The Decomposition of Leaf Litters of Some Tree Species in Temperate Deciduous Forest in Korea
Ⅰ. Losses in Dry Weight of Leaf Litter

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ABSTRACT : Losses in the dry weight of leaf litter from six tree species were studied during 16 months on the forest floor in temperate deciduous forest of Mt. Cheonma in the vicinity of Seoul in Korea by using litter bag method. The decomposition rate of each leaf litter varies with each species. After 16 months elapsed, the leaf litter of *Acer pseudo-sieboldianum* showed the highest decomposition constant (0.82) as Olson's decomposition constant, while that of *Pinus densiflora* showed the lowest decomposition constant (0.33). The decomposition constant of *Quercus mongolica, Q. serrata, Betula ermani* and *Carpinus laxiflora* showed 0.43, 0.37, 0.66 and 0.75, respectively.

The decomposition constant of leaf litter was considered with temperature and precipitation which accumulated daily during each term of litter bag collection. The decomposition constant of leaf litter showed closely positive correlation with daily accumulative temperature and precipitation. The relationships between decomposition constant and the daily accumulative temperature and precipitation at each period of litter bag collection were analyzed through multi-regression analysis. The correlation coefficients as a result of multi-regression analysis in *Q. mongolica, Q. serrata, P. densiflora, B. ermani, C. laxiflorais* and *A. pseudo-sieboldianum* were 0.83, 0.81, 0.69, 0.77, 0.77 and 0.62, respectively. The precipitation showed higher effect, about 10 times, on the leaf litter decomposition than the daily accumulative temperature.

Key words : Decomposition rate, Leaf litter decomposition, Litter bag method

INTRODUCTION

The functioning of ecosystems can be recognized as occurring within three distinct subsystems, the plant subsystem, the herbivore subsystem and the decomposition subsystem. The integrity of the ecosystem is maintained by the transfers of matter and energy between these subsystems. The decomposition subsystem performs two major functions, the mineralization of essential elements and the formation of soil organic matter. The rate of movement of essential nutrient elements and balance between primary production and decomposition through the decomposition subsystem is an important regulator of primary production, ecosystem structure, and internal ecosystem dynamics (Swift *et al.* 1979).

The leaf litter decomposition in forest floor is an important process as the nutrient flow and development in the terrestrial ecosystem, and development of other subsystems. These decomposition rates largely depend on climatic factors (Meentemeyer 1978, Swift *et al.* 1979, Whitford *et al.* 1986), quality and chemical component of litter (Shlesinger and Hasey 1981, McClaugherty *et al.* 1985, Berg and Staaf 1987, Upadhyay *et al.* 1989, Gallardo and Merino 1993), and edaphic factor as soil microbial and faunal decomposer (Vossbrinck *et al.* 1979, Berg *et al.* 1980).

The studies on the litter decomposition in South Korea have been proceeded since Kim and Chang (1965). They carried out the experiments on the decomposition rate of litter and mineral nutrient contents of soil. Kim and Chang (1967) reported litter decomposition rate and organic matter accumulation on pine and oak forest floor at Kwangneung. Park and Lee (1981) calculated decomposition constant (k) by using litter bag method at Mt. Chiri. Shim (1990) studied effects of microbial biomass and soil micro-arthropods on the decomposition of leaf litter of some tree species.

On the other hand, tree species largely grouped into four categories (subalpine, cool-temperate, warm-temperate deciduous, and warm-temperate evergreen species), according to thermal distribution (Yim 1977a). He suggested that the major tree species in subalpine,

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cool and warm temperate deciduous were *Betula ermani, Quercus mongolica, Q. serrata, Pinus densiflora, Carpinus laxiflora* and *Acer pseudo-sieboldianum.* We selected these major tree species leaf litter, which were used in this experiment.

This study was carried out to compare decomposition rate of each leaf litter in temperate deciduous forest in central Korea, and to find the relationship between the rate of dry weight loss and climatic factors such as temperature and precipitation.

MATERIALS AND METHODS

Experimental site

Our study was conducted in Mt. Cheonma (812.4 m, 127° 17′ E, 37° 40′ N) apart 20 km from Seoul in direction of NEE. This area shows the typical continental climate pattern, rainy summer and cold winter, and shows the typical temperate deciduous forest which dominated by *Quercus mongolica* community (Yim 1977b). According to the data of Seoul meteorological station, the annual precipitation was 1,055.8 ㎜, and the mean annual air temperature was 13.5℃ during the experimental period (Fig. 1).
The experimental site located at 410 m elevation and on the north-facing slope with 5～10 slope degree. This stand is a secondary forest of *Q. mongolica* dominate in the tree layer. *Q. mongolica, Styrax obassia, Symplocos chinensis* for. *pilosa, Corylus heterophylla* var. *thunbergii* and *Rhus trichocarpa* are dominate in the sub-tree layer. Shrub layer is dominated by *Euonymus sachalinensis, Stephanandra incisa, Weigela subsessilis, Rhododendron mucronulatum* and *Acer pseudo-sieboldianum. Disporum smilacinum* is most abundant species with 50～60% of coverage in the herb layer. More details on the vegetation of the area were given in Lee (1987).

The soil of the site is brown forest soil and has moderate soil moisture (32.1%), soil pH (5.9) and soil organic matter contents (12.8%).

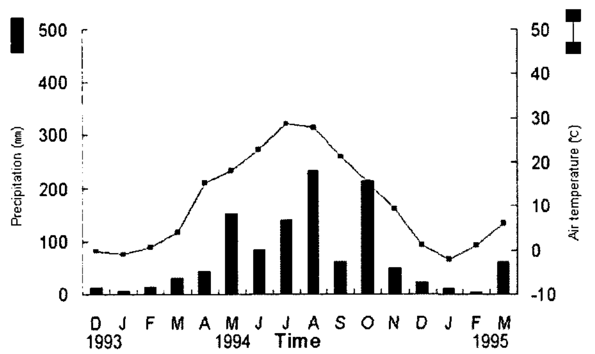

Fig. 1. Changes of monthly mean air temperature and precipitation during study period (from Seoul meteorological station).

Field Experiments

The freshly fallen leaf litters from six tree species (*Q. mongolica, Q. serrata, P. densiflora, C. laxiflora, A. pseudo-sieboldianum* and *B. ermani*) were collected during the leaf falling season. Contaminants of another leaf litter or debris were carefully eliminated from each litter collection and then litter samples were thoroughly dried at 60℃. The 2g samples of each litter collection were enclosed in polyethylene mesh bags of 18 ㎝ x 18 ㎝ with 1.7 ㎟ mesh size. One hundred twenty litter bags of each leaf litter were placed on the homogeneous forest floor on November 29, 1993. The litter bags were collected with ten replications for each litter species on 5 April, 29 May, 10 August, 20 September, and 27 November 1994, and 15 March 1995.

Measurement and calculation

For the dry weight determination of each leaf litter in collected litter bags, contaminants of other debris or soil particles carefully removed, and weighed after leaf litter was thoroughly dried at 60℃.

The amount of soil contamination was determined by igniting litter sample in the muffle furnace at 500℃ for 2 hr. The loss of dry weight in each leaf litter was determined by subtracting soil contamination from dry weight of the collected leaf litter.

According to the decomposition equation of Olson (1963), the annual decomposition constant (k) was calculated using the equation of $\ln(x_0/x_1) = kt$, where x_0 is the original amount of litter, x is the amount of litter remaining after time t, and t is the time (in years), respectively.

Other statistical analysis were carried out using statistical analysis package of MINITAB (MINITAB 2002).

RESULTS AND DISCUSSION

The dry weight loss of leaf litter

The changes in dry weight of each leaf litter remaining in the litter bag over the experimental period (471 days) were shown in Fig. 2. The dry weight loss of leaf litter of *A. pseudo-sieboldianum* showed the highest value, 65.15%, and that of *P. densiflora* showed the lowest value, 34.87%, respectively (Table 1). The dry weight loss of *Q. mongolica, Q. serrata, B. ermani* and *C. laxiflora* showed 42.63%, 38.17%, 57.20% and 61.99%, respectively. The six species may be separated into two groups on the basis of dry weight loss pattern; The dry weight loss of *B. ermani, A. pseudo-sieboldianum* and *C. laxiflora* disappeared faster than *Q. serrata, P. densiflora* and *Q. mongolica.* By Olson's equation, $\ln(x_0/x_1) = kt$, *k* values of each tree species ranged between 0.33 yr^{-1} for *P. densiflora* and 0.82 yr^{-1} for *A. pseudo-sieboldianum.* The half time (yr) in dry weight loss of *Q. mongolica, Q. serrata, C. laxiflora, P. densiflora, A. pseudo-*

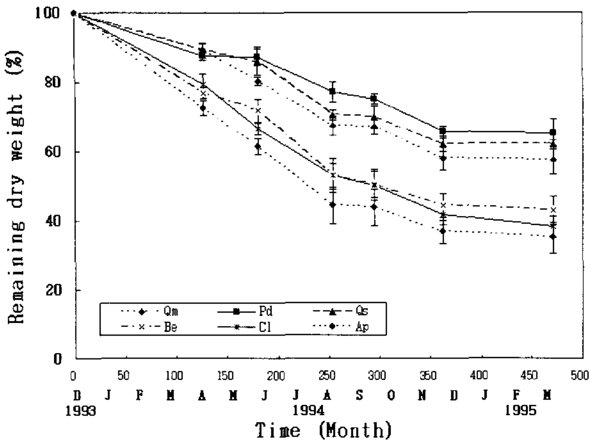

Fig. 2. The loss of dry weight in each leaf litter during 471 days study on litter layer of Mt. Cheonma. Qm (*Q. mongolica*), Pd (*P. densiflora*), Qs (*Q. serrata*), Be (*B. ermani*), Cl (*C. laxiflora*), Ap (*A. pseudo-sieboldianum*). Standard deviations are indicated, with N = 10 for each point.

sieboldianum and *B. ermani* litter was calculated 1.61, 1.86, 0.92, 2.09, 0.85 and 1.05, respectively (Table 1).

Tóth (1985) reported that k value for *Quercus petraea* was 0.435 yr^{-1} for 489 days. This result was consistent with our value (0.43 yr^{-1}) for *Q. mongolica* during similar decomposition period.

Decomposition constants of various litters from tree species in South Korea were listed in Table 2. Our values for k and half-time showed rapid decomposition rates compared with the rates in other studies, because k values estimated from our litter bag data were higher than other results by steady-state models of organic matter accumulation. These results assumed that experimental site of our study is secondary forest and is not steady-state. Shlesinger and Hasey (1981) reported that a steady state did not exist in the litter layers, and turnover rate was rapid in immature forest.

The relationships between dry weight loss and climatic conditions

The linear regression and multi regression analyses performed to identify the relative importance of temperature and precipitation on dry weight loss of leaf litter by using statistical analysis package, MINITAB. The decomposition constants (k) of each leaf litter were positively correlated with daily accumulative temperature at significant levels.

Linear regression analyses between the mass loss and precipitation during each collection interval indicated positive relationships (Table 3). The correlation between mass loss and precipitation in all leaf litters decomposition showed significant positive relationships. Values of correlation coefficient (r) of six species litters ranged between 0.62 and 0.80 (Table 3). In *Q. mongolica*, the correlation coefficient (r) between decomposition constant (k) with daily accumulative temperature, and precipitation were 0.69 and 0.79 respectively. These values were significant at $P < 0.10$, and $P < 0.05$ respectively. In *A. pseudo-sieboldianum*, daily accumulative temperature did not show any significant relationship with decomposition constant (k), while precipitation was significant. Precipitation alone accounts for 38%~64% of the variability in decomposition constant (day^{-1}) and daily accumulative temperature (℃ · day) accounts for 34%~62% of the variation in decomposition constant (day^{-1}) for six species litters. These results, based on all species, suggested that precipitation per experimental intervals was a more important factor in regulating dry weight loss for six species litters than daily accumulative temperature. Also precipitation appeared as better predictor of dry weight loss than daily accumulative tem-

Table 1. Decomposition rate, 'k' and other parameters of the leaf litter dry weight for six tree species

Tree species	Remaining biomass(%)*	Decomposition constant	Decay parameter	Half time	95% time
	mean±SD	k (yr^{-1})	1/k (yr)	0.693/k (yr)	3/k (yr)
Q. mongolica	57.37±4.12	0.43	2.32	1.61	6.97
Q. serrata	61.83±1.17	0.37	2.68	1.86	8.05
P. densiflora	65.13±4.10	0.33	3.01	2.09	9.03
C. laxiflora	38.01±3.18	0.75	1.33	0.92	4.00
A. pseudo-sieboldianum	34.85±4.49	0.82	1.22	0.85	3.67
B. ermani	42.80±3.95	0.66	1.52	1.05	4.56

* Mean ± SD(standard deviation); n = 10.

Table 2. Comparison of decomposition constants of various litters from tree species in south Korea

Tree species	Locality	Decomposition constant (yr-1)	Reference	Remark
Acer pseudosieboldianum	Mt. Jiri (35°19 ′ N)	0.674	Shim, 1990	$\ln(x_0/x_1)=kt$
Carpinus laxiflora	Mt. Halla(33°21 ′ N, 1,300m)	0.210	Park & Lee, 1981	$k=L/C_{ss}$*
C. laxiflora	Mt. Jiri (35°19 ′ N)	0.630	Shim, 1990	$\ln(x_0/x_1)=kt$
C. laxiflora	Kwangneung(450~650m)	0.269	Chang *et al.*, 1987	$k=L/C_{ss}$
C. laxiflora	Kwangneung	0.367	From Park & Lee, 1981	$k=L/C_{ss}$
C. laxiflora	Mt. Halla	0.174	Chang *et al.*, 1987	$k=L/C_{ss}$
C. laxiflora	Mt. Jiri(450~650m)	0.267	Chang *et al.*, 1987	$k=L/C_{ss}$
C. laxiflora	Mt. Jiri(35°15 ′ N)	0.364	Chang & Kim, 1983	$k=L/C_{ss}$
Carpinus spp.	Mt. Halla(33°21 ′ N, 970m)	0.443	Chang & Kwon, 1987	$k=L/C_{ss}$
Carpinus spp.	Mt. Halla(33°21 ′ N, 850m)	0.155	Chang & Kwon, 1987	$k=L/C_{ss}$
Pinus densiflora	Mt. Sickjang(35°19 ′ N, 200~250m)	0.249	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Mt. Jiri(35°10 ′ N, 360 – 650m)	0.132	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Mt. Sokri (36°33 ′ N)	0.238	Shim, 1990	$\ln(x_0/x_1)=kt$
P. densiflora	Kwangneung(37°45 ′ N, 180~200m)	0.108	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Mt. Sŏrak(38°10 ′ N, 200~300m)	0.143	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Mt. Halla(33°21 ′ N, 1,300m)	0.110	Park & Lee, 1981	$k=L/C_{ss}$
P. densiflora	Mt. Mudeung(35°08 ′ N, 550m)	0.256	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Kwangneung	0.130	From Park & Lee, 1981	$k=L/C_{ss}$
P. densiflora	Kwangneung	0.130	Kim & Chang, 1967	$k=L/C_{ss}$
P. densiflora	Mt. Halla(33°21 ′ N, 1,300m)	0.099	Chang & Park, 1986	$k=L/C_{ss}$
P. densiflora	Mt. Jiri(35°10 ′ N, 650m)	0.140	Park & Lee, 1981	$k=L/C_{ss}$
P. densiflora	Mt. Jiri(35°10 ′ N, 360m)	0.180	Park & Lee, 1981	$k=L/C_{ss}$
P. densiflora	Silim (37°12 ′ N, 300~400m)	0.096	Chang & Leem, 1986	$k=L/C_{ss}$
P. densiflora	Youngwal (37°14 ′ N, 300~400m)	0.128	Chang & Leem, 1986	$k=L/C_{ss}$
P. koraiensis	Choohcheon(450~650m)	0.148	Chang *et al.*, 1987	$k=L/C_{ss}$
P. koraiensis	Kwangneung	0.190	From Park & Lee, 1981	$k=L/C_{ss}$
P. koraiensis	Chooncheon(37°50 ′ N, 300~350m)	0.148	Chang & Park, 1986	$k=L/C_{ss}$
P. koraiensis	Kwangneung(450-650m)	0.161	Chang *et al.*, 1987	$k=L/C_{ss}$
P. rigida	Mt. Gwanak(37°28 ′ N, 150~200m)	0.191	Chang & Park, 1986	$k=L/C_{ss}$
P. rigida	Mt. Gwanak(450-650m)	0.118	Chang *et al.*, 1987	$k=L/C_{ss}$
P. thunbergii	Ulleung-do(37°28 ′ N, 150~200m)	0.177	Chang & Park, 1986	$k=L/C_{ss}$
Quercus acuta	Haenam(34°27 ′ N)	0.287	Chang & Han, 1985	$k=L/C_{ss}$
Q. acutissima	Mt. Jiri(35°10 ′ N, 600m)	0.270	Park & Lee, 1981	$k=L/C_{ss}$
Q. acutissima	Haenanm(34°27 ′ N)	0.274	Chang & Han, 1985	$k=L/C_{ss}$
Q. acutissima	Mt. Dŏkyoo(36°51 ′ N, 630m)	0.169±0.012	Chang & Chung, 1986	$k=L/C_{ss}$
Q. acutissima	Mt. Jiri(450~650m)	0.242	Chang *et al.*, 1987	$k=L/C_{ss}$
Q. dentata	Kwangneung	0.281	From Park & Lee, 1981	$k=L/C_{ss}$
Q. dentata	Kwangneung(450~650m)	0.220	Chang *et al.*, 1987	$k=L/C_{ss}$
Q. dentata	Mt. Jiri(35°10 ′ N, 360m)	0.320	Park & Lee, 1981	$k=L/C_{ss}$
Q. mongolica	Kwangneung	0.282	Kim & Chang, 1967	$k=L/C_{ss}$
Q. mongolica	Mt. Jiri (35°19 ′ N)	0.210	Shim, 1990	$\ln(x_0/x_1)=kt$
Q. mongolica	Mt. Dŏkyoo(36°51 ′ N, 1,005m)	0.222±0.027	Chang & Chung, 1986	$k=L/C_{ss}$
Q. mongolica	38°30 ′ N ~ 33°20 ′ N	0.193~0.320	Chang *et al.*, 1987	$k=L/C_{ss}$
Q. mongolica	Mt. Dŏkyoo(36°51 ′ N, 1,490m)	0.123±0.013	Chang & Chung, 1986	$k=L/C_{ss}$
Q. mongolica	Mt. Jiri(35°10 ′ N, 1,300m)	0.210	Park & Lee, 1981	$k=L/C_{ss}$
Q. serrata	Kwangneung(450~650m)	0.233	Chang *et al.*, 1987	$k=L/C_{ss}$
Q. serrata	Mt. Jiri(450~650m)	0.237	Chang *et al.*, 1987	$k=L/C_{ss}$
Q. serrata	Kwangneung(37°45 ′ N, 180m)	0.230	Park & Lee, 1981	$k=L/C_{ss}$
Q. serrata	Mt. Jiri (35°15 ′ N)	0.310	Chang & Kim, 1983	$k=L/C_{ss}$
Q. serrata	Mt. Sokri (36°33 ′ N)	0.330	Shim, 1990	$\ln(x_0/x_1)=kt$
Q. serrata	Mt. Jiri (35°19 ′ N)	0.298	Shim, 1990	$\ln(x_0/x_1)=kt$
Quercus spp.	Mt. So-back(37°N, 1,050m)	0.431	Chang & Kwon, 1987	$k=L/C_{ss}$
Quercus spp.	Mt. So-back(1,350m)	0.199	Chang & Kwon, 1987	$k=L/C_{ss}$
Quercus spp.	Mt. Tae-back(1,050m)	0.246	Chang & Kwon, 1987	$k=L/C_{ss}$
Quercus spp.	Mt. Tae-back(1,250m)	0.268	Chang & Kwon, 1987	$k=L/C_{ss}$
Quercus spp.	Mt. Tae-back(1,450m)	0.082	Chang & Kwon, 1987	$k=L/C_{ss}$
Quercus spp.	Mt. So-back(37°N, 820m)	0.448	Chang & Kwon, 1987	$k=L/C_{ss}$

*$k = L/C_{ss}$

L is an annual production of fallen leaves and dead twigs and C_{ss} is the total amount of organic carbon of F, H, and A_1 layers on the mineral soil (If the accumulation of litter on the forest floor reaches a steady state level).

Table 3. Relationships between decomposition constant (day^{-1}) and daily accumulative temperature, and precipitation for six leaf litters during collection intervals

Species	Correlation coefficients (r)	
	Daily accumulative temperature※ (℃ · day)	Precipitation※ (㎜)
Q. mongolica	0.685*	0.79**
Q. serrata	0.790**	0.80**
P. densiflora	0.610*	0.68*
C. laxiflora	0.645*	0.74**
A. pseudo-sieboldianum	0.590	0.62*
B. ermani	0.750**	0.67*

※ The mean daily air temperature above 5℃ and daily precipitation was accumulated at each experimental interval which is the term between each leaf litter collection.

* Values are significant at P < 0.10, and ** values are significant at P < 0.05.

Table 4. Regression equations describing relationships between decomposition constant (k) and daily accumulative temperature, and precipitation during collection intervals

Species	Multi regression equation*	Correlation coefficient
Q. mongolca	$y = -0.000771 - 0.0000016x_1 + 0.0000166x_2$	(r = 0.834, P < 0.025)
Q. serrata	$y = -0.000285 + 0.00000048x_1 + 0.0000054x_2$	(r = 0.805, P < 0.050)
P. densiflora	$y = -0.000313 - 0.0000006x_1 + 0.0000088x_2$	(r = 0.688, P < 0.100)
C. laxiflora	$y = 0.000378 - 0.00000133x_1 + 0.00001440x_2$	(r = 0.771, P < 0.050)
A. pseudo -sieboldianum	$y = 0.000338 - 0.00000006x_1 + 0.00001033x_2$	(r = 0.617, P < 0.250)
B. ermani	$y = 0.001216 + 0.00000307x_1 - 0.00000769x_2$	(r = 0.774, P < 0.050)

* y = decomposition constant (day^{-1}), x_1 = daily accumulative temperature (℃ · day) and x_2 = precipitation (㎜).

perature. Upadhyay *et al.* (1985) found that in *Q. leucotrichophora*, decay rate was positively correlated with monthly rainfall (r = 0.46).

Linear combinations of daily accumulative temperature and precipitation accounted for 69.61%, 47.4%, 64.8%, 59.9% 59.5%, 38.1% of the variation in decomposition constant (day^{-1}) for *Q. mongolica, P. densiflora, Q. serrata, B. ermani, C. laxiflora* and *A. pseudo-sieboldianum*, respectively (Table 4).

Daily accumulative temperature (℃ · day) accounts for 34.7%～62.2% of decomposition constant (day^{-1}) for six species litters. The addition of precipitation significantly increased the r^2 values (ranged 0.381 between 0.696). Thus, both of precipitation and temperature were most significantly correlated with the dry weight loss. *Q. mongolica* among six species litters was a best species as a predictor of loss mass due to highest correlation coefficient (r = 0.834). Upadhyay *et al.* (1989) found that at mixed oak forest, monthly rainfall accounted for 45%, 34% and 25% of variation in weight loss for *Q. lanuginosa, Q. floribunda* and *Q. leucotrichophora* litter, respectively, and a linear combination of monthly temperature and precipitation accounted for 45% of variation in weight loss for *Q. leucotrichophora* litter.

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