Mass Loss Rates and Nutrient Dynamics of Oak and Mixed-Hardwood Leaf Litters in a Gyebangsan (Mt.) Forest Ecosystem

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ABSTRACT : Patterns of mass loss and nutrient release from decomposing oak (*Quercus mongolica*) and mixed litters *(Q. mongolica, Betula schmidtii, Acer pseudo-sieboldianum, Kalopanx pictus* and *Tilia amurensis*) in a natural hardwood forest in Gyebangsan (Mt.) were examined using litterbags placed on the forest floor for 869 days. Mass loss rates from decomposing litter were consistently higher in mixed litter (59%) than in oak litter types (52%) during the study period. Nutrient concentrations such as nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) from decomposing litter were also higher in mixed litter than in oak litter types. Nutrient concentrations (N, P, Ca, and Mg) increased compared with initial concentration of litter, while K concentrations dropped rapidly at the first 5 months and then stabilized. The results suggest that mas loss and nutrient release obtained from decomposing litter of single species in mixed hardwood forest ecosystem should be applied with caution because of the potential differences of mass loss and nutrient release between single litter and mixed litter types.

Key words : Litter decomposition, Mass loss rates, Nutrient cyclings, Nutrient dynamics

INTRODUCTION

Mass loss and release of nutrients from decomposing litter are an important pathway of nutrient cycling in forested ecosystem (Melillo *et al.* 1982, Klemmedson 1992, Mun and Joo 1994, Ribeiro *et al.* 2002). Significant amounts of organic matter and nutrients in the soils can be transferred during the litter decomposition processes (Melillo *et al.* 1982, Klemmedson 1992, Ribeiro *et al.* 2002). Natural hardwood stands in the temperate forest zone of Korea are mixed with various kinds of deciduous tree species such as oak, maple, and ash etc. Although several studies have reported litter decomposition and nutrient processes in hardwood forest in Korea (Mun and Joo 1994, You *et al.* 2000), little is known about the direction and rates of change associated with mixed-hardwood forest. The objectives of the study were: 1) to examine decomposition rates in oak and mixed-hardwood litters; 2) to determine patterns of nutrient (N, P, K, Ca and Mg) release from decomposing oak and mixed-hardwood litters.

MATERIALS AND METHODS

The study was conducted in the Long-Term Ecological Research site in Gyebangsan (Mt.), Gangwon-do, Korea. This site was classified as the northern temperate forest area in Korea. Annual precipitation in the study site averages 1,287mm. The mean annual temperature is 10.1℃. Dominant tree species of the study sites were *Betula schmidtii, Quercus mongolica, Acer pseudo-sieboldianum, Kalopanx pictus, Tilia amurensis* and *Acer mono* etc. (Fig. 1).

The study sites were classified as slightly wet brown forest soils (B_3) originated from metamorphic rocks. Soil physico-chemical property in the study site was given in Table 1. Tree density in the site was 700 trees/ha and sum of basal area was 21.2 m^2/ha (Fig. 1).

The experimental design consisted of three blocks divided into 20m×10m plots. Mass loss and nutrient release in decomposing litter were estimated using the litterbag technique employing 25cm

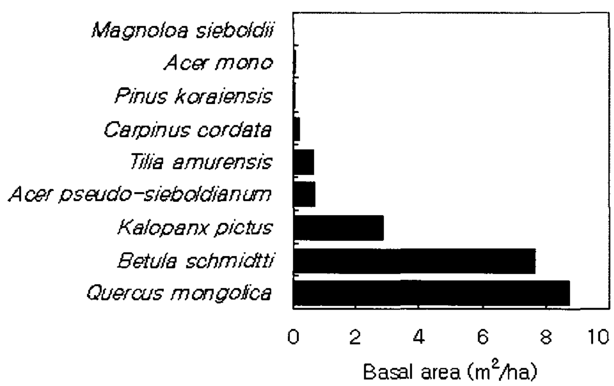

Fig. 1. Distribution of tree basal area of the study site.

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Table 1. Soil physical and chemical properties of mineral soil in the study site

Horizon	Sand	Silt	Clay	pH	O.M.	T.N.	Avail. P_2O_5	CEC	Exchangeable				Total base
									K^+	Na^+	Ca^{2+}	Mg^{2+}	
	(%)				(%)	(%)	(ppm)	(cmol$_c$/kg)					
A	44.2	42.7	13.1	5.5	7.7	0.35	10	14.3	0.65	0.11	4.51	1.09	6.36
B	38.5	46.3	15.2	5.5	3.6	0.19	7	14.3	0.37	0.11	1.82	0.48	2.78

×15cm nylon bags with 1.5mm mesh size. Fresh oak leaves and other species leaves from the stands were collected using nylon net installed above forest floor 50cm during the heavy litter season (from late October to November 1996). Collected litter samples were dried to constant mass at room temperature (25℃) for 14 days and sorted by representative deciduous foliage in the stand. Five grams of air-dried mixed litter {*Quercus mongolica* (2g), *Betula schmidtii* (1.5g), *Acer pseudo-sieboldianum* (0.5g), *Kalopanx pictus* (0.7g) and *Tilia amurensis* (0.5g)} from five dominant tree species in this stands were weighed to the nearest 0.01 g and placed in numbered litter bags. Also, five grams of air-dried oak litter (*Q. mongolica*) were weighed and placed in the same numbered litter-bags. Nine bags in mixed litter and six bags in oak litter were installed randomly on the forest floor (O_i layer) within each block on December 2, 1996. The bags were collected on five occasions {May 1, 1997 (149 days), August 6, 1997 (247 days), May 7, 1998 (521 days), September 27, 1998 (639 days), April 21, 1999 (869 days)} between 1997 and 1999. Collected bags were oven-dried at 65℃ for 48 hours, cleaned by gentle brushing with a soft paintbrush to remove mineral soil and weighed to determine litter mass loss rates. A subset of samples from each bag was ignited at 550℃ for 3 hours to determine ash content to correct for mineral soil contamination. Litter samples collected from each plot were ground in a Wiley Mill to pass a 40-mesh (0.425mm) stainless steel sieve. All nutrients (N, P, K, Ca and Mg) were analyzed by the standard method of National Institute of Agricultural Science and Technology (1988). At each sampling time, the mean values for remaining dry mass and concentration of nutrients in both litter types were compared by using analysis of variance (SAS Institute Inc. 1985). The level of significance used in the tests was $P < 0.05$.

RESULTS AND DISCUSSION

Decomposition in both litter types was characterized by an initial faster rate of disappearence, followed by a subsequent slower rate (Fig. 2). Mass loss from decomposing litter was more rapid in mixed litter than in oak litter (Fig. 2). There were significant differences in mass loss between both litter types during the study period. About 52% of the original mass in oak litter disappeared, while about 59% in mixed litter disappeared during the study period. Rapid mass loss rates of mixed litter may be attributed to the difference of substrate quality between oak and mixed litter types. For example, I observed the rapid litter disappearence of tree species such as *Betula schmidtii, Tilia amurensis* and *Acer pseudo-sieboldianum* compared with the oak (*Q. mongolica*) litter within the mixed litter bags during the study period. The relative slower decay rates in oak litter compared with mixed litter may be due to the accumulation of more recalcitrant constituents mass with their morphological characters. Thick and tough oak leaf litter decomposed slower than mixed litter including thin and less rigid leaves such as *Betula schmidtii, Tilia amurensis* and *Acer pseudo-sieboldianum.* Also, mixed litter showed high nutrient concentrations compared with oak litter (Fig. 3). Many studies have reported that litter with high nutrient concentrations was rapidly decomposed compared to litter with low nutrient concentrations (Bockheim 1991, Mun and Joo 1994, Kim *et al.* 1996, You *et al.* 2000).

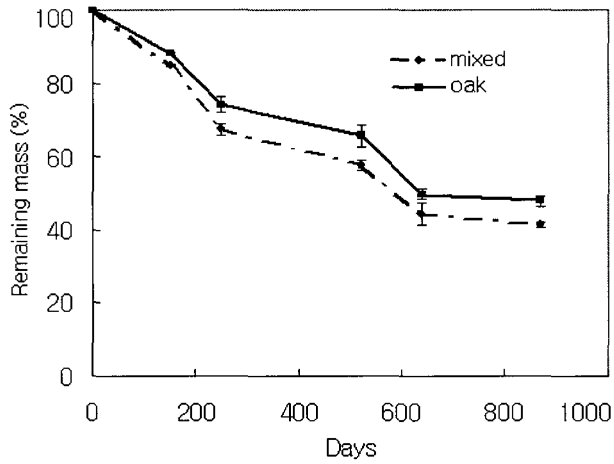

Fig. 2. Changes in mean percentage of initial remaining mass in oak and mixed-hardwood litters over 869 days. Error bars represent one standard error.

The concentration of N during the litter decomposition processes increased sharply over the study period (Fig. 3). The concentrations of N were generally higher in mixed than in oak litters. Higher

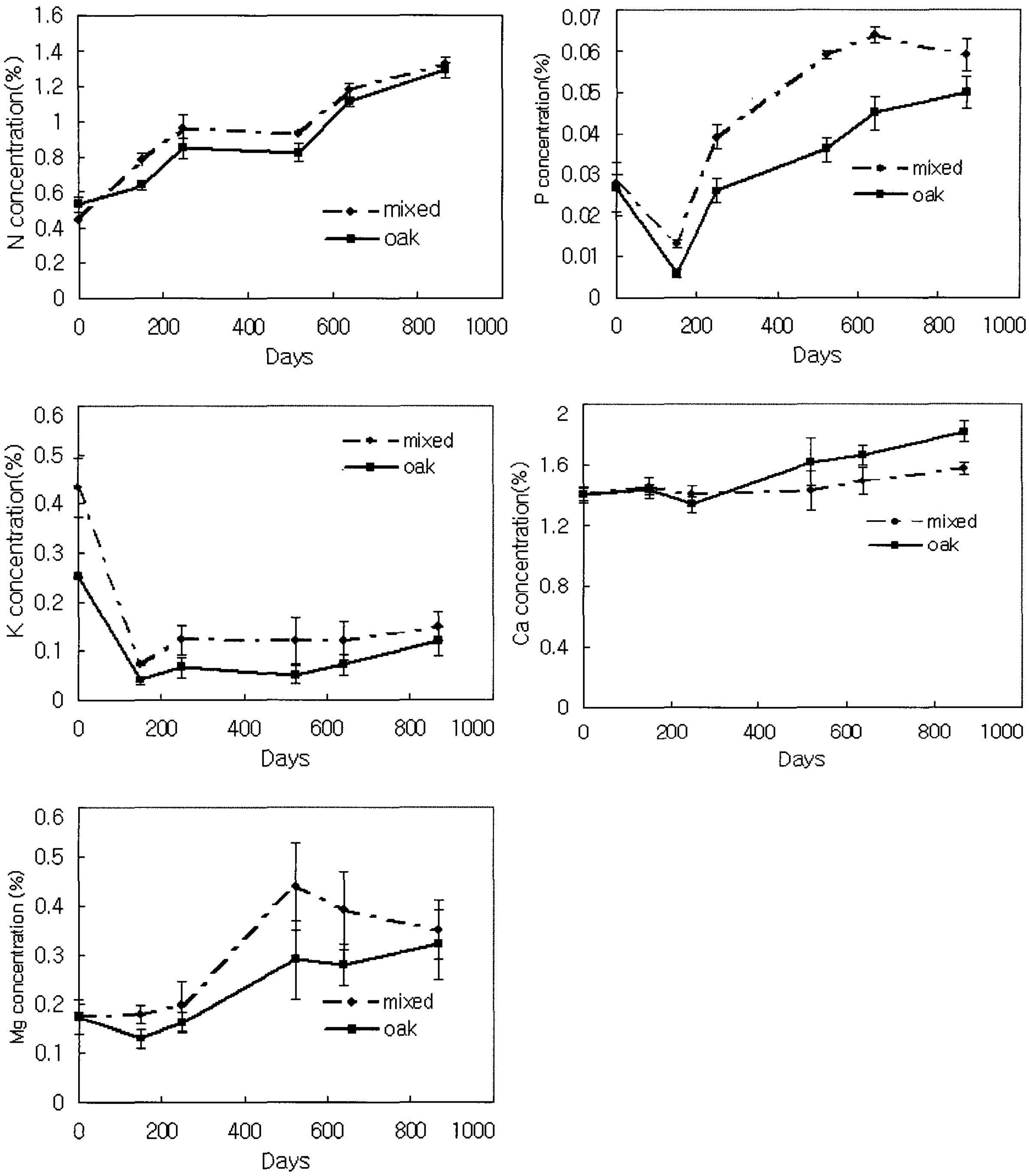

Fig. 3. Changes in mean concentration of nutrients in oak and mixed-hardwood litters over 869 days. Error bars represent one standard error.

concentration in the mixed litter compared with the oak litter may be due to rapid loss of dry matter throughout decomposition processes.

Phosphorus concentration in both litters decreased during the initial stage of decomposition, but increased after one year (Fig. 3). Similar patterns were observed in the litter of other hardwoods, such as flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*) and chestnut oak (*Quercus prinus*) in USA (Blair 1988). Phosphorus concentrations were slightly higher in mixed than in oak litter types during the study period.

It appears that K in both litter types is the most readily released element compared with other nutrients (Fig. 3). Potassium concentration dropped rapidly during the first 5 months of incubation and then stabilized. Rapid release of K early during litter decomposition process is a commonly observed phenomenon in other litter decomposition studies (Bockheim *et al.* 1991, Lisanework and Michelsen 1994, You *et al.* 2000). Ribeiro *et al.* (2002) suggested that the rapid release of K during the early decomposition stages was due to the lack of incorporation of this element into organic structures.

The concentrations of Ca remained constant over the 1-year period, then slightly increased (Fig. 3). Calcium concentrations after the 1-year incubation were greater for oak litter than for mixed litter. Higher concentration of Ca in oak litter compared with mixed litter may be due to the accumulation of more recalcitrant constituents.

Magnesium concentrations were higher in mixed litter than in oak litter (Fig. 3). Magnesium concentrations in both litter types generally tended to increase as decomposition proceeded.

Both litter types exhibited a net immobilization of N above 100% of initial amount of decomposition (Fig. 4). Many researchers have noted increased N gains in litter during decomposition processes (Berg 1988, Polglase *et al.* 1992, Kim *et al.* 1996). This increase could be due to microbial or non-microbial N immobilization and

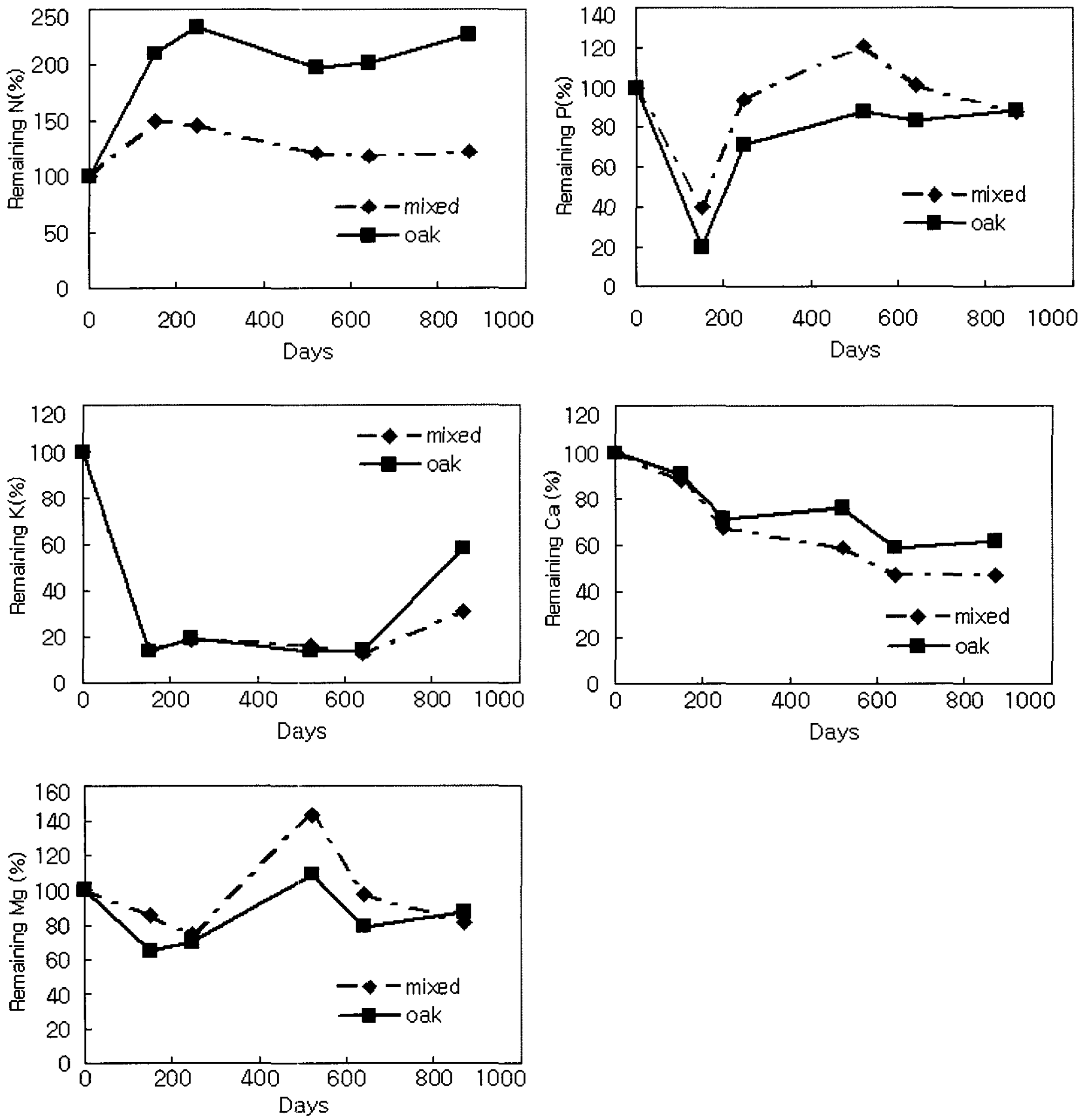

Fig. 4. Changes in absolute amounts of nutrients in oak and mixed-hardwood litters over 869 days.

additions by atmospheric N decomposition during decomposition (van Vuuren and van der Eerden 1992). Bockheim *et al.* (1991) suggested that the increase in amounts of N may be attributed to immobilization of N from throughfall by fungi. In addition, N may be taken up from the soil and incorporated in decomposing leaf litter by fungi. If a portion of this N could be absorbed by decomposing litter, it could influence the gains of N in decomposing litter in both litter types. There were also differences in absolute amounts of N in both decomposing leaf litter types over the study period. The absolute amounts of N in leaf litter were higher in oak litter than in mixed litter. This result suggests that N in oak litter with slower decomposition is readily immobilized by microorganism. The amounts of P during the early decomposition phase declined rapidly, but P levels in both litter types after the late phase were similar to the initial values in decomposed litter (Fig. 4). This result suggests that both litters are subjected to leaching in initial phase and to immobilization by microorganism in late phase of decomposition. The potential for immobilization of P was greater in mixed litter than in oak litter.

The amounts of K decreased for both litter types over the study period (Fig. 4). Other studies reported a similar loss in K (Bockheim *et al.* 1991, You *et al.* 2000) due to water soluble characteristics as nonstructural components in plants.

The amounts of Ca in both litter types showed similar values during the first 8 months of incubation, but Ca in oak litter was higher than in mixed litter after one year (Fig. 4). The release of Ca was greater for mixed litter than for oak litter because of the decreases in dry matter in mixed litter and the importance of Ca as a structural component in cell walls of a leaf.

It is difficult to explain the variation in Mg of both litter types. Both litter types exhibited the immobilization or release of Mg over the study period (Fig. 5). Other studies reported Mg as the readily released nutrient (You *et al.* 2000).

The overall release of nutrients from both leaf litter types can be ranked: K>Ca>P=Mg>N. Similarly, other studies reported K as the most readily released nutrients and N as the most slowly released nutrient (Bockheim *et al.* 1991, You *et al.* 2000).

In summary, mass loss rates were consistently higher in mixed litter than in oak litter types. Nutrient concentrations from decomposing litter were also higher in mixed litter than in oak litter types. The litter decomposition of this study showed the potential differences of mass loss and nutrient release between single litter and mixed litter types in a mixed hardwood forest ecosystem.

ACKNOWLEDGMENTS

This work is a contribution from the study on biological diversity of forest ecosystem implemented on the Korea Forest Research Institute. I am grateful to two anonymous referees for their comments on the manuscripts.

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(*Received December 10, 2003; Accepted December 17, 2003*)