Seasonal Changes in Litterfall, Nutrients in Litterfall and Nutrient Use Efficiency in a Japanese Cedar (*Cryptomeria japonica*) Stand

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Abstract

Litterfall was collected at monthly intervals over a one-year period in a Japanese cedar (*Cryptomeria japonica* D. Don) stand in an experimental field on the Nagoya University Campus. The nutrient amount in the litterfall was analyzed. Total litterfall was 934 g m^{-2} per year. Leaves, branches, fruits and flowers contributed 80.35, 7.48, 4.38 and 7.79%, respectively, to the total litterfall. Litterfall, which was the highest in September, was attributed to the effect of a typhoon. The total amount of nutrients in the litterfall was 29.04 g m^{-2} per year. The relative amount of the nutrients was in the order Ca > N > K > P > Mg. Calcium, accounted for 60.50%, N 27.73%, K 10.74%, P 2.38% and Mg 2.34% of the total. The nutrient amounts in the litterfall was significantly correlated with the litterfall mass. Nutrient concentrations of the litterfall showed seasonal variations. A high nutrient efficiently uses Mg which indicates that Mg is in a limited supply.

Keywords : Japanese cedar, litterfall, nutrient, seasonal variation, nutrient use efficiency

Introduction

Organic matter is added continually to the soil through litterfall in forests. Litter quality is major pathway in the transfer of nutrients to forest soils (JOHANSSON, 1995). Seasonal changes in litter production and litter nutrient concentration affect plant nutrient status and within-stand nutrient cycling (SHARMA and PANDE, 1989). Nutrient use efficiency, defined as the ratio of litterfall mass to nutrient, has been used as an indicator of soil nutrient conditions (*e.g.*, VITOUSEK, 1982, 1984; BOERNER, 1984; LOGO, 1992), because nutrient concentration in litterfall is expected to change with soil fertility (TSUTSUMI *et al.*, 1983; BOERNER, 1984). This study presents an account of seasonal changes in litterfall and its nutrient content and nutrient use efficiency in a Japanese cedar (*Cryptomeria japonica* D. Don) stand.

Materials and Methods

The study was carried out in a 13-year-old (as of 1994) Japanese cedar (*Cryptomeria*

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japonica D. Don) stand of the School of Agricultural Sciences, Nagoya University, from April 1994 to March 1995. Diameter at breast height, mean tree height and density were 8.3 cm, 8.1 m and 11050 trees ha^{-1}, respectively. The study site was established on a flat area at 50 m above sea level. Annual precipitation and mean air temperature were 1543 mm and 15.0℃, respectively.

Four litter traps of size 0.25 m^2 were placed in the stand to collect litterfall. The traps were emptied at monthly intervals. The litter was sorted into leaf, branch, fruit and flower, oven dried at 85℃ for 48 hours, and then weighed after 24 hours desiccation. Samples from each component were collected and ground with a vibrating sample mill. Subsamples were then taken for N, P, K, Ca and Mg content analyses. Nitrogen content was analyzed using C-N corder. For P, K, Ca and Mg analyses, the subsamples were wet digested with HNO_3-HCL-$HCLO_4$-HF. Phosphorus content was determined by phosphomolybdic blue colorimetric method, and K, Ca and Mg were analyzed by atomic absorption spectrophotometry.

Results

Total amounts of litterfall were to 934 g m^{-2} yr^{-1}. Leaf litterfall accounted for 71.09% of total, while branches, flowers and fruits accounted for 12.42, 9.10 and 7.45%, respectively (Table 1).

Figure 1 shows the seasonal fluctuations in leaf litterfall. Leaf litterfall had a peak in September and fall rate remained low from October to May, whereas from June to July, the fall rate was negligible. Pronounced peaks of branch and fruit litterfall occurred in September and low fall rates from March to May. From June to August there was little or no fall. Flower litterfall was concentrated in March, April and May.

Concentrations of Ca and N were high, whereas P and Mg were low in leaf litter. Concentration of Ca was high in leaf and branch, and low in fruit and flower (Table 2). Within the components, flower had the highest nutrient concentration except for Ca, while branch had relatively low nutrient concentrations.

Table 1. Litterfall mass and nutrients in litterfall (g $m^{-2}yr^{-1}$).

Component	Litterfall mass	Nutrient					
		N	P	K	Ca	Mg	Total
Leaf	664	5.21	0.51	1.48	15.66	0.48	23.34
	(71.09)	(74.64)	(73.91)	(47.44)	(89.13)	(70.59)	(80.37)
Branch	116	0.30	0.05	0.36	1.43	0.03	2.17
	(12.42)	(4.30)	(7.25)	(11.54)	(8.14)	(4.41)	(7.47)
Fruit	69	0.47	0.03	0.48	0.22	0.07	1.27
	(7.39)	(6.73)	(4.35)	(15.38)	(1.25)	(10.29)	(4.38)
Flower	85	1.00	0.10	0.80	0.26	0.10	2.26
	(9.10)	(14.33)	(14.49)	(25.64)	(1.48)	(14.71)	(7.78)
Total	934	6.98	0.69	3.12	17.57	0.68	29.04
	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Number in parentheses is percentage of a component.

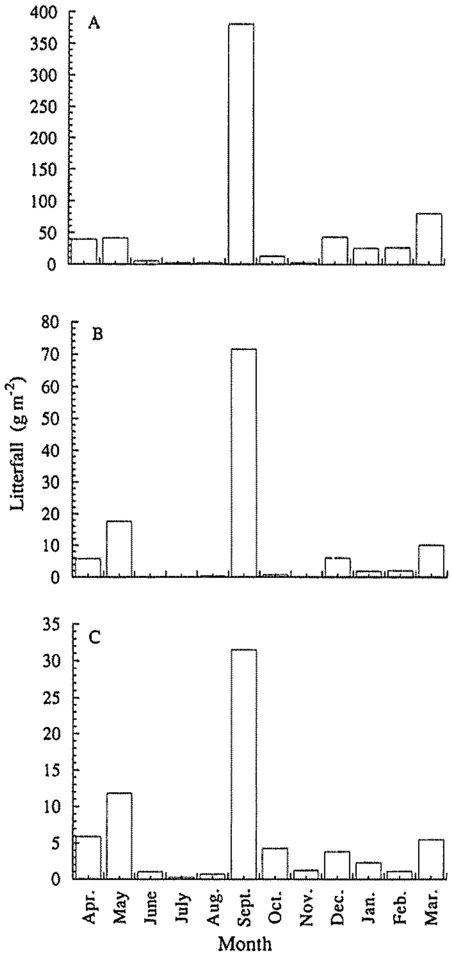

Fig. 1. Seasonal variation in rate of litterfall.
A, leaf litterfall ; B, branch litterfall ; C, fruit litterfall.

Table 2. Concentration of nutrients in litterfall (%).

Component	Nutrient				
	N	P	K	Ca	Mg
Leaf	0.81	0.08	0.23	2.43	0.07
Branch	0.26	0.04	0.31	1.23	0.03
Fruit	0.68	0.04	0.70	0.32	0.10
Flower	1.18	0.12	0.94	0.31	0.12

Concerning seasonal changes in nutrient concentrations of leaf litterfall, concentration of N increased from May towards a peak in July, and thereafter decreased towards April (Fig. 2). Concentration of P remained relatively constant, but there were high values in April, October and March. There was no clear seasonal trend in concentration of K. With regard to Ca, there was a gradual decrease in concentration from April to September, and thereafter remained more or less constant. Magnesium had lower values in spring and summer and had higher values in fall and winter.

Annual nutrients in litterfall was 29.04 g m^{-2} (Table 1). Nutrient in leaf litterfall constituted 80.37, branch 7.47, fruit 4.38 and flower 7.78% of the total. Nutrient concentration in the litter by weight was in the order Ca>N>K>P>Mg. Calcium contributed 60.50% of the total, while P and Mg contributed only 2.38 and 2.34% of the total, respectively.

Application of litterfall mass/nutrients ratios as indicators of nutrient use efficiency (VITOUSEK, 1982) showed that efficiency was high in P (1354) and Mg (1374), and low in Ca (53). Branch (53) and fruit (54) had high nutrient use efficiency, while leaf (28) and flower (38) had relatively low efficiency (Table 3).

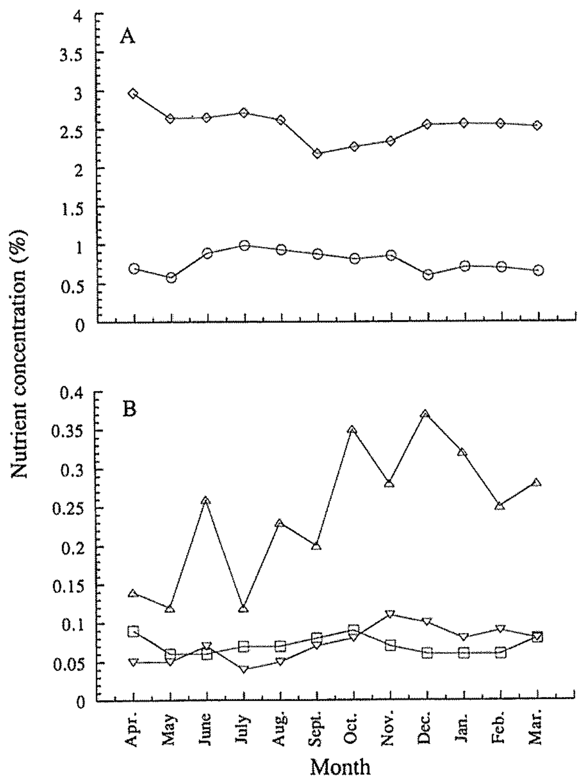

Fig. 2. Seasonal variation of nutrient concentration in leaf litterfall.
○, N ; □, P ; △, K ; ◇, Ca ; ▽, Mg.
(A, high nutrient concentration ; B, low nutrient concentration).

Table 3. Nutrient use efficiency of litterfall.

Component	Nutrient					
	N	P	K	Ca	Mg	Total
Leaf	127	1302	449	42	1383	28
Branch	387	2320	322	81	3867	53
Fruit	147	2300	144	314	986	54
Flower	85	850	106	327	850	38
Total	134	1354	299	53	1374	32

Discussion

The annual total litterfall mass in present study is high compared with the values for warm temperate stands (BRAY and GORHAM, 1964), and the values reported for warm temperate stands in Japan (TSUTSUMI, 1973). This may be attributed to a typhoon in September. Litterfall in September accounted for about 52% of the total annual litterfall. Litterfall fluctuations influenced by typhoon have been reported by UEDA and TSUTSUMI (1977). KAWAHARA (1971) and MAGGS and PEARSON (1977) also reported litterfall being affected by wind.

Seasonal changes in N, P and K could be attributed to differences in retranslocation of the three nutrients before abscission and also to leaching by rainfall. Potassium which is the easily leachable, did not show clear seasonal trend compared with N and P. Retranslocation of nutrients before leaf abscission is well documented (*e.g.*, WELLS and METZ, 1963; LUGO, 1992). Calcium, which is immobile, showed little seasonal change in concentration.

Despite seasonal differences in nutrient concentrations, nutrients in litter were primarily dependent on the weight of litterfall (ATTIWILL *et al.*, 1978). Thus the September litterfall was about 52% of the annual litterfall. The weight of N, P, K, Ca and Mg in the September litterfall was therefore 53, 50, 41, 53 and 47%, respectively, of total weights. Seasonal changes in the amounts of nutrients closely followed that of litterfall (Fig. 3). A student's *t*-test confirmed that the relationships between litterfall mass and nutrient amounts in litterfall were statistically significant. The same relationships existed between leaf litterfall mass and nutrient amounts in leaf litterfall mass (Fig. 4). This suggests that the nutrient in total litterfall and leaf litterfall could be appropriate indicators of litterfall mass in the stand. Thus litterfall mass provides a convenient method for the estimation of nutrient returned to soil by litterfall.

Indices of nutrient use efficiency have been developed as an estimate of stand-level nutrient economies for some mature forest vegetation (*e.g.*, VITOUSEK, 1982; BERENDSE and AERT, 1987; LUGO, 1992). Highly efficient systems are indicators of possible nutrient limitations to primary productivity, and less efficient systems do occur where there is adequate nutrient availability (VITOUSEK, 1982, 1984). The nutrient use efficiency of this study is compared with that of other stands in Japan (Table 4). The use efficiency of Mg was much higher than that of other stands, while the value of the other nutrients was within the ranges of the values reported (Table 4). The marked difference of Mg use

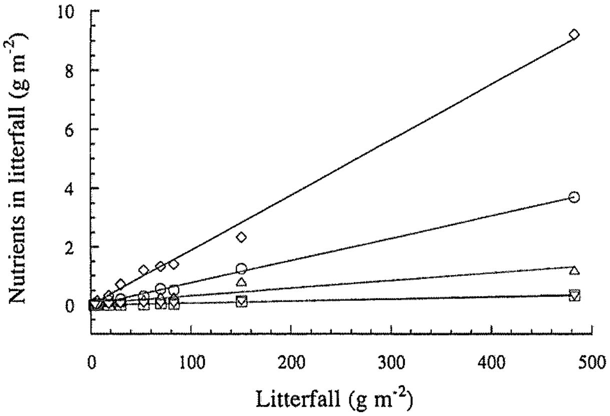

Fig. 3. Relationship between litterfall mass (w_{lit}) and nutrients in litterfall.

○, N : $N = 0.0077 w_{lit} - 0.0192$, $R^2 = 0.997$

□, P : $P = 0.0007 w_{lit} + 0.0002$, $R^2 = 0.990$

△, K : $K = 0.0026 w_{lit} + 0.0564$, $R^2 = 0.893$

◇, Ca : $Ca = 0.0188 w_{lit} - 0.0009$, $R^2 = 0.995$

▽, Mg : $Mg = 0.0007 w_{lit} + 0.0050$, $R^2 = 0.985$

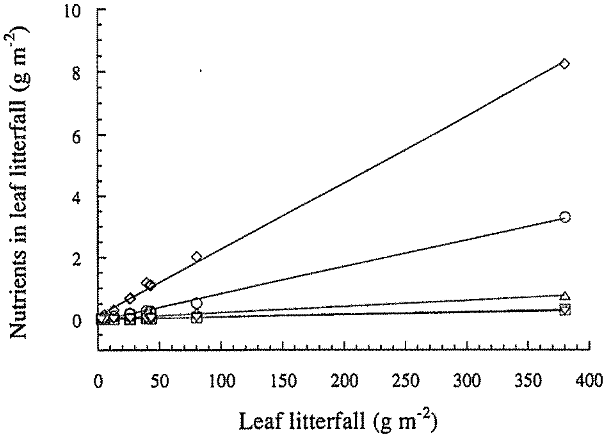

Fig. 4. Relationship between leaf litterfall mass ($w_{litleaf}$) and nutrients in leaf litterfall.

○, N : $N_{leaf} = 0.0087 w_{litleaf} - 0.0487$, $R^2 = 0.996$

□, P : $P_{leaf} = 0.0008 w_{litleaf} - 0.0022$, $R^2 = 0.998$

△, K : $K_{leaf} = 0.0020 w_{litleaf} + 0.0127$, $R^2 = 0.978$

◇, Ca : $Ca_{leaf} = 0.0216 w_{litleaf} + 0.1091$, $R^2 = 0.998$

▽, Mg : $Mg_{leaf} = 0.0007 w_{litleaf} + 0.0012$, $R^2 = 0.993$

efficiency between the present study stand and other stands could be attributed to the inadequacy of Mg in this stand. In general, the order of nutrient use efficiency in stands was P>Mg>K>N>Ca (Table 4). The fact that Mg use efficiency was higher than P could mean that Mg supply was limited.

Table 4. Nutrient use efficiency calculated for defferent stands.

Stand	Nutrient					Author
	N	P	K	Ca	Mg	
Cryptomeria japonica D. Don	134	1354	299	53	1374	Present study
Cryptomeria japonica D. Don	91	759	313	41	286	KAWADA, 1989
Cryptomeria japonica D. Don	213	5000	1250	56	476	KAWADA, 1989
Cryptomeria japonica D. Don	110		714	50	1111	KAWADA, 1989
Cryptomeria japonica D. Don	155	1584	1353	91	258	SAKAGUCHI, 1983
Chamaecyparis obtusa Endl.	161	2754	510	117	896	KAWAHARA, 1971
Pinus densiflora sieb. et Zucc.	189	2171	597	217	1119	KAWAHARA, 1971
Evergreen broad leaved	104	2696	460	104	545	KAWAHARA, 1971
Deciduous broad leaved	41	514	123	22	196	TSUTSUMI, 1987
Quercus serrata Thunb. ex Murray	118	1111	385	93	312	KATAGIRI and TSUTSUMI, 1973
Fagus crenata Blume	76	1030	294	105	435	KATAGIRI and TSUTSUMI, 1973

There must be some underestimates of nutrients in litterfall, because some dead leaves and branches remained attached to the trees for a long time. This might have resulted in leaching of nutrients, like K, which is easily leachable (DAS and RAMAKRISHNAN, 1985), and N, which is minor constituents of leaching (MORTON, 1977; SHARMA and PANDE, 1989). However, P, Ca and Mg are unlikely to cause any seriously error due to leaching losses (ATTIWILL *et al.*, 1978). Despite the easily leachability of K, its concentration in the litterfall in this study is equal to or higher than that of other stands of this species, resulted in low K use efficiency (Table 4).

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スギのリターフォールおよび養分の季節変化と養分利用効率

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名古屋大学構内の13年生スギ林のリターフォール速度および養分含有率の季節的変化を調べた。一カ年のリターフォール量は934 g m^{-2}，そのうち葉，枝，果実，花はそれぞれ全リターの80.35, 7.48, 4.38, 7.79%を占めた。9月に台風によるリターフォールのピークがあった。1年間のリターの養分量は29.04 g m^{-2}，この中カルシウム60.50，窒素27.73，カリウム10.74，リン2.38，マグネシウム2.34%であった。リターフォール量とそれに含まれる養分量にはかなり高い相関があった。養分含有率は季節的に変化した。マグネシウム利用効率は高く，そのことはその供給量が限られていることを示している。

キーワード：スギ，リターフォール，養分，季節変化，養分利用効率