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Turnover Rates of Mineral Nutrients of Litters under *Pinus koraiensis* and *Pinus rigida* Forests

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잣나무와 리기다松林下에 있어서 落葉의 無機化에 관한 研究

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ABSTRACT

The turnover rates of nitrogen(N), phosphorus(P), calcium(Ca), potassium(K), and sodium(Na) during the decomposition of litter were studied in the *Pinus koraiensis* forest in Choon Chun and in the *Pinus rigida* forest in Mt. Gwanak, Seoul.

The turnover rates of N, P, K, Ca, and Na were 0.064, 0.068, 0.040, 0.417, and 0.058 for the *P. koraiensis* litter and 0.049, 0.049, 0.023, 0.346, and 0.058 for the *P. rigida* litter respectively. The loss of elements follows the order Ca>P>N>Na>K in the *P. koraiensis* litter and the order Ca>Na>N=P K in the *P. rigida* litter.

Generally the turnover rates of cations were greater than those of anions.

INTRODUCTION

The litter fall added to the ecological system will be decomposed. The process is carried out by the decomposers in the forest. Simultaneously there is a process of accumulation of the organic composition and mineral nutrients.

On the basis of the analytic data, many authors have tried to construct mathematical models that describe the phenomena of decomposition and accumulation (Jenny *et al.* 1949, Olson 1963, Chang and Rim 1968, Minderman 1968, Oohara *et al.* 1971).

When organic composition is decayed, the mineral nutrients, N, P, Ca, K, and Na are mineralized in the soil. The turnover rates for mineral nutrient elements in litter were less than the decomposition rates for organic matters(Chang and Yoshida, 1973). Attiwill (1967) reported that the loss of elements follows the order Na>K>Ca>Mg>P in mature *Eucalyptus oblqua* forest in southeastern Australia.

In this paper, the decomposition rate of organic matter and the turnover rates of mineral nutrient elements in *Pinus koraiensis* and *Pinus rigida* litters.

The process of attaining the turnover rates of mineral nutrient elements is analogous to that of attaining the decomposition rate of organic matter.

METHODS AND MATERIALS

The study was undertaken in *Pinus koraiensis* forest in Choonchun and in *Pinus rigida* forest in Mt. Gwanak, Seoul. Quadrats ($0.5 \times 0.5m^2$) were dropped on the soil. The samples were collected from litter(L), fermentation(F), humus(H), and A_0 layer respectively on November 9, 1980.

The samples were dried in an oven at 100°C for

24 hours. The litter production was determined by the dry weight basis per m^2. And then dried samples were ground in a mill. About 2g of the ground material was ashed at 500~550°C in the furnace. The ash was taken up twice in 1 : 1 HCl and suitable aliquots of the ash solution taken for chemical analysis.

Phosphorus was determined by spectrophotometry. Calcium, potassium, and sodium were determined by flamephotometry. Total nitrogen was determined by the micro-Kjeldahl method.

THEORETICAL ASSUMPTION

The turnover rate of litter mineral is proportional to the amount of mineral accumulation, M, on the forest floor.

$$-\frac{dM}{dt} = kM \qquad (1)$$

In the equation (1), k is the turnover rate and the turnover velocity implies the negative direction against the addition of mineral of litter.

When M is M_0 at t = 0, the solution of the equation (1) is

$$M = M_0 e^{-kt} \qquad (2)$$

If the initial mineral M_0 actually change to the final levels of $M_0/2$, $M_0/20$, and $M_0/100$ at, $t_{1/2}$, $t_{1/20}$, and $t_{1/100}$ respectively, the time periods should be required for

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k} \qquad (3)$$

$$t_{1/20} = \frac{3}{k} \qquad (4)$$

and

$$t_{1/100} = \frac{5}{k} \qquad (5)$$

Therefore, the amount of turnover mineral at a certain time is given by

$$M_t = kM_0 e^{-kt} \qquad (6)$$

Then rate of storage in material stored in an ecological system of the forests equals to the rate of income or litter production minus the rate of turnover. The velocity of accumulation of minerals is

$$\frac{dM}{dt} = L - kM \qquad (7)$$

The accumulation of litter on the forest is

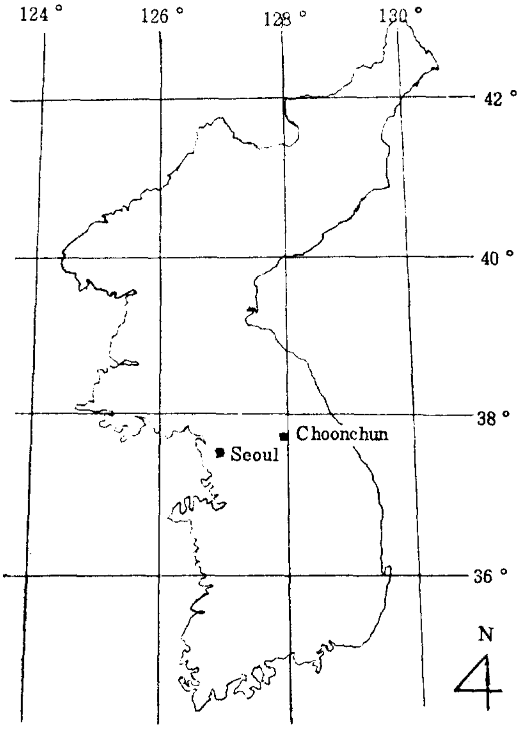

Fig. 1. Sketch map of studied area.

$$M = \frac{L}{k}(1 - e^{-kt}) \qquad (8)$$

This curve is the mirror image of the curve for turnover.

To evaluate the turnover rate k, we must find out a forest in which the amount of annual mineral production of litter equals to that of annual turnover. Thus

$$L = kM_0 e^{-kt} \qquad (9)$$

For this case, the turnover rate k, can be estimated by the ratio of income to equilibrium-state total as the ratio of the vertical axis over the horizontal axis, F, H, and A_0,

$$k = \frac{L}{M_0 e^{-kt}} = \frac{L}{M} \qquad (10)$$

RESULTS AND DISCUSSION

The amounts of the dry weight, organic matter, water content, organic carbon, and ash of litter samples in the *P. koraiensis* and *P. rigida* forests were shown in Table 1. The production of litter

Table 1. Amount of dry weight, water content, organic matter, ash and soil, and organic carbon in the litter samples (L, F, H, Ao Horizon) of the *Pinus koraiensis* forest and *Pinus rigida* forest.

Forest	Hori-zon	PH	Air dry weight (g/m^2)	Dry weight (%)	Oven dry weight (g/m^2)	Water Content (%)	Organic matter (%)	Organic matter (g/m^2)	Ash and soil (%)	Organic carbon (g/m^2)
	L	3.8	299.33	94.71	283.20	5.29	95.72	270.06	4.28	160.04
P. koraiensis	F	4.6	688.53	97.27	671.98	2.73	75.46	501.19	24.54	300.71
	H	5.0	685.73	94.32	646.79	5.68	60.60	392.30	39.40	205.38
	Ao	5.2	5300.34	98.44	5217.75	1.56	12.59	656.71	87.41	394.03
	L	3.8	342.60	92.22	315.72	7.78	92.81	293.01	6.54	175.81
P. rigida	F	3.9	825.60	89.59	738.99	10.41	68.37	505.23	20.01	303.14
	H	4.2	2461.62	93.83	1646.95	6.17	39.21	645.77	55.57	387.46
	Ao	4.7	9540.00	97.58	9320.48	2.43	11.06	1031.15	87.09	618.69

Table 2. The contents and quantities of total N, Na, K, Ca, and P in the litter samples (L, F, H, and Ao) of the *Pinus koraiensis* forest and *Pinus rigida* forest.

Forest	Hori-zon	Oven dry weight (g/m^2)	Total N (%)	Total N (g/m^2)	Na^+ (%)	Na^+ (g/m^2)	K^+ (%)	K^+ (g/m^2)	Ca^{++} (%)	Ca^{++} (g/m^2)	P (%)	P (g/m^2)
	L	283.20	0.98	2.79	0.0255	0.0656	0.0902	0.2592	0.5901	1.6995	0.0025	0.0074
P. koraiensis	F	671.98	1.19	9.09	0.0155	0.0984	0.0975	0.6451	0.5312	0.9689	0.0048	0.0308
	H	646.79	1.15	7.42	0.0138	0.0892	0.0754	0.4878	0.1482	0.9585	0.0034	0.0223
	Ao	5217.75	0.52	27.19	0.0181	0.9422	0.1032	5.3830	0.0412	2.1518	0.0011	0.0566
	L	315.72	0.49	1.64	0.0332	0.1018	0.0638	0.2067	0.3268	0.9866	0.0013	0.0041
P. rigida	F	738.99	0.67	4.81	0.0202	0.1579	0.0579	0.4509	0.1968	1.0310	0.0024	0.0171
	H	1646.95	0.62	8.17	0.0187	0.3041	0.0728	1.2446	0.0203	0.3343	0.0022	0.0328
	Ao	9320.48	0.28	20.19	0.0185	1.7159	0.0877	7.3892	0.0175	1.4893	0.0004	0.0331

and organic matter is higher in *P. rigida* forest than in *P. koraiensis* forest. On the other hand, percentages of the organic matter and dry weight of litter were higher in the *P. koraiensis* forest than in the *P. rigida* forest. The amounts of organic carbon were 930.05g/m² in *P. koraiensis* forest and 1309.29g/m² in *P. rigida* forest.

The amounts and percentages of total N, P, Ca, K, and Na of litter in *P. koraiensis* forest and in *P. rigida* forest are shown in Table 2. Generally the percentages of total P, Ca, N and K, of litter in *P. koraiensis* forest were higher than those in *P. rigida* forest. Only the percentage of Na, however, was higher in *P. rigida* forest than in *P. koraiensis* forest. The quantities of all the mineral nutrient elements showed the peak value in A_0 layer. Ovington (1954) reported that the weight of fresh litter was in all cases considerably less than of the decayed material.

Changes of the vertical distribution of mineral nutrient contents in the litter layers such as *L*, *F*, *H*, and A_0 of the *P. koraiensis* forest were similar to those of the *P. rigida* forest. Especially the lower the litter layer was, the less the contents of calcium were. It means that the turnover of calcium is rapid. On the other hand, the contents of potassium in litter were increased in lower layers.

The decomposition rates for the organic matters and the turnover rates of mineral nutrient elements were presented in Table 3. The estimates of decomposition rate for the organic matters ranged down to 1 for two forests. The value of decomposition rate for the organic matter of litter was 0.174 in the *P. koraiensis* forest and was 0.134 in the *P. rigida* forest. Kim and Chang(1966) reported that the decomposition rate of litter was 0.13 in the *Pinus densiflora* forest in Kwangnung.

The parameter $0.693/k = t_{1/2}$ may be reviewed as a "biological half time" for accumulation. The time period, $3/k$ should be that required for attaining 95 % of the final level, while $5/k$ should approximate time needed to reach 99% of the final level. Such figures for decomposition of organic matter in two forests were shown in Table 3. The turnover rates of total N, P, Ca, K, and Na were shown in that table, too. The turnover rates of Ca and Na were greater than those of N and P. Reiners and Reiners (1970) concluded that the turnover rates of the cations, Mg and Ca, were greater than those of anions, N and P. Attiwill (1967) reported that the loss of elements follows the order Na>K>Ca>Mg>P in mature *Eucalyptus obliqua* forest in southeastern Australia. A comparison of the turnover rates of mineral nutrients is confusing the dispatiries in their

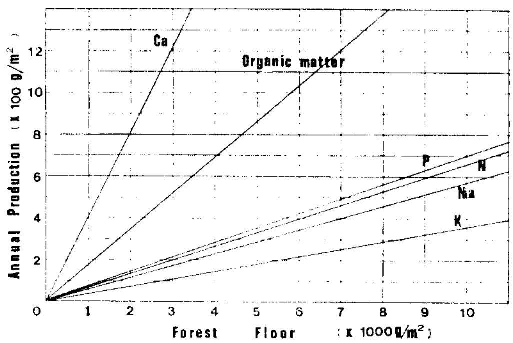

Fig. 2. Estimates of decomposition rate for organic matter and turnover rates for mineral nutrient elements in *Pinus koraiensis* forest.

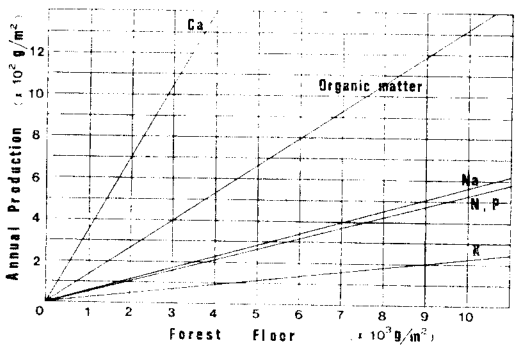

Fig. 3. Estimates of decomposition rate for organic matter and turnover rates for mineral nutrient elements in *Pinus rigida* forest.

Table 3. Parameters for mineralization of total N, P, K^+, Ca^{++}, and Na^+ in the litter on the *Pinus koraiensis* forest and *Pinus rigida* forest.

	Forest	K	Decay Parameter 1/K	Half time 0.693/K	95% time 3/K	99% time 5/K
Organic	*P. koraiensis*	0.1742	5.74	3.98	17.22	28.70
matter	*P. rigida*	0.1343	7.45	5.16	22.34	37.23
Total N	*P. koraiensis*	0.0638	15.67	10.86	47.02	78.37
	P. rigida	0.0494	20.24	14.03	60.73	101.21
Na^+	*P. koraiensis*	0.0581	17.21	11.93	51.64	86.06
	P. rigida	0.0578	17.30	11.99	51.90	86.51
K^+	*P. koraiensis*	0.0398	25.12	17.41	75.38	125.63
	P. rigida	0.0228	43.86	30.39	131.58	219.30
Ca^{++}	*P. koraiensis*	0.4166	2.40	1.66	7.20	12.00
	P. rigida	0.3456	2.89	2.01	8.68	14.47
P	*P. koraiensis*	0.0675	14.81	10.27	44.44	74.07
	P. rigida	0.0494	20.24	14.03	60.73	101.21

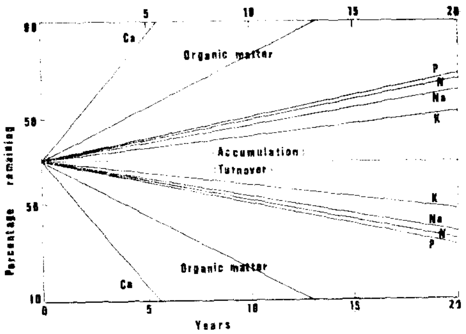

Fig. 4. Exponential patterns of turnover and accumulation for mineral nutrient elements in a *Pinus koraiensis* forest.

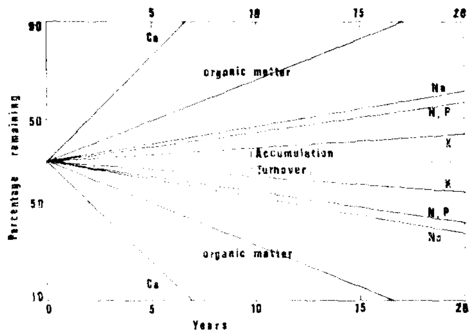

Fig. 5. Exponential patterns of turnover and accumulation for mineral nutrient elements in a *Pinus rigida* forest.

Table 4. The annual production of organic matter and mineral nutrients on the *Pinus koraiensis* and *Pinus rigida* forest floors.

Forest	Oven dry weight (g/m^2)	Total N (g/m^2)	Na^+ (g/m^2)	K^+ (g/m^2)	Ca^{++} (g/m^2)	P (g/m^2)
Pinus koraiensis	283.20	2.79	0.0656	0.2592	1.6995	0.0074
Pinus rigida	315.72	1.64	0.1018	0.2067	0.9866	0.0041

order tendency. The outstanding difference between the two results is turnover rates of K. In the *Eucalyptus obliqua* forest, the turnover rate of K was higher than that of Ca. But in the *Pinus koraiensis* forest and the *Pinus rigida* forest, the turnover rate of K was the lowest value. Probably the reason may be that *Pinus koraiensis* and *Pinus rigida* have the resin which affect the mineralization of potassium.

Generally the turnover rates for mineral nutrient elements in litter were less than the decomposition rates for organic matters (Chang and Yoshida, 1973). The graphical expressions were given in Figs. 2 and 3.

The turnover times of N, P, Ca, K, and Na were also aligned one another (Figs. 4 and 5). As shown in Figs. 4 and 5, the order of decomposition or turnover time for chemical compositions were reverse to that of the decomposition rates. When litter is almost steadily falling, the accumulation curves are the mirror image of the curve for turnover and were shown in Figs. 4 and 5.

The predictions for the steady-state level of litter accumulation according to annual litter production were shown in Table 4. The litter is accumulated to approach the steady state in an ecosystem which has not become a steady state. In the case of annual accumulation of organic matter, the *Pinus rigida* forest has higher value than *Pinus koraiensis* forest. However, the accumulation of the mineral nutrient elements of the *Pinus koraiensis* forest represents higher values than that of *Pinus rigida* forest.

The decay system is related to the loss of the useless material. The further study on the decay system of the ecosystem will contribute to the purification of the environments.

要 約

春川의 잣나무林과 冠岳山의 소나무林에 있어서 落葉의 無機化를 연구하였다. N, P, K, Ca 및 Na의 무기화 常數를 보면 잣나무林에서는 각각 0.064, 0.068, 0.040, 0.047, 0.417, 0.058이었으며 소나무林에서는 0.049, 0.049, 0.023, 0.346, 0.058이었다.

無機物이 무기화되는 순서는 잣나무林에서는 Ca>P>N>Na>K였으며 소나무林에서는 Ca>Na>N=P>K로 나타났다.

일반적으로 양이온의 무기화는 음이온의 무기화 보다 빨랐다.

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