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A Study on the Decomposition of Litter and the Leaching of Mineral Nutrients in the Stands of *Pinus rigida* on Mt. Gwan-ak and *Pseudosasa japonica* on Odong-do

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관악산의 리기다소나무林과 오동도의 이대林에서 落葉의 分解와 無機養分의 洗脫에 관한 연구

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ABSTRACT

The decay rates of organic matter were investigated and the leaching rates were determined from the concentration distribution of N,P,K, Ca and Na in the soil profile at *Pinus rigida* stand on Mt. Gwan-ak and at *Pseudosasa japonica* stand on Odong-do. In order to determine the leaching rates θ_0/W was substituted with K_L in Towner's equation.

Decay rates were 0.191 at *Pinus* stand on Mt. Gwan-ak and 0.234 at *Pseudosasa* stand on Odong-do. Concentration distributions of N,P,K and Na in soil profiles were corresponed with Towner's model curve. Leaching rates determined from concentration distributions were 0.086, 0.079, 0.041, 0.029, 0.096 on Mt. Gwan-ak and 0.080, 0.056, 0.051, 0.008, 0.028 on Odong-do. The soil of *Pseudosasa* stand showed on the whole lower leaching rates than that of *Pinus* stand. The soil of *Pseudosasa* stand showing higher decay rate and lower leaching rates contained more concentration of each nutrient than that of *Pinus* stand.

INTRODUCTION

The movement and distribution of water and salts in the soil are to make an important change to the ecosystem. Fertilizers applied at or near the soil surface are displaced and dispersed into the profile with infiltrating water. Nutrients moving beyond the root zone are lost to the plant and contribute to ground water pollution. Thus it is desirable to be able to predict such movements and distributions in order not only to make the most efficient and safe use of such agricultural chemicals, but also to determine the amount of nutrient recycled in the forests.

Many researches reported on this topic deal with the movement of salts and water during infiltration and redistribution without evaporation (Warrack *et al.*, 1971; Kirda *et al.*, 1973; Ghuman *et al.*, 1975; Ghuman and Prihar, 1980).

But chang *et al.*, (1978) and Merrill *et al.*, (1983) reported that the salts were accumulated on the soil surface by evaporation and transpiration of soil water.

Many researches have been carried out in the arable land but there were few reports on the salt distribution in the soil profile of forests in which nutrients were come into the soil profile every year by decomposition of fallen leaves and stems. Objectives of this investigation were to determine the concentration distributions of N, P, K, Ca and Na in the soil profiles of *Pinus rigida* stand on Mt. Gwan-ak and *Pseudosasa japonica* stand on Odong-do. Second objective was to determine the leaching rates from modified Towner's equation devised with reference to the partial differential equation governing dispersion (Towner, 1983).

METHODS

Experimental method The sites selected for this study were *Pinus rigida* stand on Mt. Gwan-ak in Seoul and *Pseudosasa japonica* stand on Odong-do in Yoeu-su. The sites were at equilibrium of inflow and outflow of water and litter. Mt. Gwan-ak locates at the central part of Korea and 629m above the sea level, where the annual mean rainfall was 1,169mm and the annual mean temperature was 10.1°C. The soil was clayey sand of which color was blackbrown at the top and yellowish with increasing depth.

Odong-do locates at the coastal area of southern sea of Korea where the annual mean rainfall was 1,310mm and the annual mean temperature was 13.2°C. The soil color was black at the top and blackbrown with increasing depth.

Studies were carried out on April, 1985. Soils were sampled at three sites randomly selected at depth increments of L.F.H. A, 0~5, 5~10, 10~15, 15~20, 20~25, 25~30, 30~35cm. All samples were air-dried and were sieved through a stainless steel 2mm mesh to determine the amount of organic matter, total and available phosphorus, total and exchangeable K, total and exchangeable Ca and total and exchangeable Na.

Water contents were measured after the soils were dried at 105°C and organic matters were done after they were burned at 450°C in the furnace.

Nitrogen was determined by the microkjeldahl method and expressed as a percentage of the oven dry weight of soil. The amount of phosphorus was determined colorimetrically by the stannous-reduced molybdophosphoric method (Dickman and Bray, 1940). The amounts of K, Ca and Na were determined with flame photometer. Total amounts of metal ions were extracted by 1N HCl solution, and exchangeable ions were done by 1N ammonium acetate solution of pH 7.0.

The decay rates of organic matter were determined from the decay model of Olson (1963).

Theoretical model Horizontal and vertical flows of water in the soil affect the movement of dissolved material. Trying to determine the water exchange of ecosystem in quantitative terms requires the acceptance of basic principles which describe in mathematical statements the relationship that govern the water exchange between the ecosystem and its adjacent systems as well as between the internal compartments of the ecosystem. Such a generally accepted basic principle is the equation of continuity, also known as the law of conservation of matter. Another fundamental principle is Darcy's law (Benecke, 1976).

The corresponding equations governing water flow are

Darcy's law $$v=-K\frac{d\phi}{dz}=-K\frac{\partial p}{\partial z}+K \qquad (1)$$

Continuity equation $$\frac{\partial\theta}{\partial t}=-\frac{\partial v}{\partial z} \qquad (2)$$

where ϕ is the hydrolic potential and P is the soil water pressure at depth z(positive downward) and time t; K is the water-dependent hydraulic conductivity; θ is the volumetric water content; v is the flux density of water.

If the redistribution profiles of the added water are known as a function of time, then the flux density v can readily be determined from

$$v=-\int_0^z\left(\frac{\partial\theta}{\partial t}\right)dz \qquad (3)$$

Mathematical models based on the theory of dispersion of soluble salts in porous media have been developed by Towner (1983). The partial differential equation governing the hydrodynamic dispersion in an saturated soil of a soluble salt, which is not absorbed by the soil, is

$$\frac{\partial(\theta c)}{\partial t}=\frac{\partial}{\partial z}\left[\theta D\frac{\partial c}{\partial z}\right]-\frac{\partial(vc)}{\partial z} \qquad (4)$$

where c is the concentration of the salt in the water at depth z at time t; D is the dispersion coefficient; and the other terms are as defined before.

After dropping the diffusing term, equation (4) becomes

$$\frac{\partial(\theta c)}{\partial t}=-\frac{\partial(vc)}{\partial z} \qquad (5)$$

Combining equation (2) and (5) gives

$$\theta\frac{\partial c}{\partial t}+v\frac{\partial c}{\partial z}=0 \qquad (6)$$

The solution of equation(6), when no further water is added at the surface after an inital deposition, is

$$C=Co\ F\left(\int_0^z\theta\ dz\right) \qquad (7)$$

where F is a function to be determined.

The concentration distribution at infinite time (i.e. when the initially added water has drained away) is given by

$$C=Co\ \exp\ (-\theta_0 z/w) \qquad (8)$$

where W is the depth of water added to the soil surface; and θ_0 is the initial water

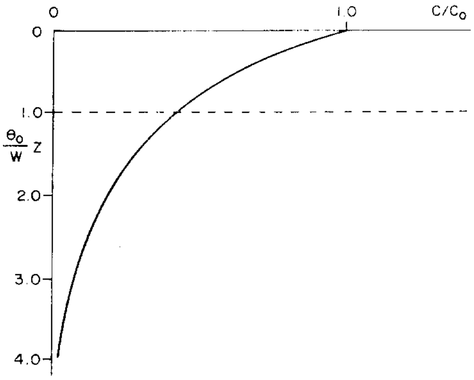

Fig. 1. The concentration distribution as a function of depth. Depth of wetting is indicated by the horizontal dashed line.

content of the soil, assumed constant with depth, to which the soil returns after the added water has drained away.

Model curve representing the distribution of concentration with increasing depth is shown in Fig. 1.

In order to determine the leaching rate, we substituted θ_0/w with K_L.

$$C = Co \exp(-K_L \cdot z) \cdots\cdots\cdots\cdots\cdots\cdots (9)$$

K_L is the leaching rate which can be determined from equation (9) when the distribution of concentration with increasing depth z is known.

RESULTS AND DISCUSSION

In the forest the flow of nutrient matter is largely through the trees and the ground flora, and is returned to the soil as litter every year. Nutrient materials decomposed from the litter are reabsorbed by the plants or infiltrated down the soil profile beyond the root zone. Decay rates of litter are influenced by temperature, humidity, soil pH, nitrogen content and the rates of carbon-nitrogen ratio.

Table 1. Amounts of dry weight, organic matter, and organic carbon in the litter samples of *Pinus rigida* stand in Mt. Gwan-ak

Horizon	Dry Weight (g/m^2)	Organic Matter (g/m^2)	Organic Matter (%)	Organic Carbon (g/m^2)
L	692.9±142.8	682.3±137.6	98.55±0.45	393.91± 79.46
F	1786.4±301.21	1623.8±312.4	90.53±2.23	940.20±177.74
H	1390.3±324.78	1006.8±200.3	73.04±2.66	581.30±115.64
A_1	1628.4±456.9	258.6± 90.4	18.95±3.65	149.32± 52.16

Table 2. Amounts of dry weight, organic matter, and organic carbon in the litter samples of *Pseudosasa japonica* stand in Odong-do

Horizon	Dry Weight (g/m^2)	Organic Matter (g/m^2)	Organic Matter (%)	Organic Carbon (g/m^2)
L	449.9±36.4	445.4±36.1	98.97±0.03	257.1±20.9
F	744.19±0.1	681.2±28.4	91.53±3.81	393.3±16.4
H	212.4±62.9	161.0±36.4	82.09±1.24	93.0±21.0
A_1	965.8±13.1	621.9±35.5	64.36±2.8	359.1±20.5

The amount of organic matter was determined in the L, F, H and A_1 layers in order to determine the decay rates (Tables 1 and 2). Dceay rates of organic matter, K_D was determined from the decay model of Olson(1963). Decay rate was higher at *Pseudosasa* stand than at *Pinus* stand (Table 3); K_D was 0.234 at *Pseuosasa* stand and 0.191 at *Pinus* stand. The amount of nutrients infiltrated into the soil layer is influenced by the decay rate.

Table 3. Parameters and time for decompositon of organic matter

Site	k_D	$1/k_D$	half time $0.693/k_D$	95% time $3/k_D$	99% time $5/k_D$
Pinus rigida	0.191	5.237	3.630	15.725	26.202
stand on Mt. Gwan-ak	±0.0008	±0.0023	±0.0159	±0.0776	±0.1293
Pseudosasa japonica	0.234	4.281	2.967	12.846	21.405
stand on Odong-Do	±0.0017	±0.0311	±0.0216	±0.0935	±0.1558

Table 4. The decay and accumulation model of litters

Site	Decay Model	Accumulation Model
Pinus rigida stand on Mt. Gwan-ak	$C=1670.9e^{-0.19t}$	$C=1670.9(1-e^{-0.234t})$
Pseudosasa japonica stand on Odong-Do	$C=845.3e^{-0.234t}$	$C=845.3(1-e^{-0.234t})$

Nutrient materials such as N, P, K, Ca and Na supplied to the soil profile by decomposition of organic matter in litter layer are distributed in the soil profile at the state of dissolved materials in the soil solution. Thus when water infiltration occurs as a consequence of rainfall or irrigation, these soluble nutrients tend to move downward by mass flow with the flowing soil water. The vertical distributions of N, P, K and Na were shown in Figs. 2, 3, 4, 5 and 6. Most graphs tended to correspond with the model curve in Fig. 1, so that leaching rates for each nutrient were determined from equation (9).

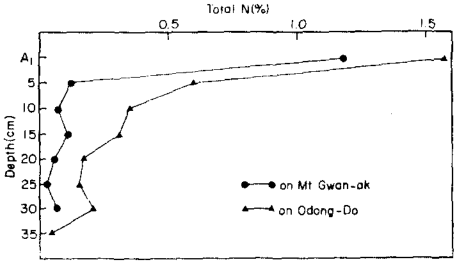

Fig. 2. The concentration distribution of total N in the soil of Mt. Gwan-ak and Odong-do as a function of depth.

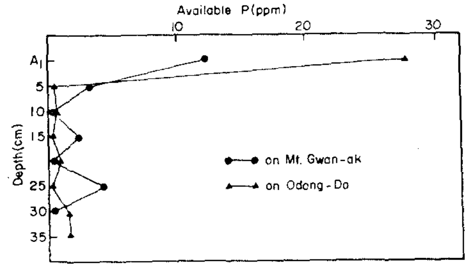

Fig. 3. The concentration distribution of available phosphorus in the soil of Mt. Gwan-ak and Odong-do as a function of depth.

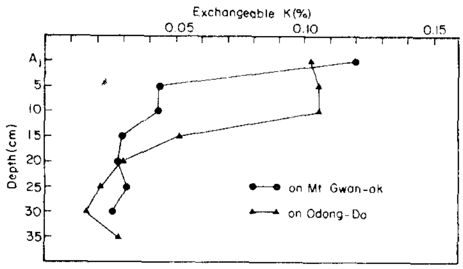

Fig. 4. The concentration distribution of exchangeable K in the soil of Mt. Gwan-ak and Odong-do as a function of depth.

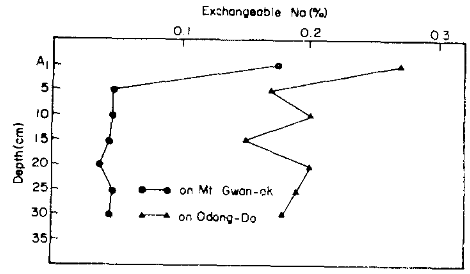

Fig. 5. The concentration distribution of exchangeable Na in the soil of Mt. Gwan-ak and Odong-do as a function of depth.

Table 5. The leaching model of mineral nutrients in the soil of Mt. Gwan-ak and that of Odong-Do

Mineral Nutrients	Site	
	Mt. Gwan-ak	Odong-Do
N	$C_N = 1.116e^{-0.086z}$	$C_N = 1.556e^{-0.080z}$
P	$C_P = 12.123e^{-0.079z}$	$C_P = 27.656e^{-0.056z}$
K	$C_K = 0.122e^{-0.041z}$	$C_K = 0.102e^{-0.051z}$
Na	$C_{Na} = 0.176e^{-0.029z}$	$C_{Na} = 0.265e^{-0.008z}$
Ca	$C_{Ca} = 0.398e^{-0.096z}$	$C_{Ca} = 0.825e^{-0.028z}$

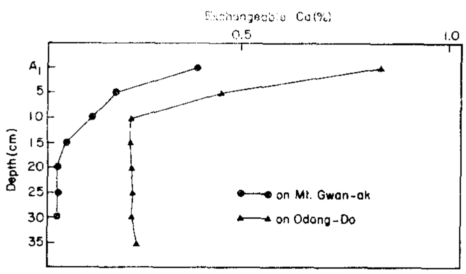

Fig. 6. The concentration distribution of exchangeable Ca in the soil of Mt. Gwan-ak and Odong-do as a function of depth.

The vertical distribution of nitrogen was shown in Fig. 2. The nitrogen content was 10~20 times greater on the litter layer than on the soil layer. The leaching rates of nitrogen determined from the vertical distribution with increasing depth were 0.086 and 0.080 on Mt. Gwan-ak and on Odong-do (Table 5). Leaching rate of nitrogen was greater than most of other nutrients both on Mt. Gwan-ak and on Odong-do. This means that much amount of nitrogen is leached to the ground water not to be used by plants. Many researches on nitrate leaching was carried out (Burns, 1975; Towner, 1983; Jaakkola, 1984) as compared to other nutrients.

The phosphorus are present as various types in the soil and the amount of available phosphorus in the soil has a close relation with that of litter on the soil surface (Kim & Chang, 1965). The vertical distribution of phosphorus in the soil profile was shown at Fig. 3. The leaching rates were higher on Mt. Gwan-ak than on Odong-do. The leaching rates and the leaching models of phosphorus werealso represented in Table 5.

The content of phosphorus showed a great difference between the litter layer and soil layer and the total phosphorus content was much greater than the available phosphorus on the L, F and H layers (Tables 6 and 7). It is thought that the considerable amount of phosphorus remains as an organic phosphorus composing the organic matter rather than most of decomposed phosphorus come into the soil (Anderson, 1975).

The potassium is present as various types which affect distribution of potassium considerably. The distribution of potassium on Odong-do was a little different with that of other nutrients such as nitrogen, phosphorus, calcium and sodium (Fig. 4). Potassium concentration kept constant from the top soil to the depth of 15cm, but the contents were exponentially decreased with increasing soil depth below 15cm on Odong-do. Leaching rate on Odong-do was 0.051, which was greater than that on Mt. Gwan-ak, 0.041. All leaching rates of N, P, Ca and Na were higher on Mt. Gwan-ak than on Odong-do but that of potassium was contrary to the tendency.

Vertical distribution of sodium showed the exponentially decreasing function(Fig. 5). Peculiar aspect was that the sodium content was very high in the lower depth of soil on Odong-do. It is thought that great amount of sodium in the soil was owing to the geographical trait of Odong-do such as proximity of the sea. Leaching rate of sodium on Odong-do, therefore, was very low which was 0.008, while that on Mt. Gwan-ak was 0.029.

The distribution of calcium in the soil profile corresponded with the model curve (Fig. 6). The amount of total calcium was decreased in the order of L, F, H and A_1 layer but exchangeable Ca content was greater on the F and H layer than on the L layer (Tables 6 and 7). It is thought that exchangeable calcium produced from the decayed litter remained on the F and H layers at any forms which can not be infiltrated easily toward the soil layer. Leaching rates of Ca were 0.096 and 0.018 on Mt. Gwan-ak and on Odong-do. The calcium content was kept considerably high at soil depths below 10cm, so that low leaching rate of calcium was shown on Odong-do.

The leaching rates were the highest in the case of nitrogen and on the whole the soil of Odong-do showed the lower leaching rates than that of Mt. Gwan-ak. Leaching mechanism is dependent on the physical characteristics of soils and the kinds of nutrient salts. The soil of Odong-do contained more plentiful nutrients owing to higher decay rate and lower leaching rates than that of Mt. Gwan-ak. More systematic research on the leaching rates in the soil profile is to contribute to the estimation of nutrient cycle in the ecosystem.

摘 要

本 研究에서는 관악산의 리기다소나무(*pinus rigida*) 林과 오동도의 이대(*pseudosasa*

japonica) 林을 擇하여 落葉의 分解速度를 구하고, 土壤垂直斷面에서 N, P, K, Ca, 및 Na의 濃度分布를 調査함으로써 각 營養鹽類의 洗脫係數를 구하였다. 洗脫係數는 Towner의 鹽類濃度式인 $C = Co \exp(-\theta_0 z/w)$에서 $-\theta_0/w$를 常數 K_L로 代替함으로써 決定하였다.

分解速度는 관악산의 리기다소나무林에서 0.191이었고, 오동도의 이대林에서는 0.234이었다. N, P, K, Ca 및 Na의 土壤내 垂直分布는 Towner의 모델曲線과 一致하였다. K, P, K, Ca, 및 Na의 洗脫係數는 관악산에서 0.086, 0.079, 0.041, 0.029, 0.096인데 비하여 오동도의 경우는 0.080, 0.056, 0.051, 0.008, 0.028로 대체로 낮았다. 오동도의 이대林의 경우에 높은 分解速度와 낮은 洗脫速度를 보임으로써 관악산의 경우보다 토양내에 含有된 각 鹽類의 濃度가 높은 것으로 나타났다.

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