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Nutrient Dynamics in Litterfall and Decomposing Leaf Litter at the Kwangneung Deciduous Broad-Leaved Natural Forest

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광릉 천연활엽수림의 낙엽낙지와 낙엽분해에 따른 양분동태

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ABSTRACT

Litterfall and litter decomposition represent a major contribution to the carbon and nutrient inputs in a forest ecosystem. We measured litterfall quantity and nutrient dynamics in decomposing litter for two years at the Kwangneung broadleaf natural forest (DK site) in Korea. Litterfall was collected in circular littertraps (collecting area : 0.25 m^2) and mass loss rates and nutrient release patterns in decomposing litter were estimated using the litterbag technique employing 30 cm×30 cm nylon bags with 1.5 mm mesh size. Total annual litterfall was 5,627 kg/ha/yr and leaf litter accounted for 61% of the litterfall. The leaf litter quantity was highest in *Quercus serrata*, followed by *Carpinus laxiflora* and *C. cordata*, etc., which are dominant tree species in the site. Mass loss from decomposing leaf litter was more rapid in *C. laxiflora* and *C. cordata* than in *Q. serrata* litter. About 77% of *C. laxiflora* and 84% of *C. cordata* litter disappeared, while about 48% in *Q. serrata* litter lost over two years. Lower mass loss rates of *Q. serrata* litter may be attributed to the difference of substrate quality such as lower nutrient concentrations compared with the other litter types. Nutrient concentrations (N, P, Mg) of three litter types except for potassium (K) increased compared with initial nutrient concentrations of litter over the study period. Compared with *Q. serrata* litter, nutrients (N, P, K, Ca, Mg) in *C. laxiflora* and *C. cordata* litter were released rapidly. The results suggest that litter mass loss and nutrient dynamic processes among tree species vary considerably in the same site conditions.

Key words **: litterfall, litter decomposition, DK site, nutrient cycling**

I. INTRODUCTION

Litterfall inputs and litter decomposition represent a large and dynamic portion of the nutrient cycling in a forest ecosystem (Bray and Gorham 1964; Kim *et al.* 1996; You *et al.* 2000). In addition, the turnover of litter is a major pathway of the nutrient and carbon inputs to forest soils. Significant amounts of organic matter and nutrients in the soils can be transferred during litter decomposition processes (Lisanework and Michelsen 1994).

Natural hardwood stands in the temperate forest zone of Korea are mixed with various kinds of deciduous tree species. Although several studies have reported litterfall inputs and litter decomposition in hardwood forest ecosystem in Korea (Kim *et al.* 1997; You *et al.* 2000), little is known about the direction and rates of change associated with mixed-hardwood forest eco-

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system. The objectives of this study were 1) to measure litterfall and nutrient quantity; 2) to examine decomposition rates in *Quercus serrata*, *Carpinus laxiflora* and *C. cordata* litter; 3) to determine patterns of nutrient release from decomposing litters at the LTER site of Kwangneung, a mixed-hardwood forest ecosystem in Korea.

II. MATERIAL AND METHODS

2.1. Study Site

This study was conducted in the broadleaf deciduous forest in Kwangneung, Kyunggi-do, Korea. This area has been designated as the DK site by the KoFlux network in 2002 (Kim *et al.* 2002) and also a LTER site since 1998 (Oh *et al.* 2000). The study site (37°45′ 16″ N, 127°10′ 20″ E) was located in the central cool-temperate forest zone in Korea, and the soils were classified as brown forest soils (mostly Inceptisols) developed on granite gneiss. Annual precipitation in the site averages 1,365 mm and is higher than the average of the country (1,274 mm). Annual mean temperature is 11.3°C. Tree density of the site was 1,473 trees/ha and basal area was 28 m^2/ha. Dominant tree species in the site were *Q. serrata,* which occupies 51% of the basal area, followed by 23% *C. laxiflora,* and 7.8% *C. cordata* (Lim *et al.* 2002).

2.2. Litterfall Collection

Litterfall was collected in circular traps devised by Hughes *et al.* (1987) using 1.5 mm nylon net. The collecting area was 0.25 m^2. Twelve traps in three plots (20×10 m) were installed 50 cm above ground. Litter was collected at approximately monthly intervals from October 1998 to October 2000. Litter collected from each trap was transported to the laboratory and oven-dried at 65°C for 48 hours. All dried samples were separated into leaf, bark, flowers, acorn, woody and miscellaneous components, and each portion was weighed.

2.3. Litter Decomposition and Nutrient Concentration

Mass loss and nutrient release in decomposing litter were estimated using the litterbag techniques employing 30×30 cm nylon bags with a 1.5 mm mesh size. Fresh leaf litter from the site was collected during the heavy litterfall season (late November) in 1998. Collected litter samples were dried to constant mass at room temperature for 14 days and sorted into representative deciduous foliage in the stands. Ten grams of litter of air-dried three dominant tree species (*Q. serrata, C. laxiflora, C. cordata*) was weighed to the nearest 0.01 g and placed in numbered litter bags. Subsamples from each litter type were also taken to determine the oven-dried mass at 65°C for 48 hours. The litterbags were randomly placed on the forest floor on 4 December 1998. The twenty-seven bags (3 plots×3 species×3 replications) in each sampling time were collected on five occasions over the study period. Collected bags were oven-dried at 65°C for 48 hours. Litter in the bag was cleaned by gentle brushing with a soft paintbrush to remove mineral soil and weighed to determine litter mass loss rates.

Litterfall and litter in the bag were ground in a Wiley mill to pass a 40-mesh stainless steel sieve. All nutrients (N, P, K, Ca, Mg) were analyzed by the standard method of the National Institute of Agriculture Science and Technology (1988).

III. RESULTS AND DISCUSSION

3.1. Litterfall and Nutrient Inputs

The mean annual litterfall at the Kwangneung DK site was 5,627 kg/ha/yr (Table 1). Litterfall production in the present study is comparable to values reported in other Korean temperate deciduous forests (Kim *et al.* 1997). Leaf litter was the major component of total

Table 1. Annual litterfall inputs (kg/ha) at the Kwangneung DK site

Year	Leaf litter				Other tree component					
	Q. serrata	*C. laxiflora*	*C. cordata*	Others	Bark	Branch	Acorn	[1]Repr.	[2]Misc.	Total
1998-1999	2,583	480	118	112	54	1,215	632	204	457	5,651
1999-2000	2,510	584	157	447	449	685	104	196	668	5,604

[1]Repr.: Reproductive parts except acorn
[2]Misc.: Miscellaneous

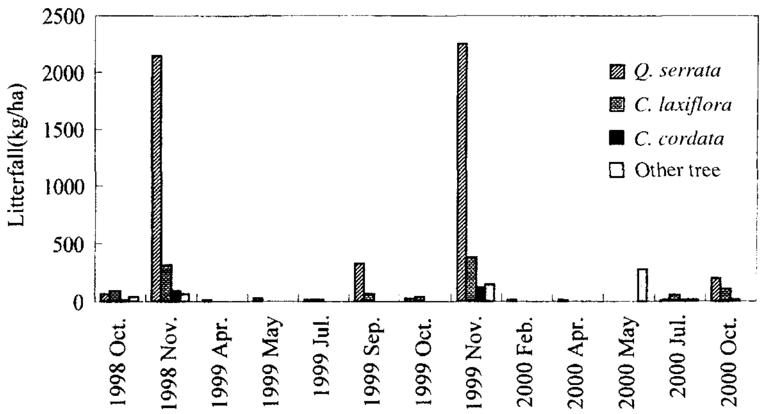

Fig. 1. Monthly patterns of leaf litter inputs at the Kwangneung DK site.

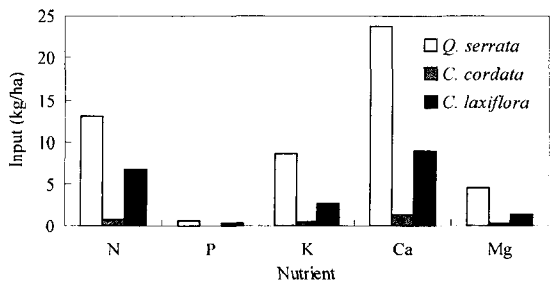

Fig. 2. Nutrient inputs by annual leaf litter at the Kwangneung DK site.

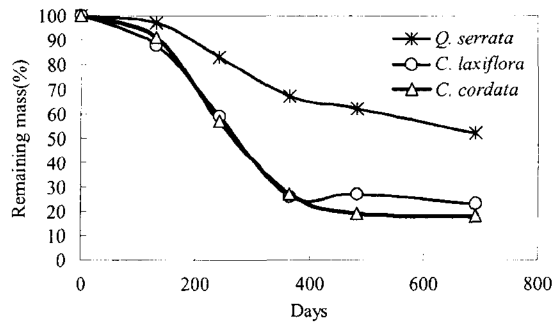

Fig. 3. Remaining mass of leaf litter for two years at the Kwangneung DK site.

litterfall in the stands. Leaf litter accounted for 61% of the total annual litterfall, followed by branch (16%) > miscellaneous (10%) > acorns (6%) > bark (4%). In seasonal variation, the heavy litterfall month in the site was November (Fig. 1). Litterfall production during this period involved 53% of the annual litterfall.

Nutrient inputs (kg/ha/yr) by leaf litter were highest in Ca (34.0), followed by N (20.5) > K (11.8) > Mg (6.0) > P (1.0) (Fig. 2). A *Q. accutisima* stand in the Kwangneung area showed a similar nutrient distribution pattern that is highest in Ca and lowest in P (Kim *et al.* 1997). *Q. serrata* (67.1 kg/ha/yr) among dominant tree species was a major contributor of the nutrient inputs in the site, followed by *C. laxiflora* (20 kg/ha/yr) *and C. cordata* (2.7 kg/ha/yr).

3.2. Litter Decomposition

Mass loss rates for two years from decomposing litter were *Q. serrata* < *C. laxiflora* < *C. cordata*. Mass loss rates were lowest in *Q. serrata* litter among the three litter types (Fig. 3). About 48% of the original mass in the *Q. serrata* litter disappeared, while about 77% in *C. laxiflora and* 84% in *C. cordata* disappeared. Lower mass loss in *Q. serrata* litter may be attributed to the difference of substrate quality such as lower nitrogen concentration compared with the other litter types (Fig. 4). Also three litter types showed different morphological characteristics which are a thin and smooth leaf litter in *C. laxiflora* and *C. cordata* and a thick and tough litter in *Q. serrata.*

3.3. Changes in Nutrients Concentrations

Nitrogen concentration of decomposing litter in the three litter types increased over the study period (Fig. 4). The species over the study period could be ranked in terms of N concentration: *C. cordata* > *C. laxiflora* > *Q. serrata*. Many studies have noted increased N concentration in litter during decomposition processes (Berg 1988, van Vuuren and van der Eerden 1992). This increase could be due to microbial or non-microbial

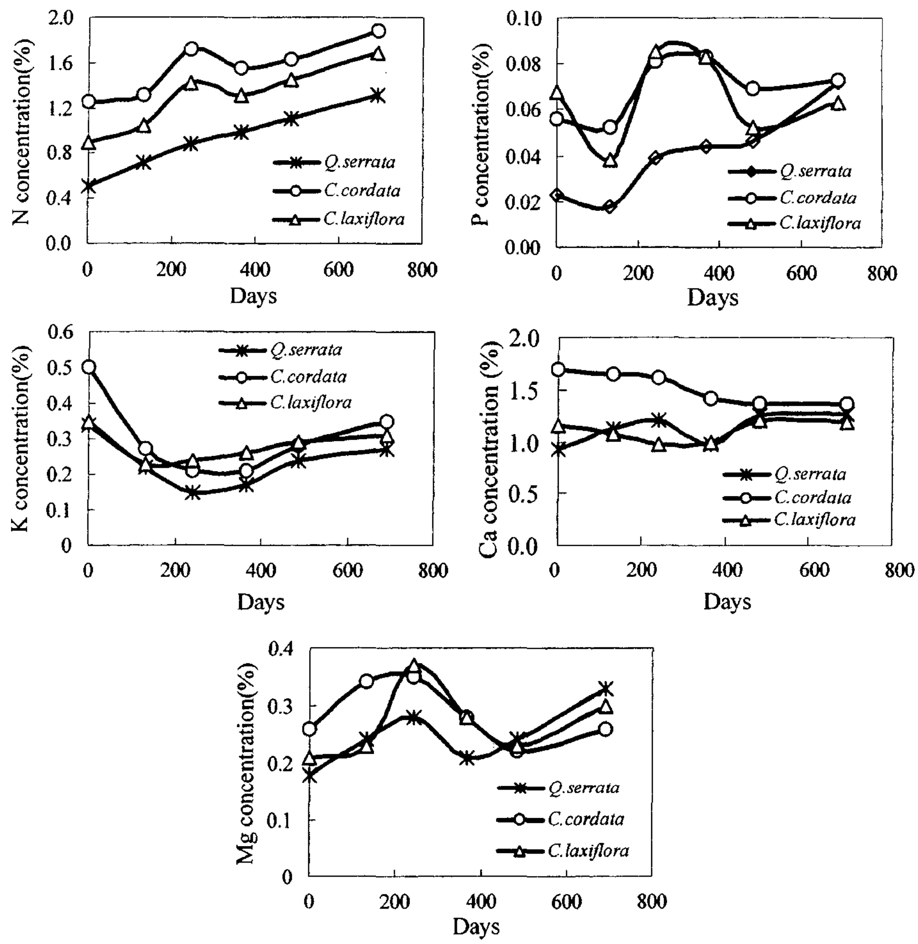

Fig. 4. Nutrient concentration change of decomposing litter at the Kwangneung DK site.

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 (Bockheim and Jepsen 1991). Fungal mycelia contain 3~5% N on a dry mass basis and have the capacity to translocate N from organic and mineral soil layers during litter decomposition. Also, microorganisms decomposing litter can take up ^{15}N applied in artificial rain water (van Vuuren and van der Eerden 1992). If a portion of this N could be absorbed by decomposing litter, it could influence the gains of N in decomposing litter.

It is difficult to explain the variation in P concentrations of three litter types during the study period (Fig. 4). Phosphorus concentration decreased during the initial stage of decomposition, but increased after one year. Similar patterns were observed in the litter of other hardwoods, such as flowering dogwood, red maple, and chestnut oak (Blair 1988). Phosphorus concentrations were also higher in *C. laxiflora* and *C. cordata* than in *Q. serrata* litter. Higher P concentration in *C. laxiflora* and *C. cordata* litter may be due to the rapid loss of dry matter throughout decomposition processes.

Potassium was the most readily released element compared with other nutrients because potassium is present in litter as a water soluble nutrient (Fig. 4). Potassium concentration dropped rapidly during the first 5 months of litter incubation and then stabilized. Rapid release of K early in litter decomposition processes is a commonly observed phenomenon in other litter decomposition studies (Lisanework and Michelsen 1994, You *et al.* 2000).

Calcium showed similar concentrations during the litter decomposition processes (Fig. 4). Calcium which is a structural component in cell walls of a leaf is present in plant tissues in the form of calcium ions or insoluble salts in the vacuoles (Bockheim and Jepsen 1991). It is firmly bound as calcium pectates in the cell walls. This result suggests that calcium may have fewer leaching characteristics compared with other nutrients.

Magnesium concentration generally tended to increase over the study period (Fig. 4). Magnesium is generally mobile in litter and vulnerable to leaching. The increase of Mg concentration in three litter types may be due to rapid loss of dry matter throughout decomposition processes.

The rapid loss of N was observed in *C. cordata* and *C. laxiflora* litter, while amounts of N in *Q. serrata* increased slightly during the decomposition processes (Fig. 5). Compared with *Q. serrata* litter, the release of N in *C. cordata* and *C. laxiflora* litter may be attributed to rapid loss of dry mass in both litter types (Fig. 3). A similar result was observed in mixed litter of *Q. serrata, C. laxiflora,* and *C. cordata* in the Kwangneung area (You *et al.* 2000).

The amounts of P during early decomposition stages declined rapidly, but P levels in *Q serrata* litter after the late stages exceeded the initial values in decomposed litter (Fig. 5). This result suggests that *Q. serrata* litter is subject to immobilization by microorganisms in decomposing leaf litter. Phosphorus levels in *C. laxiflora* and *C. cordata* litters over the 2-year period did not exceed the initial values in decomposed litter, indicating that organic P was mineralized from litter and released

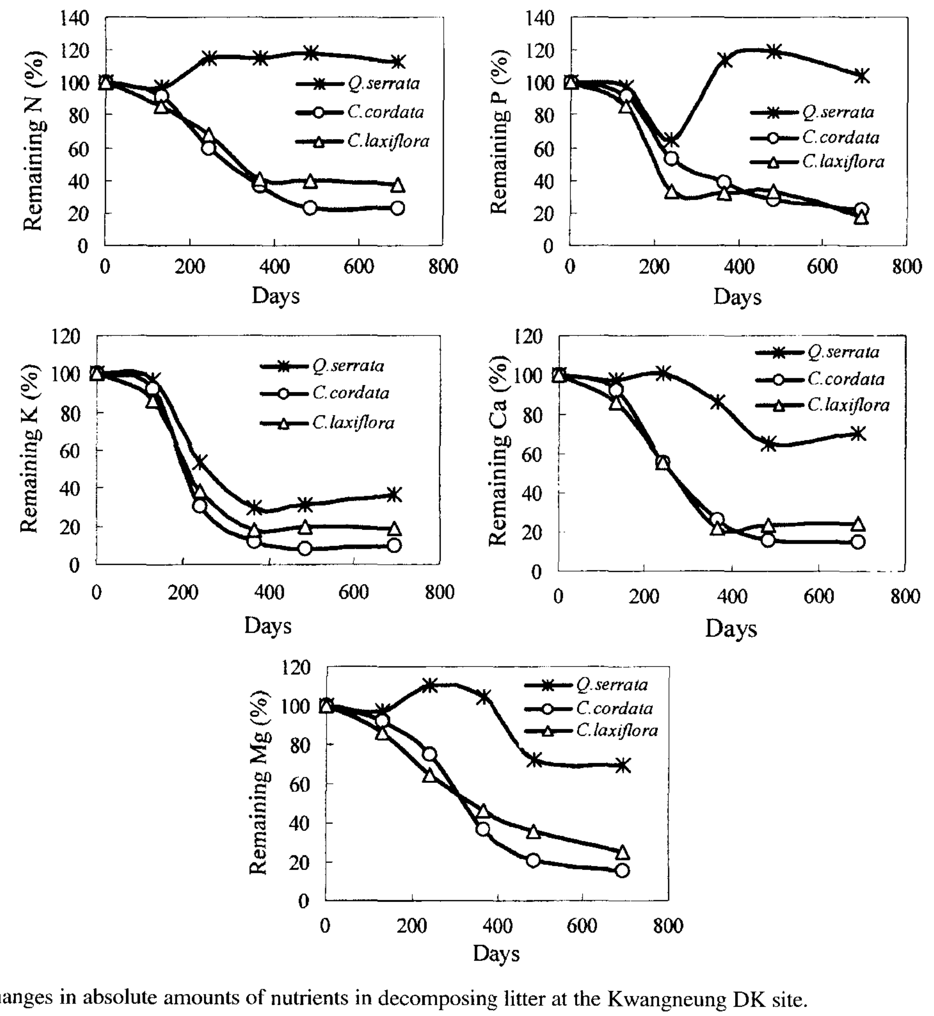

Fig. 5. Changes in absolute amounts of nutrients in decomposing litter at the Kwangneung DK site.

to the soil.

Absolute amounts of K decreased for all species over the study period (Fig. 5). Other studies reported a similar loss in K (Bockheim and Jepsen 1991, You *et al.* 2000) due to water-soluble characteristics as nonstructural components in plants. Potassium release was greater for *C. laxiflora* and *C. cordata* than for *Q. serrata*.

Calcium amounts in *Q. serrata* litter remained constant for the 1-year period and decreased after a 1-year incubation. However, Ca was released in two other *Capinus* litters over the study period. You *et al.* (2000) reported a decrease in Ca during leaf litter decomposition.

Magnesium showed a trend similar to that of Ca. However, the release pattern of Mg varied according to species. The absolute amounts of Mg declined for all three species in the late stages of decomposition. Compared with *Q. serrata* litter, magnesium was released rapidly in decomposing *C. laxiflora* and *C. cordata* litter. Bockheim and Jepsen (1991) reported a loss in Mg in decomposing leaf litter.

These results indicate that nutrient mobility release pattens varied in relation to leaf litter types. The relative release of nutrients was lower in *Q. serrata* litter than in *C. cordarta* and C. *laxiflora* litter.

적 요

산림생태계에서 낙엽낙지의 유입과 유입된 낙엽낙지의 분해는 산림의 주요한 탄소 및 양분의 공급원이다. 본 연구는 온대중부지역에 속하는 경기도 광릉의 천연활엽수림에 위치한 DK-site를 대상으로 2년 동안 연 낙엽낙지 유입량과 낙엽분해율을 측정하였다. 낙엽낙지량은 원형의 낙엽수집기(수집면적 0.25 m^2)를 낙엽분해율은 30×30 cm 크기의 낙엽분해주머니(메쉬 1.5 mm)를 이용하였다. 광릉 장기생태연구조사구의 연 낙엽낙지량은 5,627 kg/ha/yr으로 이중 순수한 엽량은 총 낙엽낙지량의 61%를 차지하였다. 수종별 유입량은 본 조사구의 우점종인 졸참나무 잎이 가장 많은 양을 보였으며 서어나무, 까치박달 순이었다. 낙엽분해율은 서어나무, 까치박달 낙엽이 졸참나무 낙엽에 비해 분해속도가 빨라 2년의 조사기간 동안 까치박달 낙엽 84%, 서어나무 낙엽 77%, 졸참나무 낙엽 48%가 분해되었다. 졸참나무 낙엽의 분해가 느리게 진행된 것은 타수종의 낙엽에 비해 졸참나무 낙엽내 낮은 양분함량 같은 기질의 차가 원인인 것으로 나타났다. 칼륨을 제외한 양분(N, P, Mg) 함량은 분해 초기함량에 비해 낙엽분해과정동안 증가하였다. 또한 낙엽분해과정동안 양분(N, P, K, Ca, Mg)의 방출량은 까치박달과 서어나무낙엽이 졸참나무낙엽에 비해 신속한 것으로 나타났다. 본 연구결과에 따르면 광릉장기생태연구 조사구내 우점종의 낙엽분해와 양분의 동태는 동일한 입지에 있어서도 수종간에 상당한 차이를 나타내었다.

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