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Mass Loss Rates and Nutrient Dynamics of Decomposing Fine Roots in a Sawtooth Oak and a Korean Pine Stands

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ABSTRACT: Fine root decomposition and nutrient release patterns were examined using *in situ* buried fine root (< 2mm in diameter) bags inserted vertically into the mineral soil to a depth of the top 15 cm in a sawtooth oak (*Quercus acutissima*) and a Korean pine (*Pinus korainesis*) stands in the Jungbu Forest Experiment Station, Kyonggi-do, Korea. The pine roots compared with the oak roots showed rapid mass loss in early stages of decomposition, but decomposed similarly after 12 months of incubation. Decomposition rates of fine roots were about 33%/yr for the oak roots and 37%/yr for the pine roots. Nutrients except for calcium and phosphorus showed similar concentrations between the oak and the pine roots during the study period. However, calcium concentration was significantly higher in the oak than in the pine roots. Nutrient concentrations in both stands except for nitrogen decreased during the study period. In addition, potassium compared with other nutrients was the most mobile ion and about 70% of initial amount was released during the first 3 months of incubation. The results indicate that tree species influence mass loss and nutrient dynamics of fine roots on similar site conditions.

Key words: Decomposition rate, Fine root, *Pinus korainesis*, *Quercus acutissima*, Root nutrients

INTRODUCTION

Fine roots in forest stands represent a large and dynamic portion of the belowground biomass and nutrient capital (Nadelhoffer *et al.* 1985, Yin *et al.* 1989, Burke and Raynal 1994). The turnover of fine roots represents a major contribution to the nutrient and carbon inputs to soil (Chen *et al.* 2001, 2002). Significant amounts of organic matter and nutrients in the soils can be transferred during root decomposition. Many studies of nutrient cycle by decomposition dynamics in forest ecosystems have concentrated mainly on aboveground litter decomposition (Melillo *et al.* 1982, Klemmedson 1992, Mun and Joo 1994), while the role of belowground litter decomposition such as fine roots poorly understood. Although few root decomposition studies were conducted to determine the decay rates, N and P dynamics of some tree species in Korea (Pyo *et al.* 2002), little is known about other macro-nutrients such as potassium, calcium and magnesium.

Korean pine (*Pinus korainesis*) is the most major planting species for forest regeneration throughout the country last thirty years. Also sawtooth oak (*Quercus acutissima*) is one of dominant hardwood species in natural stands, Korea. It is needed to better understand decomposition and nutrient dynamics in fine roots of both tree species. The objectives of the study were: 1) to examine patterns of decomposition of fine roots; 2) to determine patterns of release of N, P, K, Ca and Mg from decomposing fine roots in a sawtooth oak and a Korean pine stands.

METERIALS AND METHODS

The study was conducted in the Jungbu Forest Experiment Station in Gwangnung, Kyonggi-do, Korea. The study sites (Table 1) were classified as slightly dry brown forest soils (mostly Inceptsols). Annual precipitation in the site averages 1,365mm and is higher than the average of the country (1274 mm). Dominant understory species of the study sites were *Capinus laxflora, Viburnum dilatatum, Stephanandra incisa, Disporum smilacinum*, and *Syneilesis palmata* in the oak stand. *Capinus laxiflora, Viburum dilatatum*, and *Disporum smilacina* were dominant in the pine stand. Soil characteristics of the study sites are given in Table 2.

Fine root decomposition rates were estimated using *in situ* buried root decay bag technique employing 15 cm ×15 cm nylon

Table 1. Characteristics of the study sites

Characteristics	Oak	Pine
Stand age	70	31
Slope	15-25	20-25
Aspect	N, W	E
Basal area(m^2/ha)	33	28
Mean height(m)	28	12

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Table 2. Soil physical and chemical properties in the top 15cm of mineral soil in the study site

Stand	Soil texture	pH (1:5 H_2O)	Organic matter (%)	T.N. (%)	Avail. P_2O_5 (ppm)	CEC	Exchangeable K^+	Exchangeable Na^+	Exchangeable Ca^{2+}	Exchangeable Mg^{2+}	Total base	BS(%)
						(cmolc/kg)						
Oak	Loam	4.8	4.9	0.23	15.5	11.8	0.36	0.10	1.91	0.57	2.94	24.9
Pine	Loam	4.6	3.4	0.12	9.0	11.2	0.18	0.08	1.12	0.21	1.59	14.5

bags with 1.2 mm mesh size. Fresh fine roots from each stand were collected from sampling point located randomly on the 15 cm mineral soil depth in April 5, 1995. For this study the fine root system was defined as woody and non-woody root <2 mm in diameter and their associated root tips. After collection, the fine roots were gently rinsed by tap water, sorted into size classes, and air dried to constant mass at room temperature for 14 days. The root samples with an air dried mass of 1 g were weighed to the nearest 0.01 g and placed in numbered bags. Sub-samples from each root type were also taken to determine oven-dried mass at 65°C for 48 hours.

Nine root bags were randomly placed on the mineral soils in both stands (oak roots in oak stands and pine roots in pine stands). Total of 90 root bags (3 blocks × 3 replicates × 5 sampling times × 2 stand types) were incubated in the mineral soil layer in both stands (28 April 1995). The bags were inserted vertically into the mineral soil to a depth of 15 cm with a straight-blade shovel. The bags were collected on five occasions {21 July 1995 (84 days), 24 November 1995 (210 days), 25 April 1996 (362 days), 1 August 1996 (460 days), 12 November 1996 (563 days)} between 1995 and 1996. After collection, each bag sample was oven-dried at 65°C for 48 hours, weighed to the nearest 0.01 g, and mass loss rates determined. Nine bags were collected in each stand (total of 18 bags) during the sampling time. Collected bags were oven-dried at 65°C for 48 hours, cleaned by gentle brushing with a soft paintbrush to remove mineral soil and weighed to determine fine root mass loss rates. A subset of samples from each bag was ignited at 550°C for 3 hours to determine ash content to correct for mineral soil contamination. All root nutrients (N, P, K, Ca, Mg) were analyzed by the standard method of National Institute of Agricultural Science and Technology (1988).

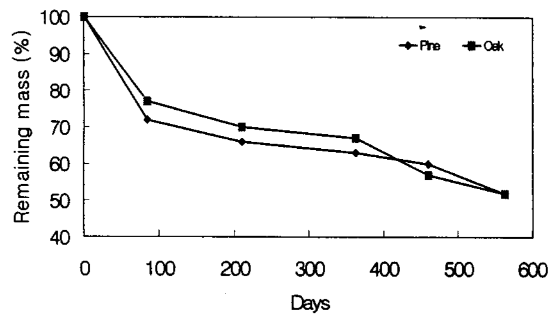

Fig. 1. Changes in mean percent of initial mass remaining from decomposing oak and pine roots.

RESULTS AND DISCUSSION

Fine root decomposition

The pine roots compared with the oak roots showed rapid mass loss in the early stages (before 7 months of incubation), but decomposed similarly in the latter stages (after 12 months of incubation) of decomposition (Fig. 1). There were significant differences in mass losses between both species before 7 months of incubation ($p<0.05$), but no significant differences were evident after 12 months of incubation ($p>0.05$). Rapid root mass loss of the pine roots in the early stages of decomposition may be due to slightly higher N concentration compared with oak roots (Fig. 2). In addition, pines have the characteristics of softwood (specific gravity of green wood in Korean pine : 0.68 g/cm^3), while oaks have the characteristic of hardwood (specific gravity of green wood in sawtooth oak : 1.05 g/cm^3).

Decomposition rates of fine roots were about 33%/yr in the oak roots and 37%/yr in the pine roots. Decomposition rates of fine roots in this study were similar to those reported for other deciduous forest. Annual decomposition rates ranged from 27% to 52% at a depth of 10 cm in northern hardwood forest ecosystem, USA (McClaugherty *et al.* 1982, Joslin and Henderson 1987, Burke and Raynal 1994). About 47% of the original mass in both root types disappeared during 18 months of incubation. The decomposition rates of this study were slightly higher than other oak and pine species. About 38% of fine roots in a sawtooth oak stand and 43% of a Pitch pine (*Pinus rigida*) stand was decomposed during the 2 years in Kongju, Korea (Pyo *et al.* 2002).

Fine root decomposition showed rapid decomposition (0.15%/day) in tree growing season (0~210 days), while slower rate (0.02%/day) of tree dormant seasons (211~362 days). Although soluble materials of fine roots can be leached during the initial stage of root decomposition processes, root decomposition may be related to soil temperature. Soil temperature was one of the main abiotic factors influencing root decomposition (Vogt *et al.* 1986, Joslin and Henderson 1987, Chen *et al.* 2000).

Nutrient dynamics

The mean initial nutrient concentration of fine roots in a sawtooth oak stand followed the order : Ca (9.5 mg/g) > K (5.1 mg/g) > N(2.9 mg/g) > Mg(1.9 mg/g) > P(0.5 mg/g). The concentration in a Korean pine stands was Ca(4.7 mg/g) > K(4.0 mg/g) > N(3.3 mg/g) > Mg(2.0 mg/g) > P(0.7 mg/g). Nutrients of both stands showed similar concentrations except for Ca. Joslin and Henderson (1987) observed a similar Ca concentration pattern for white oak stands in central Missouri, USA. Mean fine root nutrient concentrations in this study were generally within the range of values reported elsewhere for forest communities (Joslin and Henderson 1987, Chen *et al.* 2001, Pyo *et al.* 2002).

Initial root N concentration was similar to both root types (Fig. 2). However, nitrogen was rapidly immobilized during the early stages of decomposition (Fig. 3). After 3 months of incubation, N concentration in both stands increased about 3 times of initial concentration. Similarly, Ostertag and Hobbie (1999) reported that decomposing fine roots immobilized up to 2.6 fold of initial N concentration after 1 year of decomposition. There was a stable increased pattern in N concentration during the early decomposition stages. Chen *et al.* (2001) suggest that N accumulation of roots during the decomposition process may be related to high initial C/N ratio. Many researchers have noted increased N concentrations and gains during fine litter decomposition (Melillo *et al.* 1982, Berg 1988, Van Vuuren and Van der Eerden 1992). This increase could be due to microbial and non-microbial N immobilization and additions by atmospheric N deposition during decomposition. In addition, fungal activity has been reported to be a major source of increased N in decomposing litter. Phosphorus concentration was generally higher in the pine roots than in the oak roots. Phosphorus concentration in the initial stage of decomposition was significantly higher in the pine roots than in the oak roots (Fig. 2). This result may be due to higher mycorrhizal infection in the pine roots compared with the oak roots (personal observation). Phosphorus was leached in the pine roots, while the oak roots were not varied (Fig. 3). Rapid release of P in both root types occurred in the first year of incubation. The loss of P may be associated with the loss of dry matter throughout decomposition.

Potassium concentration dropped during the first 3 months and then stabilized (Fig. 2). The rapid decrease of K is due to initial leaching losses because K is not a structure component of plant tissues. In addition, changes in K concentration of roots were similar to those of aboveground litter decomposition (Klemmedson 1992). It appears that K in the fine root litter is the most easily released element, while N is the least mobile (Fig. 3).

Calcium concentration was different between the oak and the pine root types (Fig. 2). Calcium concentration in roots was always higher in the oak than in the pine roots. This is due to the nature of Ca as a structure component of cell wall within plant tissues. The oak fine roots were much tougher than the pine fine roots. In the initial stage of decomposition in the pine roots, the increase in Ca concentration may be due to a mass loss of roots.

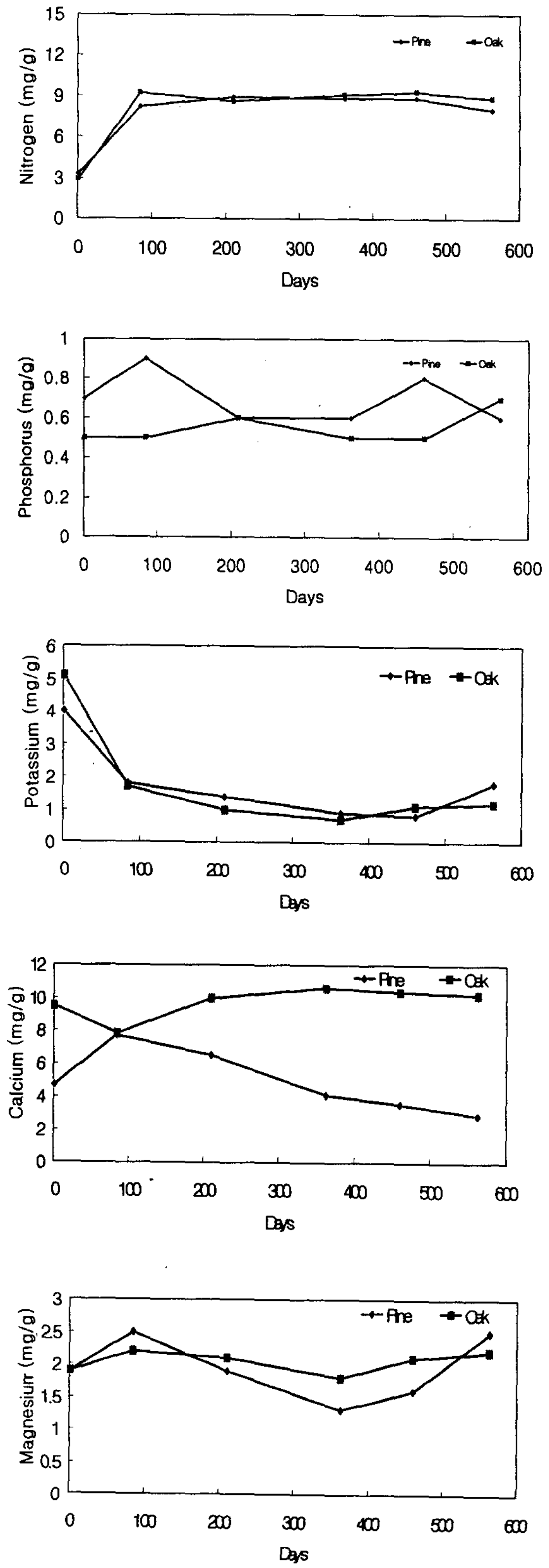

Fig. 2. Changes in mean concentration of nutrients from decomposing oak and pine roots.

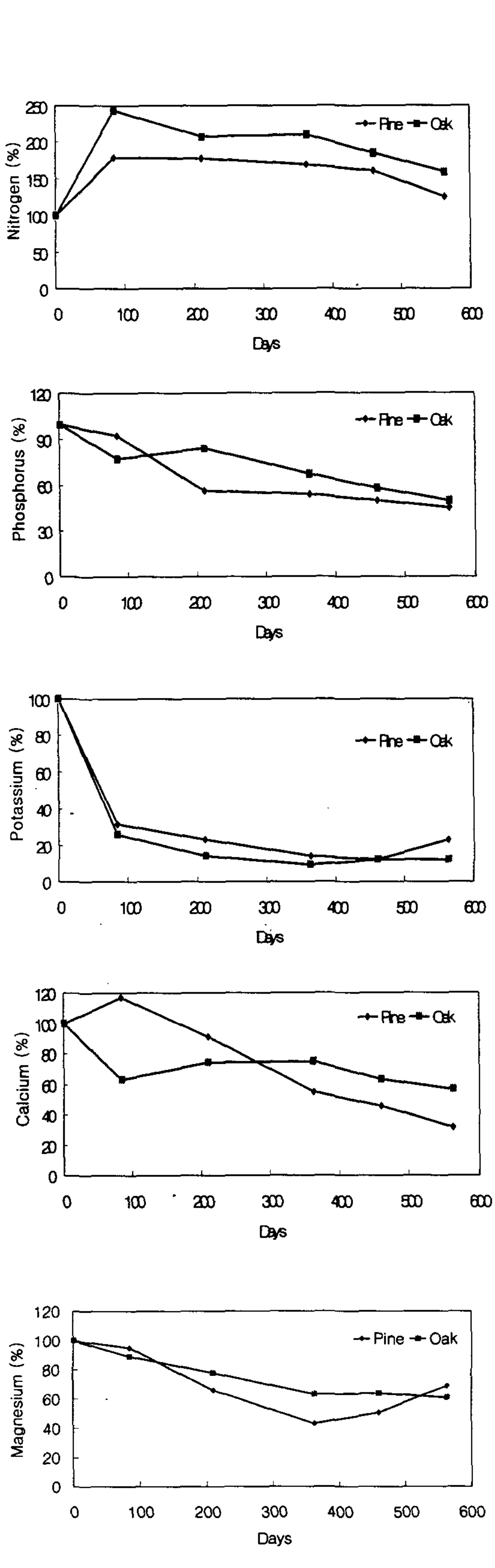

Fig. 3. Changes in absolute amounts of nutrients from decomposing oak and pine roots.

It appeared that root decomposition was responsible for Ca losses.

Magnesium concentration showed rapid decrease in the pine roots, while Mg in the oak roots exhibits little change during the first year of incubation (Fig. 2). Magnesium concentration after one year was more variable, but generally tended to increase as decomposition proceeded. Leaching appeared to play an important role in the release of Mg (Fig. 3).

Nutrient levels except for N over the study period did not exceed the initial values of undecomposed fine root litter, indicating that nutrients from decomposing fine roots were released to the soils in both stands. The order of mobility of nutrients over the study period 564 days incubation in decomposing oak and pine fine roots litter was K > Ca > P > Mg > N.

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