The Decomposition of Leaf Litters of Some Tree Species in Temperate Deciduous Forest in Korea
Ⅱ. Changes in Nutrient Content During Litter Decomposition

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ABSTRACT : Dry weight loss and nutrient release from leaf litter for six tree species were studied using litter bag methods. The litter bags were incubated for 16 months on the forest floor in temperate deciduous forest in Mt. Cheonma, located at the middle part of Korean Peninsula. The changes in nutrient content and the rate of dry weight loss in leaf litter varied with litter types. The litter of *Pinus densiflora* showed the lowest rate of mass loss (k=0.33), nitrogen concentration (0.89%) and ash concentration (2.50%), while showed the highest C/N ratio (63.40). On the other hand, the litter of *Acer pseudo-sieboldianum* showed the fastest rate of mass loss (k=0.82), the highest nitrogen concentration (1.11%), and the lowest C/N ratio (49.40). During the decomposition, nitrogen, phosphorus and calcium in the leaf litters showed relatively slow decreasing pattern compared to other elements (carbon, potassium, magnesium, manganese and sodium), but potassium and sodium decreased at early stage of the decomposition for all leaf litters.

Differences in annual decomposition rates of litter among species were consistent with the particular chemical characteristics of their leaf litters. The initial concentration of nitrogen was positively correlated with litter decomposition rate for six species, while litter decomposition rate of six species was negatively correlated with C:N ratio of initial leaf litters.

Key words : C:N ratio, Decomposition rate, Litter decomposition, Nutrient elements

INTRODUCTION

Litter decomposition is the fundamental process of terrestrial ecosystem because it is a major determinant of nutrient cycling and regulator of nutrient availability needed for plant growth. The decomposition consists of three basic processes; biological action, weathering and leaching (Swift *et al.* 1979, Moretto *et al.* 2001, Koukoura *et al.* 2003). Therefore, soil biota, litter quality and physicochemical environment are very important factors affecting the decomposition rate.

Plant nutrients are released from litter either by physical leaching or breakdown of structural organic components by soil organisms. The rates at which elements are released from litter are generally governed by the rate of dry weight loss during decomposition. However, each nutrient releases at different rate and exhibits different release patterns because the chemical composition and litter quality are dependent on the litter types.

Inorganic non-structural elements such as sodium, potassium, magnesium and manganese are susceptible to initial leaching (Gosz *et al.* 1973, Bockheim *et al.* 1991, Laskowski *et al.* 1995, Semwal *et al.* 2003). In addition, the release of organic structural elements are affected by litter quality such as chemical composition, palatability and hardness (Melillo *et al.* 1982, Taylor *et al.* 1989, Cotrufo *et al.* 1995, Moretto *et al.* 2001, Smith and Bradford 2003).

After a study about the decomposition rate of some litter in Korea by Kim and Chang (1965), Kwak and Kim (1992) and Mun and Pyo (1994) surveyed the release of plant nutrients during decomposition of the litter.

In this study, we studied the mass loss and release of major nutrient elements from the decomposing leaf litter of tree species dominated in temperate forest in the middle part of Korean Peninsula, and examined the releasing pattern of each nutrient for 16 months of experimental period. Also, we investigated the relationship between dry weight loss of litter and litter quality such as chemical composition and C/N ratio in the fresh leaf litter.

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MATERIALS AND METHODS

Study site

This study was conducted for 16 months (Nov. 1993~Mar. 1995) in a natural secondary oak forest dominated by *Quercus mongolica* (DBH 5~20cm) in Mt. Cheonma (127° 17′ E, 37° 40′ N). The understory vegetation was dominated by *Disporum smilacinum*, *Carex siderostica*, *Smilax nipponica*, etc. and showed 80% coverage. The soil is a sandy loam with pH 5.9 and brown forest soil with well developed soil horizons. More details on the experiment site were provided by Yang and Shim (2003).

Litter bag experiment

Fresh leaf litter of the six dominant species (*Quercus mongolica, Q. serrata, Carpinus laxiflora, Pinus densiflora, Acer pseudo-sieboldianum* and *Betula ermani*) was collected in Oct. 1993 from the study area. In nylon litter bag (18 cm × 18 cm) with 1.3 mm × 1.3 mm mesh size, about 2 g of leaf litter was placed. Total 720 litter bags were placed in an area of 100 ㎡ and arranged in a randomized complete block design. All litter bags were numbered and naturally placed on the litter layer. The litter bags were retrieved with ten replications for each litter at an interval of about 3 months.

Analysis of litter samples

The retrieved and dried litter samples were weighed and ground with Willy mill to pass through 1mm sieve for chemical analysis. The ash after sample ignition at 500℃ for 4hr dissolved in HCl (1:1), and then diluted with H_2O and filtered through Whatman No. 1. This filtrate was used for determination of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn) and sodium (Na) using Inductively Coupled Plasma (ICP) Atomic Emission Spectrometer (Jobin Yvon JY-24) by a method by Helrich (1990).

Total carbon (C) was analyzed using 25mL 0.0675M chromic acid mixture and 0.4M $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ solution by rapid titration method (Allen *et al.* 1974). Total nitrogen (N) was analyzed by semi-micro Kjeldahl procedure after digestion in 2g K_2SO_4+HgO catalyst and 3mL concentrated H_2SO_4. The concentrations of all elements except C and N are the results of three replicates.

Calculation

By combining these results with data on dry weight loss, the remaining amounts of each element after different incubation periods were calculated. Percentage of the nutrient remaining in decomposing leaf litter was derived from the equation below.

$$\% \text{ Nutrient remaining} = (C / C_0) \times (\text{DM} / \text{DM}_0) \times 100$$

Where C is the concentration of element in the leaf litter at the time of sampling; C_0 is the concentration of the initial litter used for decomposition; DM is the mass of dry matter at time of sampling; and DM_0 is the mass of initial dry matter of the litter sample used for decomposition (Bockheim *et al.* 1991).

The decomposition constant (k) of nutrient release was calculated by Olson's $X = X_0e^{-kt}$, where X_0 is the initial amount of litter, X is the amount of litter remaining after time t, and t is the time (in years), respectively (Olson 1963). All statistical analyses were conducted using statistical analysis package of MINITAB (MINITAB 2002).

RESULTS AND DISCUSSION

Dry weight loss

The remaining of dry weight of each litter in litter bag was decreased with time. The slopes k of all parameters of the regression $X = X_0e^{-kt}$ are given in Table 1.

To investigate the pattern of dry weight loss with time, percentage of dry weight remaining was regressed against the time (days) as exponential equation. The regression equations for six species litters are given in Table 1. In all cases, the determination coefficient (r^2) was significant at P<0.001.

Nutrient element dynamics in the decomposing leaf litter

The percentage of C remaining in decomposing leaf litters for six species were decreased with time. The extent of C loss varied with species; *Q. mongolica, Q. serrata* and *P. densiflora* with relatively small decrease in C content compared to those of other three species (Fig. 1(B)). Also, the pattern of C loss was similar to that of dry weight loss (Fig. 1(A)).

Nitrogen release after four months was fastest in *A. pseudo*

Table 1. Relationship between percentage dry weight remaining of six species litters (y) and number of days elapsed (x)

Species	Decomposition constant(k*)	Regression equation	r^2
Q. mongolica	0.43	$y = 100.30 \times e^{-0.0013x}$	0.94
Q. serrata	0.37	$y = 100.50 \times e^{-0.0012x}$	0.93
C. laxiflora	0.75	$y = 99.11 \times e^{-0.0022x}$	0.97
P. densiflora	0.33	$y = 100.26 \times e^{-0.0010x}$	0.95
A. pseudo-sieboldianum	0.82	$y = 94.12 \times e^{-0.0024x}$	0.94
B. ermani	0.66	$y = 96.64 \times e^{-0.0020x}$	0.94

* Data from Yang and Shim (2003).

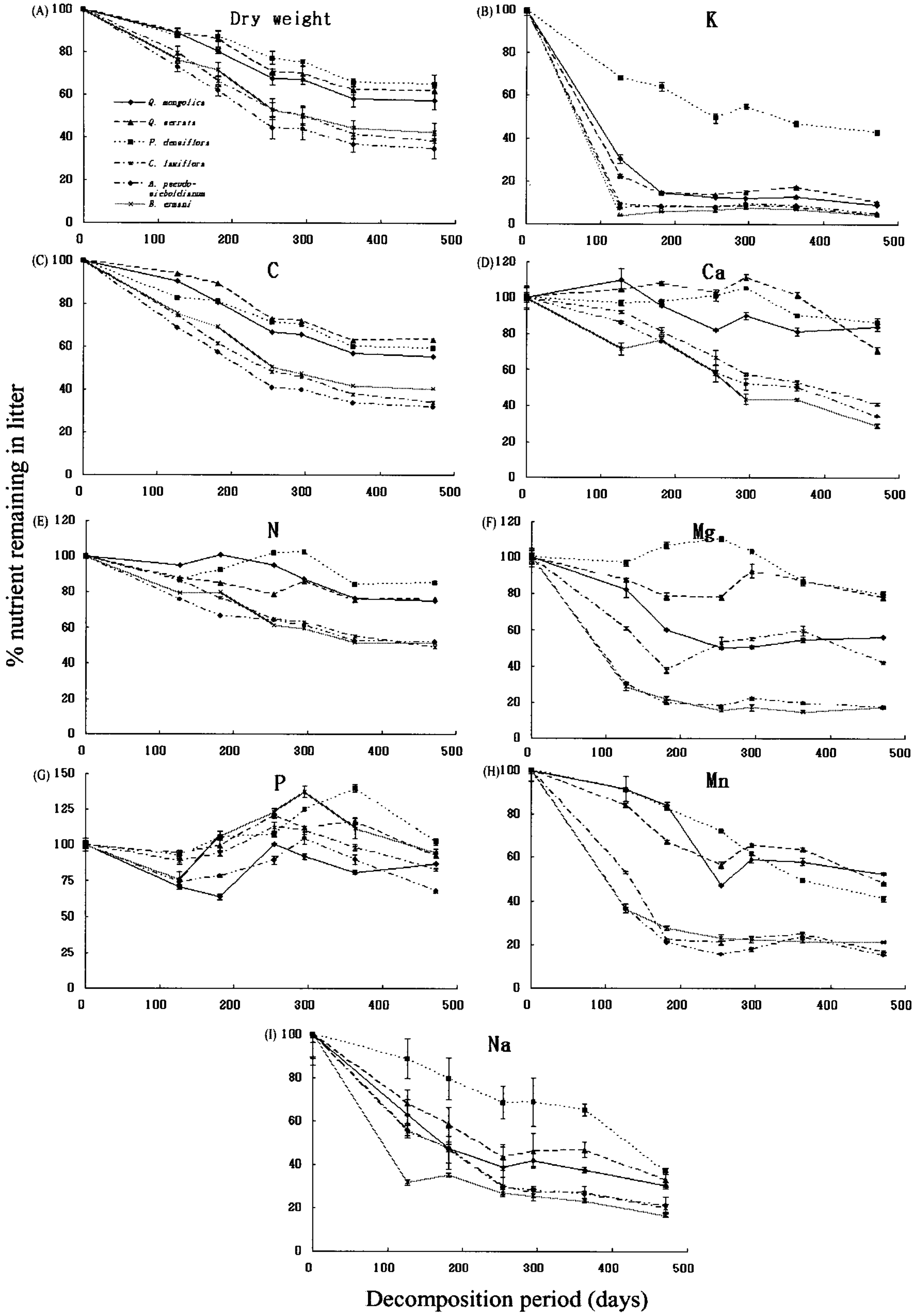

Fig. 1. Dry weight and nutrients remaining (%) in the litter bags for six tree species with various collection time intervals in Mt. Cheonma, south Korea. The vertical lines represent a standard deviation. (A)is data from Yang and Shim (2003).

sieboldianum (24%), whereas *Q. mongolica* showed only 5.5% release rate (Fig. 1(C)). The release of N was relatively lower than dry weight loss in all species (Fig. 1(A)). Increases of N content in pine litter might be due to the input from the environment. Similar accumulations of N have been observed in many litter bag experiments and were probably the results of one or more processes including absorption of N from atmospheric precipitation or imports of N in fungal hyphae and contaminating debris (Bocock 1963, Gosz *et al.* 1973, Lousier and Parkinson 1978, Berg and Staaf 1981).

The release rate of P was slower than the dry weight loss of the litter from all species (Fig. 1(A)). Also, there was an accumulation of P in the litter for all species (Fig. 1(D)), which might result from the microfauna on the litter (Will 1967). Potassium showed the fastest release rate, particularly much of it was released in the early stage of decomposition (Fig. 1(E)). Several studies reported that since the initial content of K in the litter was beyond the decomposer demand and K was not structural component of plant tissue, it could be released easily (Gosz *et al.* 1973, Brown 1974).

Attiwill (1967) and Upadhyay and Singh (1989) indicated that Ca was much less susceptible to leaching and was a more important structural component of leaf tissue than K and Na. The pattern of Ca loss from the litter of *C. laxiflora*, *A. pseudo-sibodianum* and *B. ermani* was closely paralleled with that of weight loss throughout decomposition (Fig. 1(F), Fig. 1(A)). Calcium release rate in *Q. mongolica*, *Q. serrata* and *P. densiflora* was slower than dry weight loss. Also, Ca of these species seemed to be temporarily immobilized during decomposition. Many workers reported that the Ca may be transferred from the forest floor to the decomposing litter through attached fungal hyphae (Fahey 1983, Waring and Schlesinger 1985).

The dynamic patterns of Mg content differed among species (Fig. 1(G)). The differences may be a consequence of the difference in the initial Mg concentration of the leaf litter. *A. pseudo-sieboldianum* and *B. ermani* had relatively high initial Mg concentrations (%), which were 0.248 and 0.324, respectively, compared with *Q. serrata* (0.087) and *P. densiflora* (0.050) (Table 3). So, Mg in litter for *A. pseudo-sieboldianum* and *B. ermani* was more rapidly released than that of other species. This suggests that a certain quantity of Mg was required by decomposer and that in excess was easily released (Gosz *et al.* 1973).

In *Q. serrata, P. densiflora* and *Q. mongolica*, the release rates of Mn were similar to those of dry weight loss and in *C. laxiflora, A. pseudo-sieboldianum* and *B. ermani* the release rates of Mn were much faster than those of dry weight loss (Fig. 1(H), Fig. 1(A)).

The release rate of Na was faster than dry weight loss for all species (Fig. 1(I), Fig. 1(A)). Evidently Na were actively leached so that the litter residue had a lower content than the original litter as shown by K in this study. Almost half of Na was leached from decomposing litter for *Q. mongolica* and *Q. serrata* within 6 months, and a third of the initial content remained after 1.5 years. In *B. ermani*, almost 68% of initial content of Na was released from decomposing litter within first 4 months.

In terms of the releasing rate calculated, the releasing rate of K showed the highest in all species except for *P. densiflora* (Table 2). *A. pseudo-sieboldianum* showed the highest rate of release for C, P,

Table 2. Nutrient releasing rate of six tree species leaf litter in Mt. Cheonma, south Korea. The calculation of the releasing rate was based on Olson's equation $X = X_0e^{-kt}$

Nutrients \ Species	*Q. mongolica*	*Q. serrata*	*C. laxiflora*	*P. densiflora*	*A. pseudo-sieboldianum*	*B. ermani*
Carbon	0.46	0.36	0.83	0.41	0.89	0.70
Nitrogen	0.23	0.21	0.55	0.13	0.51	0.52
Phosphorus	0.11	0.06	0.14	ND	0.30	0.04
Potassium	1.86	1.78	2.42	0.66	2.29	2.34
Calcium	0.14	0.27	0.69	0.12	0.83	0.96
Magnesium	0.45	0.19	0.67	0.17	1.37	1.36
Manganese	0.50	0.56	1.37	0.69	1.44	1.19
Sodium	0.92	0.86	1.24	0.77	1.20	1.38

ND; not-determined.

Mg and Mn. The highest rate of release for N and K was observed in *C. laxiflora* and the lowest in *P. densiflora.* The highest rate of release for Ca and Na was observed in *B. ermani* and the lowest in *P. densiflora.* The latter also showed the lowest rate of release for Mg.

Initial chemical composition of leaf litter and dry weight loss

Chemical composition of leaf litter in the present study was highly variable (Table 3). N concentration of initial litter was highest for *A. pseudo-sieboldianum* (1.11%) and lowest for *P. densiflora* (0.89%). *P. densiflora* had the lowest concentration of Ca, K, Na, Mn and Mg. This resulted in the lowest content of ash in *P. densiflora.* Waring and Schlesinger(1985), Taylor *et al.*(1989), Moretto *et al.*(2001) and Koukoura *et al.*(2003) reported the differences in concentration of each element within litter species. Melillo *et al.*(1982), Taylor *et al.*(1989), Cotrufo *et al.*(1995) and Smith and Bradford (2003) suggested that litter decomposition rate was dependent not only on these chemical composition of litter but also on climate and soil biodiversity.

Each leaf litter samples showed similar C concentration but exhibited various N concentration among the species. Therefore, C:N ratio of the leaf litter in this study was determined by N concentration. Pine showed the lowest N concentration (0.89), oak species about 0.9%, and maple and birch above 1%. The highest C:N ratio was 63.4 in *P. densiflora* and the lowest C:N ratio was 49.4 in *A. pseudo-sieboldianum.* This difference in C:N ratio might account for the lowest decomposition rate of *P. densiflora* and the highest of *A. pseudo-sieboldianum.*

The correlation between dry weight loss of each leaf litter and their initial N concentration showed a positive relationship, while dry weight loss of each leaf litter showed negative relationship with C:N ratio (Fig. 2). The C:N ratio of the leaf litter of quickly decomposing species (*A. pseudo-sieboldianum* and *C. laxiflora*) were lower than those of other species with slow decomposition rate (*P. densiflora* and *Q. serrata*).

Many previous workers also found such positive relationship (Taylor *et al.* 1989, Constantinides and Fownes 1994, Cotrufo *et al.* 1995, Jamaludheen and Kumar 1999, Smith and Bradford 2003). Cotrufo *et al.* (1995) and Smith and Bradford (2003) defined that good quality of litter showed high content of N and low value of C:N ratio. This litter quality provides palatable or unpalatable sources to the soil organism (Moretto *et al.* 2001), controls decomposition of hardwood leaf litter (Melillo *et al.* 1982) and could be used as predictors of litter decay rates (Taylor *et al.* 1989). Salamanca *et al.*(2003) reported leaf litters of *Q. serrata* and *Q. accutissima* with lower C:N ratio were decomposed faster than *P. densiflora* with higher C:N ratio.

In conclusion, *Pinus densiflora* showed the lowest rate of mass loss, nitrogen concentration and ash concentration, while showed the highest C/N ratio. However, *Acer pseudo-sieboldianum* showed the fastest rate of mass loss, the highest nitrogen concentration, and the lowest C/N ratio. Nitrogen, P and Ca in the leaf litters showed relatively slow decreasing pattern compared to other elements, but K and Na decreased at early stage of the decomposition for all leaf

Table 3. Initial concentrations of chemical elements in leaf litters of six species in Mt. Cheonma

Nutrient \ Species	*Q. mongolica*	*Q. serrata*	*C. laxiflora*	*P. densiflora*	*A. pseudo-sieboldianum*	*B. ermani*
Carbon	52.99	51.87	56.60	56.43	54.83	52.83
Nitrogen	0.96	0.91	1.06	0.89	1.11	1.04
Phosphorus	0.049	0.041	0.048	0.012	0.040	0.029
Potassium	0.198	0.145	0.200	0.018	0.183	0.230
Calcium	1.179	0.893	0.868	0.399	1.075	1.595
Magnesium	0.167	0.087	0.107	0.050	0.248	0.324
Manganese	0.102	0.093	0.118	0.060	0.094	0.126
Sodium	0.044	0.036	0.041	0.022	0.037	0.052
C/N ratio	55.20	57.00	53.40	63.40	49.40	50.80
Ash	8.21	5.30	6.77	2.50	7.10	8.20

Values in % of dry weight.

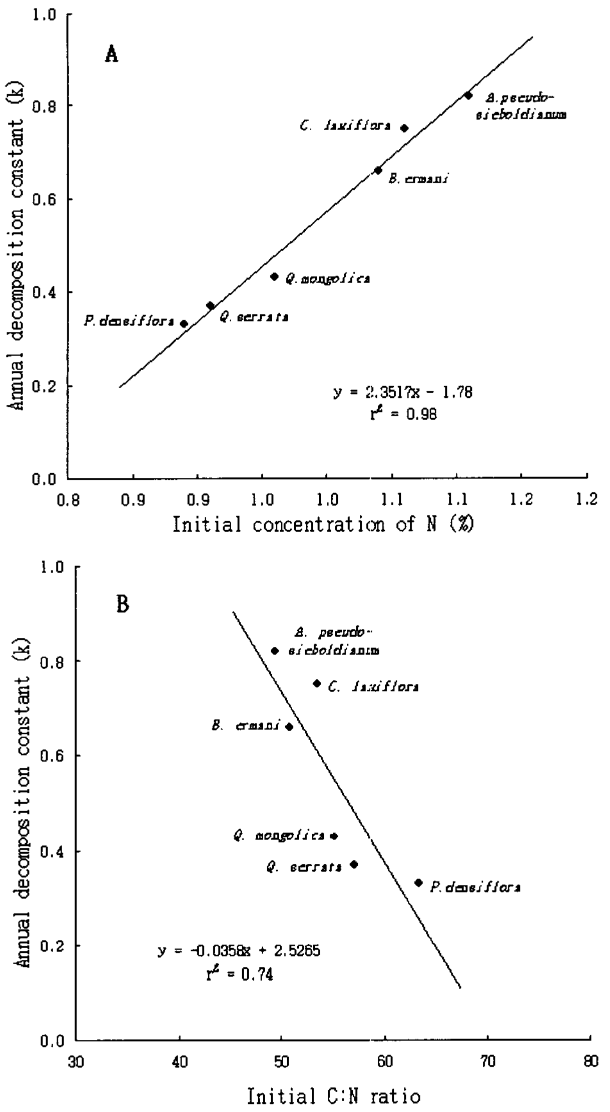

Fig. 2. Results of linear regressions of annual decomposition constants (k) of six species leaf litters against initial nitrogen concentration (A) and C:N ratio (B).

litters.

Annual rates of litter decomposition among species showed close associations with the particular chemical characteristics of their leaf litters. Also, the initial concentration of nitrogen exhibited a positive relationship with litter decomposition rate for all species, while litter decomposition rate of six species was negatively correlated with C:N ratio of initial leaf litters.

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