Korean Jour. Botany
Vol. 20, No. 3, 109—118(1977)

Distributions and Cyclings of Nitrogen, Phosphorus and Potassium in Korean Alder and Oak Stands

Mun, Hyeong Tae[1], Choon Min Kim[2] and Joon Ho Kim[1]
(Department of Botany[1] and Department of Biology Education[2], Seoul National University, Seoul)

물오리나무와 상수리나무 숲의 窒素, 燐 및 加里의 分配와 循環

文炯泰[1] · 金遵敏[2] · 金俊鎬[1]
(서울大學校 植物學科[1] 生物敎育科[2])

ABSTRACT

Seasonal distribution of N, P and K contents and their cycling were studied in Korean oak (*Quercus acutissima*) and Korean alder (*Alnus sibirica*) stands in central part of Korean peninsula. The amounts of three minerals were high in young leaves but gradually decreased with the process of leaf development in both stands. The amounts of minerals in the branches, trunks and roots were decreased in summer, however, they increased again in autumn. Seasonal changes of these minerals were not significant in the two stands. The amounts of phosphorus and potassium in plant and soil were higher in the oak stand than the alder one. but those of nitrogen were reversed. The amounts of minerals absorbed during one year were greater in the oak stand than in the alder one, but those returned into soil through mineralization of litter were less in the former than in the latter. The nutrient requirements of the oak stand were greater than the alders, but the cycling rate, the ratio of the amount of minerals absorbed to returned, was opposite.

INTRODUCTION

The biological cycle of nutrients and the flow of energy in the terrestrial ecosystems are fundamental processes affecting the production of organic matter in them. It is a well known fact that biological essential elements act upon as one of the important limiting factors on the productivity of ecosystem or community. There have been many reports on the relationships between nutrient elements and tree growth in forest ecosystems (Ovington, 1959; Ovington and Medgwick, 1959; Ingestad, 1959; Ingestad and Molin, 1960; Ernst, 1975). Since a systematic approach of nutrient cycling in forest ecosystem has been attempted by Ovington(1962), many ecologists have made a considerable effort to explain this field. The study on the cycling of some mineral elements in the temperate deciduous forests was made by Duvigneaud and Denaeyer-de Smet(1970). According to them, the nutrient requirement of oak stand was much greater than that of other temperate forest ecosystems. Iwatsbo *et al.* (1969) have investigated the mineral cycling in the evergreen-deciduous forest and artificial Cryptomeria stand. They pointed out that the main source of mineral elements supplied was from both rain-water and soil and that no deficiency of minerals for the growth of trees was observed because of the contribution by litter fall. Johnson and Risser(1974) have analyzed biomass, annual net primary production, and dynamics of six mineral elements in a post oak-blackjack oak forest in central Oklahoma. Rochow(1975) has made the amounts of macro-nutrients and its cycling of the above ground standing crops in oak-hickory forest. Tappeiner and Alm(1975) and Song and Monsi(1975) have done similar works with the floor vegetations. Jordan and Kline(1972) also have studied the mineral cycling in tropical rain forest.

On the other hand, Bormann and Likens (1967) and Jhonson and Swank (1973) studied on mineral cycling in a watershed ecosystem, and Burton and Likens(1975) have pursued the role of salamender population on energy flow and mineral cycling in the same ecosystem. However, never have the data concerning on the mineral cycling in forest ecosystem in Korea. The purpose of this study is to elucidate the mineral cycling for several important elements which may affect productivity. With this in mind seasonal changes of distribution of N, P and K and its cyclings were analyzed in Korean oak and Korean alder stands.

STUDY AREA

This study was carried out in Korean oak (*Quercus acutissima*) and Korean alder (*Alnus sibirica*) stands in the Arboretum of Seoul National University which is at Bisan-dong, Anyang city, Kyunggido Province, located in central part of Korea. Data of climate from the Seoul Central Meteological Station, which is about 14km apart on north of the study area, is as follows.

Annual precipitation during this study period (September, 1975—October, 1976) was 1,065mm and mean monthly temperature was −3.9°C in January and 23.7°C in August. Hythergraph of the study area during study and for past 20 years is available (Chae and Kim, 1977). The soil of the study area was originated from granite. Soil texture of the alder stand was loam soil, it consisted of : coarse sand 22.2%, fine sand 19.0%, silt 33.3%, clay 22.4%, that of the oak stand was sandy loam soil : coarse sand 55.1%, fine sand 22.4%, silt 12.7% and clay 9.8%. The contents of N, P, K and organic matter (Org.M) and pH values of soil with depth of the study area were shown in Fig. 1. In the alder stand tree was 12-13 years old and its density was 1,667 trees/ha. There were several species of understories, dominated by *Step-*

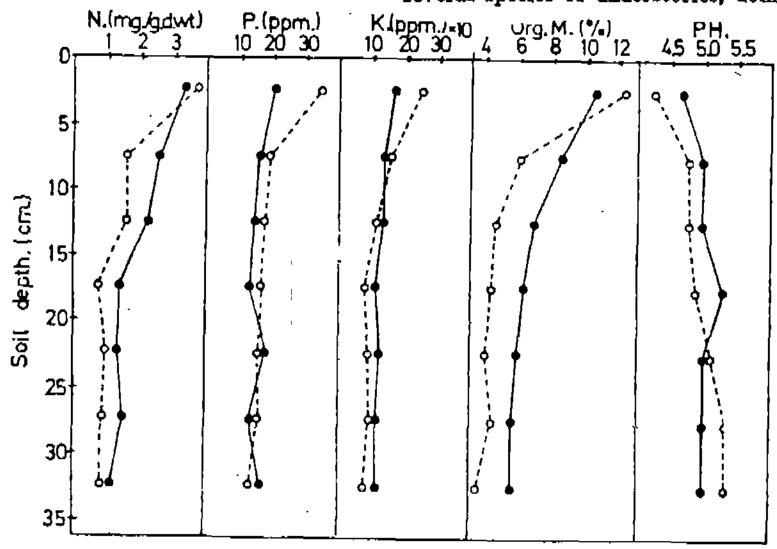

Fig. 1. Amounts of Nitrogen(N), phosphorus (P), potassium (K) and organic matter (Org. M) and pH of the soil with depth. Solid lines and broken lines indicate those in the alder and in the oak stands, respectively.

hanandra incisa, Styrax japonica, Lindera obtusilobum and *Pueraria thunbergiana* as shrubs, and *Convallaria keiskei, Carex lanceolata* and *Arundinera hirta* as herbs. In the oak stand, the tree was 12-14 years old and the density was 2,388 trees/ha. The dominant shrubs were *Lespedeza bicolar, Stylax japonica, Pueraria thunbergiana* and herbaceous species were *Miscanthus sinensis* and *Sophora angustifolia*.

EXPERIMENTAL METHODS

1. Sampling

During the study period, sampling was made separately for leaves, branches, stems, roots and soils in the stands at one-month intervals. Plant materials were dried for 48 hr at about 80°C. They were ground, sieved with a 0.5mm sieve and than stored in air tight containers. Soil was dried in shade place, sieved with a 2 mm sieve and stored.

2. Estimation of biomass

Without obtaining data of the biomass and the net primary production, it would be impossible to quantify the mineral cycle in a forest ecosystem. Chae and Kim (1977) have previously estimated biomass and net primary production of both alder and oak stands in this study area. These data were also used here to the mineral cyciling. To estimate the biomass of the floor vegetation herbs were clipped at the ground level within $1m^2$ quadrats in October, 1976. These materials were separated into woody and non-woody components and dried for 48 hr at about 80°C and weighed. Total biomass of the floor vegetations in the study area was obtained as dry weight per unit area.

3. Estimation of litter

The estimation of the amount of litter was made by collecting the fallen leaves within a unit land area and weighed them in December, 1975. A part of the sampled materials was carried to laboratory and treated through the same procedure as the plant materials mentioned above. The amount of litter reduced by decay for a year was estimated from difference between the litter amount in last year and that of remaining just before the defoliation in current year.

4. Chemical analyses

Total nitrogen, available phosphorus and potassium were determined for each organ of trees, the litter, the floor vegetations and soils in the alder and the oak stands, respectively. Total N was determined by a modified micro-Kjeldahl method. Available P was determined by the stannous-reduced molybdophosphoric blue color method. To analyze available K, 10g of the dry soil with 50 m*l* of 2N ammonium acetate and 0.5g of plant material with 50m*l* of 0.2N hydrochloric acid were shaken constantly for an hour and then filtered. The filtrate was used for the measurement of available K with a flame photometer.

RESULTS AND DISCUSSION

1. Seasonal changes of minerals

The cycling of minerals in forest ecosystems occurs as a function of time (Duvigneaud and Denaeyer-de Smet, 1970), therefore, it is necessary to analyze annual as well as seasonal cycles. Fig. 2 to 7 show seasonal variations of the total-N, available P and available K in each organ of the tree and of the alder and the oak stands. In the alder stand, the contents of N, P and K of leaves were 42.32, 4.28 and 12.90 mg/g dry weight in April, however, they were gradually decreased to 13.26, 1.86 and 6.90 mg/g in October. In the oak stand, those of leaves were 25.88, 2.74 and 13.20 mg/g in May, thereafter decreased to 7.84, 1.24 and 7.50 mg/g in October, respectively. These decreasing trends in fall, as stated by Davy and Taylor (1975), would be due to the dilution of the inorganic nutrient resources with increasing dry matter. The potassium contents of branches, stems and roots in the alder stand were 1.0, 0.7 and 3.3 mg/g in spring but decreased to 0.76, 0.55 and 2.06 mg/g in summer and then increased again to 0.99, 0.77 and 3.90 mg/g in October. Those of the oak stand were 0.90, 1.10 and 6.74 mg/g in spring, decreased to 0.80, 0.93 and 4.12 mg/g in summer, thereafter increased again to 0.85, 1.04 and 5.23 mg/g in October. The seasonal changes of nitrogen and phosphorus showed a similar tendency to potassium. It is assumed that a large quantity of

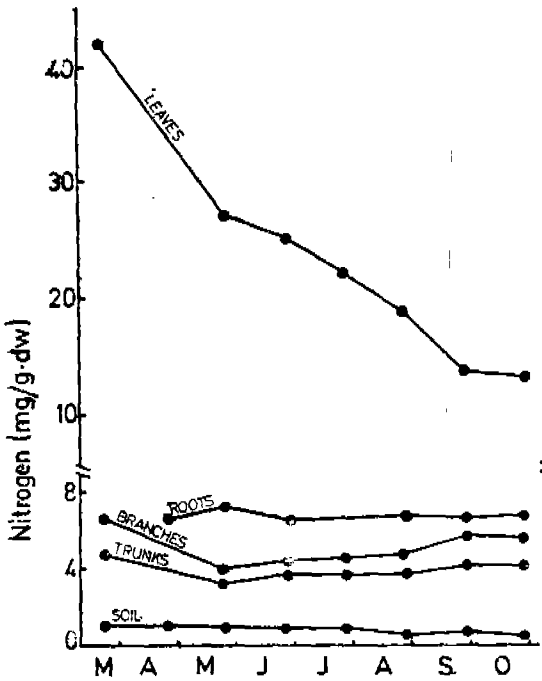

Fig. 2. Seasonal variations of nitrogen in the components of the alder stand.

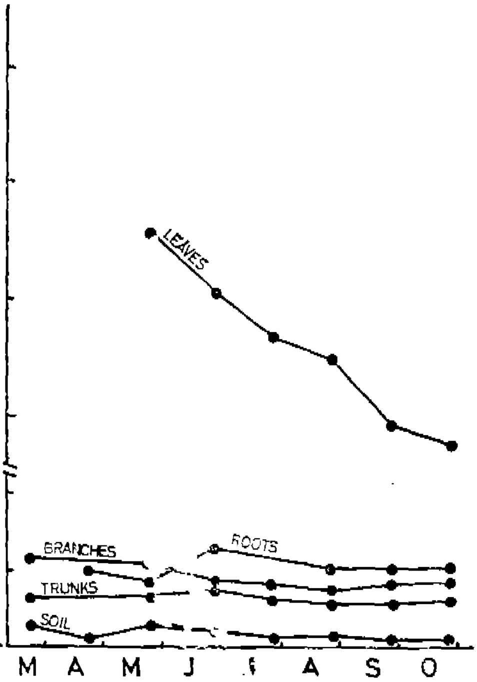

Fig. 3. Seasonel variations of nitrogen in the components of the oak stand.

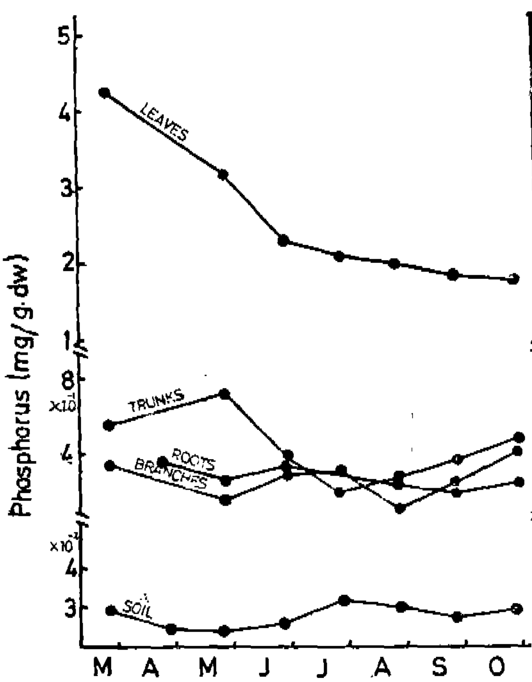

Fig. 4. Seasonal variations of phosphorus in the components of the alder stand.

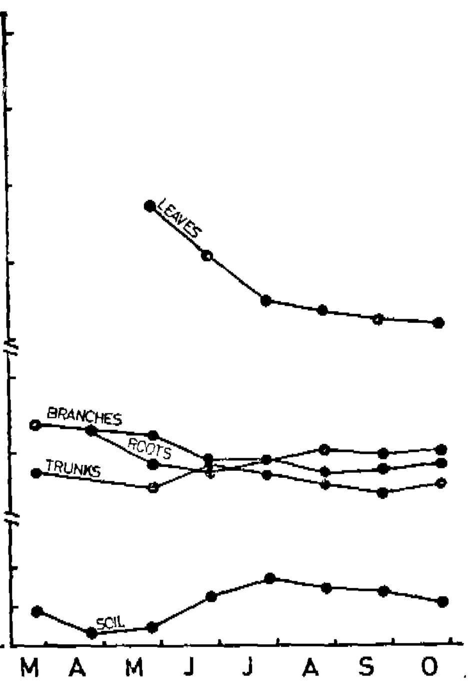

Fig. 5. Seasonal variations of phosphorus in the components of the oak stand.

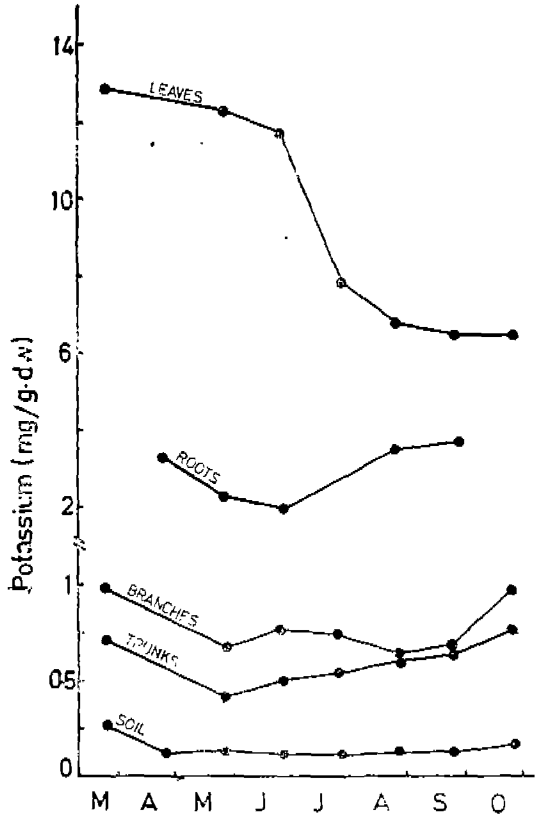

Fig. 6. Seasonal variations of potassium in the components of the alder stand.

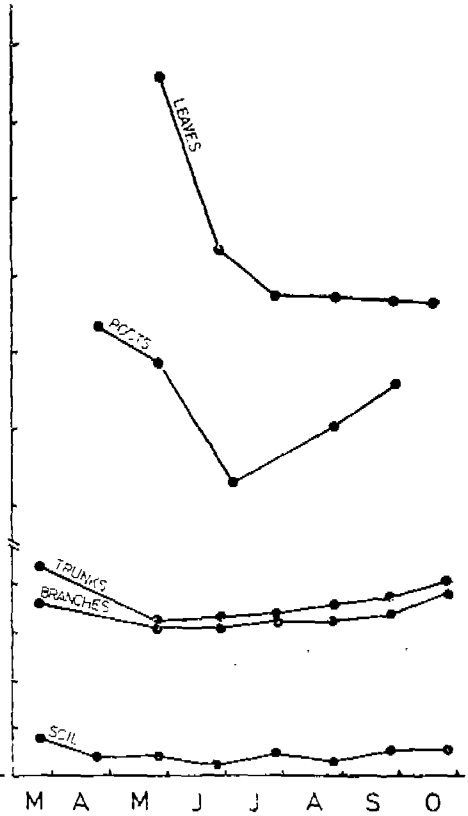

Fig. 7. Seasonal variations of potassium in the components of the oak stand.

mineral elements are translocated to leaves from spring to summer, however, that it takes place from leaves to branches, stems and roots in fall. Ranges of the contents of N, P and K in soil of the alder stand were 0.60—1.18, 0.002—0.003 and 0.12—0.27 mg/g, and those of the oak stand were 0.41—1.15, 0.002—0.003 and 0.10—0.19 mg/g, respectively. These did not show the seasonal fluctuation as did the plant components (Figs. 5 and 6).

2. Distribution of biomass and net primary production

Fig. 8 indicates the distribution of biomass and net primary production, which is estimated in the previous paper by Chae and Kim (1977), in both stands. The total biomass of trees in the oak stand was 1.5 times as much and the net primary production was 2 times as much greater than those in the alder stand. It may be due to the fact that high density and the active growth of the oak stand compared with of the alder stand, because the trees are younger in the former than in the latter. The biomass of floor vegetations under the alder stand shows 1.4 times as much

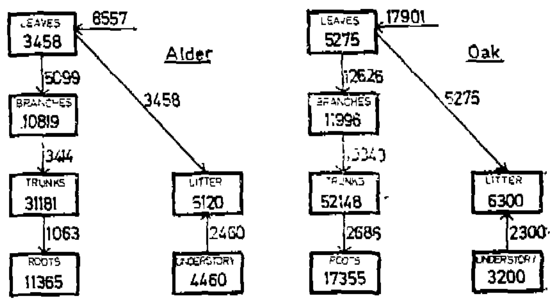

Fig. 8. Distribution of dry weight of biomass and net production in the alder and the oak stands. Numerals in compartments and on arrows stand for biomass, kg/ha, and for flows of net production, kg/ha/year.

greater than that in the oak one. This result may be explained by the facts of the low density of the alder stand and penetration of much solar radiation into the forest floor (Ovington, 1968; Chae and Kim, 1977).

The amounts of litter in the alder and the oak stands were 5,120 kg/ha and 6,300 kg/ha, respectively. The reason of such a difference between both stands would be due to the fact that the leaf of oak was not only much in the amount but also hard in the leaf texture. It was observed that in fact oak leaf was slowly decayed compared with alder one. The amount of litter in this study was less than the result reported by Johnson and Risser (1974). The reason might be that a considerable amount of litter seemed to be removed by the local inhabitants surrounding of the study area lately.

3. The contents of minerals

As shown in Table 1, the contents of minerals of each part of tree were much more in the alder stand than those in the oak stand. In the alder stand, ratio of mineral contents of stem, branch, root, leaf were 1.0: 1.3: 1.6: 3.0 in nitrogen, 1.0: 1.8: 1.0: 7.5 in phosphorus, 1.0: 1.5: 8.5: 13.0 in potassium and in the oak stand, 1.0: 1.4: 1.7: 3.2 in nitrogen, 1.0: 1.5: 2.7: 7.6 in phosphorus, 1.0: 1.8: 6.4: 11.6 in potassium, respectively. The nitrogen contents of the floor vegetation compared with those of tree leaves were 1.8 or 1.4 times as much of the alder or the oak stand. However, the contents of phosphorus and potassium in the floor vegetation had generally similar to those of tree leaves. Never were the mineral contents of litter shown great difference compared with those of the tree leaves in both stands except potassium. Potassium contents of litter were diminished to one tenth in the alder and to one-sixth in the oak less than those of the live leaves.

Table 1. Contents of three mineral elements in various components of the alder and the oak stands

Components	N	P	K
	mg/g dry weight		
Alder			
Leaves	13.26	1.857	8.400
Branches	5.60	0.460	0.992
Trunks	4.36	0.249	0.646
Roots	6.80	0.254	5.500
Understory	24.00	2.328	12.283
Litter	23.24	1.330	0.946
Soil	0.60	0.003	0.125
Oak			
Leaves	7.84	1.238	7.500
Branches	3.36	0.252	1.154
Trunks	2.44	0.163	0.646
Roots	4.12	0.432	4.124
Understory	27.00	1.088	11.137
Litter	10.76	1.150	1.223
Soil	0.39	0.004	0.145

4. Standing amounts of minerals

The distribution of minerals contained in each component, the amounts of minerals absorbed by plants and those returned to soil through litter decay in both stands are summarized in Table 2

Table 2. Uptake, retention, return and standing amount of three mineral elements in the alder and the oak stands

Elements	Uptake kg/ha/yr	Retention kg/ha/yr	Return kg/ha/yr	Standing amount kg/ha
Alder				
N	120.0	31.0	89.0	379.0
P	11.5	2.6	8.9	25.9
K	70.0	11.0	59.0	159.7
Oak				
N	131.0	44.0	87.0	345.5
P	12.5	3.5	9.0	23.0
K	112.0	21.4	90.6	215.6

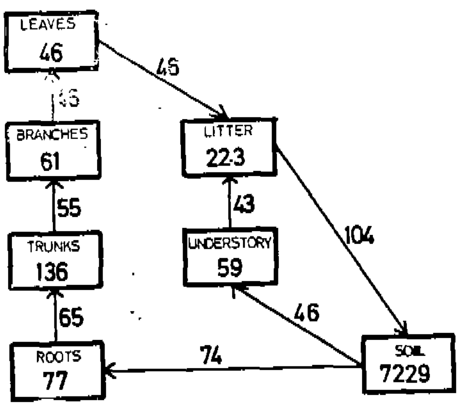

Fig. 9. Distrbutions of nitrogen among the components of the alder stand. Numerals in compartments and on arrows mean nitrogen content of each omponent, kg/ha, and nitrogen flows between component, kg/ha/ year.

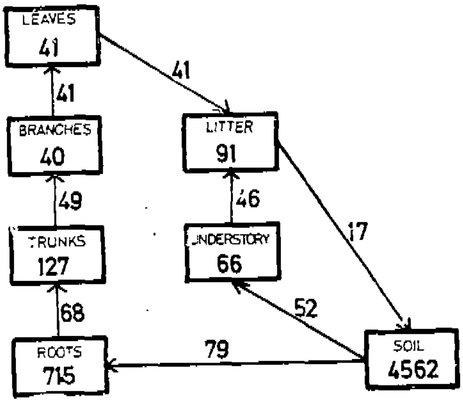

Fig. 10. Distribution of nitogen among the components of the oak stand. Numerals in compartments and on arrows mean nitrogen content of each component, kg/ha, and nitrogen flows between components, kg/ha/year.

and Figs. 9 to 14. The total amounts of minerals contained in trees and floor vegetations in the alder and the oak stands were 379.0 and 345.5 kg/ha for nitrogen, 25.9 and 29.0 kg/ha for phosphorus, 159.7 and 215.6 kg/ha for potassium. The amounts of minerals were greater in the alder stand than in the oak one except for nitrogen. The large amounts of nitrogen in each component of the alder stand may be resulted from nitrogen fixation by symbiotic nodule bacteria in its root. Ranges of the amounts of minerals of deciduous forests studied by Rodin and Bazilevich (1967, cited in Johnson and Risser, 1974), Duvigneaud and Denaeyer-de Smet (1970), Nihlgard (1972, cited in Johnson and Risser, 1974), and Johnson and Risser (1974) were 530 to 1,200 kg/ha of nitrogen, 40 to 100kg/ha of phosphorus and 340 to 1/400kg/ha of potassium. These values are higher than the values of the upper limits obtained in this study. This is because the biomass was small and the age of the trees was younger in this study area than those in the others. However, the amounts of minerals obtained in ever-

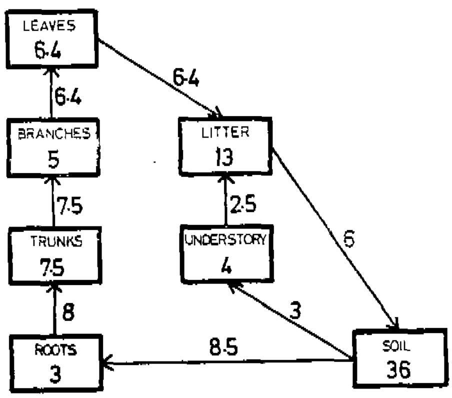

Fig. 11. Distributions of phosphorus among the components of the alder stand. Numerals in compartments and on arrows mean the element content of each component, kg/ha, and it flows between components, kg/ha/year.

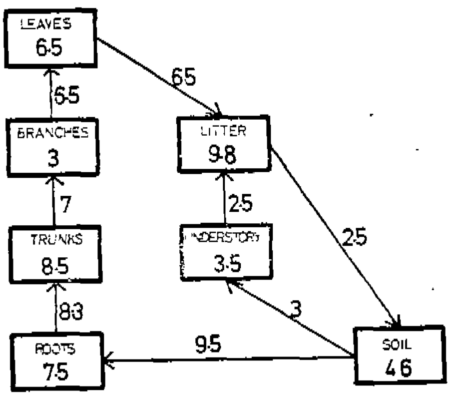

Fig. 12. Distributions of phosphorus among the component of the oak stand. Numerals in compartments and on arrows mean the element content of each component, kg/ha, and it flows between compartments, kg/ha/year.

green deciduous forest and artificial cryptomeria stand (Iwatzbo *et al.*, 1969) were smaller than those of the present study. The distribution ratios of standing amounts of minerals in each organ of the tree in alder stand—leaves: branches: stems: roots—were 1.0 : 1.3 : 3.0 : 1.7 in nitrogen, 2.1 : 1.7 : 2.5 : 1.0 in phosphorus, 2.7 : 1.0 : 1.9 : 5.9 in potassium and those in oak stand were 1.0 : 1.0 : 3.2 : 1.8 in nitrogen, 2.2 : 1.0 : 2.8 : 2.5 in phosphorus, 2.9 : 1.0 : 1.4 : 5.2 in potassium, respectively. The amounts of nitrogen and potassium in the litter and the floor vegetations in the oak stand were higher than those in the alder one, however, that of phosphorus was *vice versa*. In the soil, the nitrogen content was 58% as high in the alder stand compared with the oak stand, on the contrary, the oak stand rather had 28% as much as high in phosphorus and 13% in potassium.

5. Mineral cycling

As shown in Fig. 9 to 14 the estimated amounts of mineral elements absorbed by the alder and the oak stands for a year were 120 and 131 kg/ha for nitrogen, 11.5 and 12.5 kg/ha for phosphorus, 70 and 112 kg/ha for potassium. Uptakes of N, P and K in the oak stand were 9.1%, 8.6% and 60.0% higher than those in the alder one (Table 2). This partly explainable in terms of greater biomass and net primary production in the oak stand than in the alder.

The amounts of the absorbed minerals in the temperate deciduous forests analyzed by Duvigneaud and Denaeyer-de Smet (1970), Nihlgard (1972, cited in Johnson and Risser, 1974) and Johnson and Risser (1974) were 92-204 kg/ha/yr of nitrogen, 43-99kg/ha/yr of phosphorus and 49-201kg/ha/yr of potassium. The absorbed amounts of each element in the present study, in general, correspond with the ranges of their results mentioned above, except that phosphorus are less than the lower limit of them. The rates of minerals absorbed by plant to minerals contained in soil for a year were 1.7 and 2.9% in nitrogen, 31.9 and 27.2% in phosphorus, 4.6 and 6.5% in potassium in the alder and the oak stands, respectively. These results suggest that the study area are suffering from the deficiency of phosphorus. Therefore, if one supplies sufficient quantity of phosphorus it would be able to expect much higher matter production than in the present conditions. The amounts of minerals returned to the forest floor by means of litter fall were 89 and 87 kg/hr/yr of nitrogen, 8.9 and 9.0kg/ha/yr of phosphorus, 59 and 91kg/ha/yr of potassium in the alder and the oak stands. The returned amounts were similar in the two stands except for potassium. The amounts of minerals returned to soil through litter decay per one

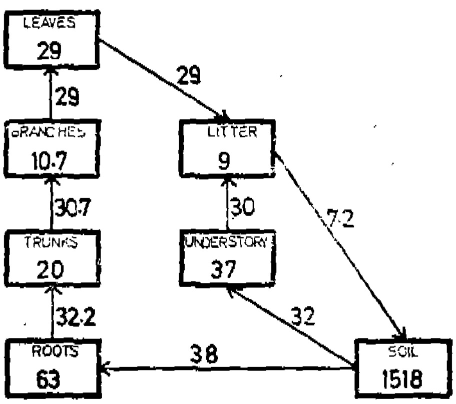

Fig. 13. Distributions of potassium among the components of the alder stand. Numerals in compartments and on arrows mean potassium content of each component, kg/ha, and phosphorus flows bteween comartments, kg/ha/year.

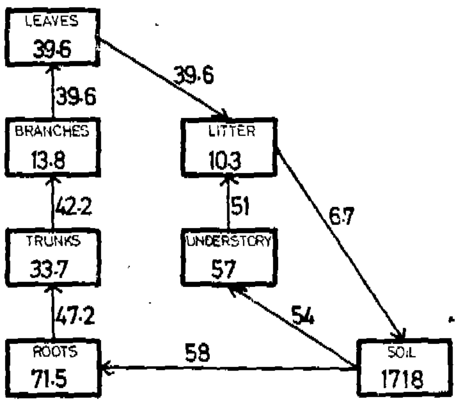

Fig. 14. Distributions of potassium among the omponents of the oak stand. Numerals in co mpartments and on arrows mean phosphorus content of each component, kg/ha, and phosphorus flows between compartments, kg/ha/year.

year in the alder and the oak stands were 104 and 17 kg/ha/yr of nitrogen, 6.0 and 2.5 kg/ha/yr of phosphorus, 7.2 and 6.7kg/ha/yr of potassium, respectively. Retention, the difference between uptake by plants and return to soil by litter decay, was evaluated from the data obtained from measurement of annual biomass increment and from the chemical components of each organ of the tree. The annual retentions of minerals in the alder and the oak stands were 31 and 44 kg/ha/yr of nitrogen, 2.6 and 3.5kg/ha/yr of phosphorus, 11.0 and 21.4 kg/ha/yr of potassium. Thus the oak stand greatly accumtlated minerals compared with the alder stand. This must have correlation with active matter production in the oak stand. The mineral accumulation in the oak stand of this study is greater than those obtained from oak forest by Duvigneaud and Denaeyer de Smet (1970) and from post oak-blackjack oak forest by Johnson and Risser (1974). The present study areas are still in a phase of rapid growth or immature stage, as shown by the high values for annual increment of biomass and retention of minerals.

Some workers(Ovington, 1968; Iwatsubo *et al.*, 1969) have been reported that a considerable amounts were supplied to forest ecosystem by precipitation, however, it was not considered in this study.

摘 要

물오리나무와 상수리나무 숲에서 窒素, 燐 및加里 含量의 季節的 變化와 그들의 循環을 조사하였다.

1. 잎의 N, P 및 K含量은 兩樹種이 幼葉에서는 높고 성숙해감에 따라 감소하는 경향을 보였다.

2. 가지, 줄기 및 뿌리의 鹽類含量은 봄에는 높고 여름에는 감소되며 가을에는 다시 봄의 水準까지 증가하였다.

3. 植物體와 土壤 중의 燐과 加里의 現存量은 각각 상수리나무 숲이 많았고 窒素의 그것은 오히려 물오리나무 숲에서 많았다. 물오리나무 숲에서 窒素가 많은 이유는 根瘤菌에 의한 窒素固定 때문이라고 생각된다.

4. 물오리나무 숲의 窒素, 燐酸 및 加里의 吸收量은 상수리나무 숲보다 적었다. 그러나 落葉의 無機化에 의한 鹽類의 回收量은 전자가 후자보다 많았다.

5. 窒素, 燐 및 加里의 循環率(吸收量/回收量)은 물오리나무 숲에서 각각 1.15, 1.91 및 9.70, 상수리나무에서는 각각 7.7, 5.0 및 16.7로서 후자가 높았다.

REFERENCES

Bormann, F. H. and G. E. Likens. 1967. Nutrient cycling. *Science* 155 : 424—429

Bormann, F. H. and G. E. Likens. 1970. The nutrient cycles of an ecosystem. *Sci. Am.* 223 : 92—101.

Burton, J. M. and G. E. Likens. 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook experimental forest, New Hampshire. *Ecology* 56 : 1068—1080.

Chae, M. I. and J. H. Kim. 1977. Comparisons of biomass, productivity and productive structure between alder and oak stands. *Korean J. Ecol.* 1:57—65.

Davy, A. J. and K. Taylor. 1975. Seasonal changes in the inorganic nutrient concentrations in *Deschampsia caespitosa* (L.) Beauv. in relation to its tolerance of contrasting soils in the Chiltern Hills. *J. Ecol.* 63 : 27—39.

Duvigneaud, P. and S. Denaeyer-de Smet. 1970. Biological cycling of minerals in temperate deciduous forests. pp. 199—255. In D. Reichle. (ed). Analysis of temperate forest ecosystems. Springer—Verlag, New York.

Ernst, W. 1975. Variation in the mineral contents of leaves of trees in Miombo woodland in South Central Africa. *J. Ecol.* 63 : 801—807.

Ingestad, T. 1959. Studies on the nutrition of forest tree seedings. II. Mineral nutrition of spruce. *Physiol. Plant.* 12 : 568—593.

Ingestad, T. and N. Molin. 1960. Soil disinfection and nutrient status of spruce seedlings. *Ibid.* 13 : 90—103.

Iwatsubo, G., Y. Nishida, and T. Tsuzumi. 1962. On the nutrient cycling in forest ecosystem (in Japanese). *JIBP·PT-F.* 43 : 75—78.

Jhonson, P. L. and W. T. Swank. 1973. Studies of cation budgets in the southern Appalachians on four experimental watersheds with contrasting vegetation. *Ecology* 54 : 70—80.

Johnson, F. L. and P. G. Risser. 1974. Biomass, annual net primary production and dynamics of six mineral elements in a post oak-blackjack oak forest. *Ibid.* 55 : 1246—1258.

Jordan, C. F. and J. R. Kline. 1972. Mineral cycling : Some basic concepts and their application in a tropical rain forest. *Ann. Rev. Ecol. Syst.* 2 : 33—50.

Ovington, J. D. and H.A.I. Madgwick. 1959. Distribution of organic matter and plant nutrients in a plantation of Scots pine. *Forest Science* 54 : 344—355.

Ovington, J. D. 1962. Quantitive ecology and the woodland ecosystem concept. *Advan. Ecol. Res.* 1 : 103—192.

Ovington, J. D. 1968. Some factors affecting nutrient distribution within ecosystems. *UNESCO Natural Resources Research* 5 : 95—105.

Rochow, J. J. 1975. Mineral nutrient pool and cycling in a Missouri forest. *J. Ecol.* 63 : 985—994.

Song, S. D. and M. Monsi. 1974. Studies on the nitrogen

and dry-matter economy of a *Lespedeza bicolor* var. *japonica* community. *Journ. Fac. Sci. Univ.* Tokyo III. 11 : 283—332.
Tappeiner, J. C. and A. A. Alm. 1975. Undergrowth vegetation effects on the nutrient content of litterfall and soils in red pine and birch stands in Northern Minnesota. *Ecology* 56 : 1193—1200.

(Received July 11, 1977)