Fig. 4D). During the same period, decomposing fine roots of oak and pitch pine released about 42% and 17%, respectively, of their initial phosphorus content.

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