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Nitrogen Mineralization and Dynamics in the Forest Soil

Mun, Hyeong-Tae

Dept. of Biology, Kongju National University

삼림토양의 질소 무기화와 무기질소의 동태

文 炯 泰

공주대학교 이공대학 생물학과

ABSTRACT

Mineral nitrogen dynamics and net mineralization of nitrogen in oak(*Quercus accutissima*) and pine(*Pinus rigida*) forest soils were studied. Nitrogen mineralization was determined over 8-week period by incubation method at laboratory. Initial water content of incubating soils was adjusted by applying suction(30mmHg), and loss of water during incubation was recovered with deionized water using syringe at every 3 or 4days. Temperature of incubator was maintained with 35±0.3℃ during the incubation period. Content of organic matter, total nitrogen, NH_4-N and NO_3-N in soils in oak stand were significantly higher than those in pine stand. Soil pH was lower in pine stand than in oak stand. Initial NH_4-N and NO_3-N of soils used in incubation experiment were 12.6 μg/g and 6.5 μg/g for oak stand, and 5.3 μg/g and 5.1 μg/g for pine stand, respectively.

Production of NH_4-N increased from the beginning at both stands, and showed a peak at 5th week in oak stand(28.5 μg/g) and 6th week in pine stand(16.7 μg/g), and then decreased. Intial NO_3-N of soils in oak(6.5 μg/g) and pine(5.1 μg/g) stands, increased to 36.2 μg/g in soils of oak stand(5th week) and 13.4 μg/g in pine stand(4th week), respectively. The low values of NO_3-N of the field soil in the growing season compared with those of incubating soils at both stands indicate that considerable amount of NO_3-N might be uptaken by plants, and leached downward in the soil. The amount of NH_4-N and NO_3-N produced in soils of oak and pine stands during two-months incubation were 59.7 and 141.6mg/kg soil, and 51.9 and 41.2mg/kg soil, respectively.

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INTRODUCTION

Nitrogen mineralization, the release of ammonium from decomposing organic material, provides the major source of biologically available nitrogen in forest soils(Marion *et al.*, 1981 ; Vitousek and Matson, 1985). Many workers have studied the nitrogen mineralization on various soil types, temperature and moisture regime, and incubation methods (Eno, 1960 ; Bremner and Douglas, 1971 ; Stanford and Smith, 1972 ; Smith *et al.*, 1977 ; Laura, 1977 ; Matson and Vitousek, 1981 ; Klopatek, 1987 ; Strader *et al.*, 1989 ; Sasser and Binkley, 1989).

The mineralization of nitrogen in soil under optimal temperature and moisture for an infinite time has been suggested as a basis for predicting the amount of soil nitrogen mineralized(Standford and Smith, 1972 ; Smith *et al.*, 1977 ; Stanford, 1982). However, Westermann and Crothers(1980) suggested that the modifying effects of soil temperature and water content under field conditions must also be considered. In many cases, the supply of inorganic nitrogen from soil organic matter is normally measured in short-term incubations at constant temperature and moisture(Herlihy, 1979).

The buried polyethylene bag technique has been used to validate the soil nitrogen mineralization potential approach to predicting nitrogen mineralization potential under field conditions(Eno, 1960 ; Smith *et al.*, 1977). Recently, ion exchange resin bag method is used for measuring nitrogen availability, and for predicting nitrogen mineralization potential of soils(Binkley and Matson, 1983 ; Binkley, 1984).

The purpose of this study was to compare the seasonal patterns of inorganic nitrogen production in the fields with different soil texture, moisture and organic matter, and net nitrogen mineralization during short-term laboratory incubation of soils in oak and pine stands.

MATERIALS AND METHODS

Study sites

Two sites were chosen for this study in Kongju, Chungnam Province. One is oak (*Quercus accutissima*) stand which is located in watershed area protected from artificial disturbances, and the other is pine(*Pinus rigida*) stand which is located within the compus area of Kongju National University. In oak stand, *Quercus variabilis*, *Platycarya strobilacea*, *Castenea crenata* and *Prunus sargentii*, as well as *Q. accutissima*, had a high importance value. In pine stand, however, the tree layer was solely consisted of *P. rigida*. The mean coverage of herb layer in oak stand and pine stand was 60% and 10%, respectively(Mun, unpublished).

Soil temperature was measured at 10cm soil depth with soil thermometer(Weston, Model 2261) in the pine stand during experimental period. Soil temperature was recorded around

midday. Mean temperature was calculated at every five-day intervals.

Soil sampling

Soil samples were collected monthly in both stands for 1 year from August 1990 to July 1991 from top soil(0~10cm) and subsoil(10~20cm). Subsamples were taken for the determination of soil water content by oven-drying method and inorganic nitrogen(NH_4-N and NO_3-N) concentration. Soils were air-dried and sieved with a 2-mm sieve.

Incubation preparation

About 3kg of soil samples were taken from the both stands in March 1991. About 300g of fresh soil sample, sieved with a 2-mm sieve, were placed in a nalgene plastic Buchner funnel(11cm diameter) and covered with polyethylene film(0.0125mm thick) to permit aeration and reduce moisture loss(Bremner and Douglas, 1971). Four Buchner funnels were prepared for each soil type.

The initial moisture content of the incubating samples was set to 30mmHg by suction and adjusted every 3 or 4 days during the incubation by weighing each container, where necessary adding distilled water using a syringe(Fisher *et al.*, 1987). The incubating temperature was maintained with 35±0.3℃; this choice of moisture and temperature regime is considered optimal for nitrogen mineralization(Sandford, 1982 ; Fisher *et al.*, 1987). Net nitrogen mineralization was calculated as the increase in ammonium and nitrate in the soil relative to initial values(Sasser and Binkley, 1989).

Soil analysis

Soil pH was measured with glass electrode pH meter after shaking a 1 : 2.5 soil : water solution for 1 hr on a rotary shaker. Soil organic matter was determined by loss on ignition. Total nitrogen was determined by a modified microKjeldahl method(Wilde *et al.*, 1979). Inorganic nitrogen(NH_4-N and NO_3-N) was determined every week during incubation period. 10g of soil was removed from each of the incubating soil sample, placed in a cornical flask with 100mL of 2N KCl and filtered with Whatman #42 after shaking thoroughly for 1 hour. Ammonium and nitrate nitrogen in KCl extracts of soil were determined by salicylate method(Nelson, 1983), and by West and Lyles(1960), respectively.

RESULTS AND DISCUSSION

Soil properties

There were significant differences in the soil properties between the oak stand and the pine stand. Soil moisture content was significantly higher in oak stand than in pine stand (t-test, $p<0.01$, Fig. 1A). This may be due to higher organic matter in the former than the latter, and the soil texture difference(Table 1). Moisture content in top soil was higher than those of subsoil at both stands. In top soil of oak stand, soil moisture decreased

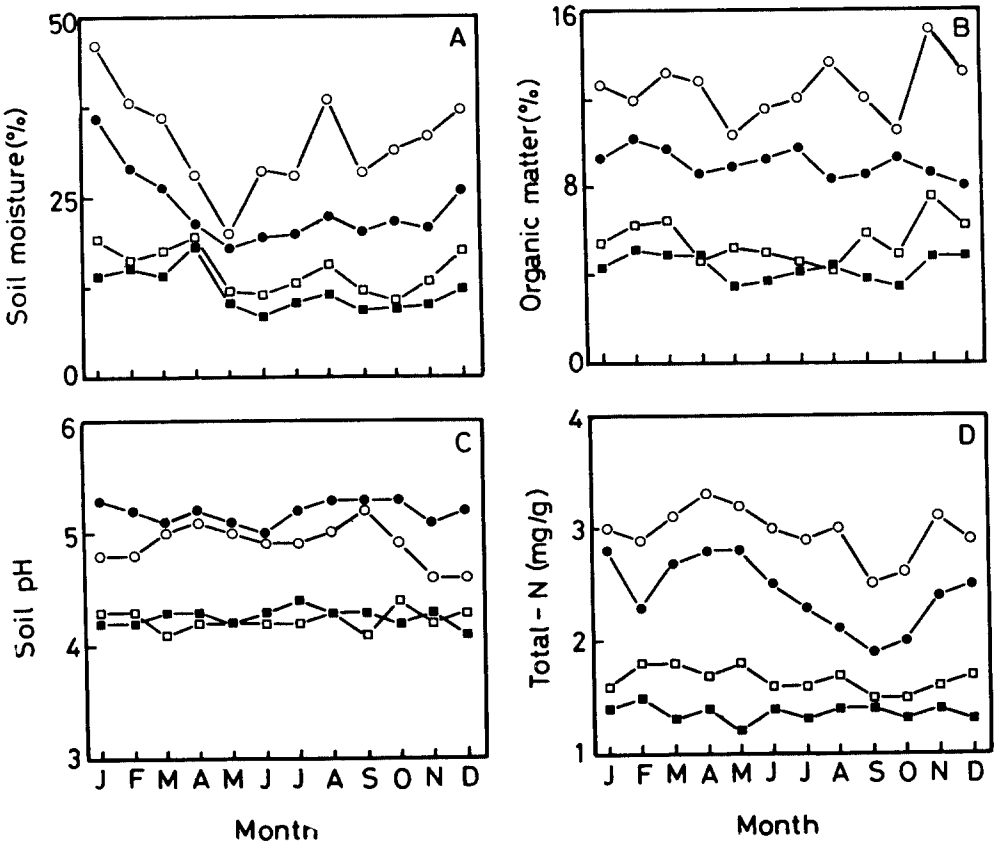

Fig. 1. Seasonal patterns of soil moisture(A), organic matter(B), pH(C) and total nitrogen(D) in the oak(circle) and pine(rectangle) stands. Open circle and rectangle indicate surface soil, and closed circle and rectangle indicate subsoil.

Table 1. Physico-chemical properties of soils used for nitrogen mineralization studies

Soil properties	Oak stand	Pine stand
Texture	Loam	Sandy loam
pH	5.0 ±0.4*	4.1 ±0.3
Organic matter(%)	13.2 ±1.2***	6.5 ±0.7
Total-N(%)	0.31±0.03***	0.18±0.01
NH_4-N(mg/kg soil)	12.6 ±1.47***	5.3 ±0.62
NO_3-N(mg/kg soil)	6.5 ±2.83	5.1 ±1.71

*$p<0.05$, ***$p<0.001$

from 46.2% in January to 20.0% in May, and then increased to 37.1% in December.

Soil organic matter content was also significantly higher in oak stand than in pine stand (Fig. 1B). Average content of organic matter in top soil and subsoil was 12.4±1.3(mean ±S.D) and 9.0±0.7% in oak stand, and 5.5±1.0 and 4.3±0.6% in pine stand,

respectively. Soil pH ranged from 4.1 to 4.3 in pine stand(Fig. 1C), which was significantly lower than the results of red pine forests in Yongwol(pH range, 7.0~7.4, Choung and Kim, 1987), and Chech'on(pH range, 7.9~8.3; Kim *et al.*, 1990) limestone area. Soil pH in this oak stand(ranged from 4.6 to 5.3) was also significantly lower than in Chinese oak stand(pH range, 7.8~8.4, Kim *et al*, in press) in Chech'on limestone area, but similar with the results in *Q. variabilis* stand(Koh and Yim, 1987) and *Q. accutissima* stand(Mun *et al.*, 1977) in noncalcareous soil. Soil pH was slightly higher in subsoil than in top soil at both stands. Total nitrogen content was significantly higher in oak stand than in pine stand(Fig. 1D). Average content of nitrogen in top soil and subsoil was 3.0 ±0.2 and 2.4±0.3mg/g in oak stand, and 1.7±0.1 and 1.4±0.1mg/g in pine stand, respectively.

The quantity of NH_4-N exceeded that of NO_3-N for the year at both stands. The content of mineral nitrogen was consistently higher in top soil than in subsoil at both stands(Fig. 2). In oak stand(Fig. 2A), content of NH_4-N increased sharply from 7.5 μg/g in January to 19.3 μg/g in May, and then decreased gradually to 9.4 μg/g in December in top soil. In pine stand, however, content of NH_4-N showed a peak in July with 12.3 μg/g. The data of NH_4-N content in the soils at both stands indicate that the most nitrogen mineralization took place in the top soil where the soil organic matter content was high. The quantity of NH_4-N in these oak and pine stands were much lower than that in the semi-natural grassland soils of the DMZ(Kim, 1976). In case of NO_3-N, it decreased gradually from 6.7 μg/g in January to 4.2 μg/g in July, and then increased to 9.4 μg/g in November in top soil of oak stand. Harmsen and van Schreven(1955) reported that nitrogen mineralization can only proceed when there is sufficient moisture in the soil.

Binkley(1984) and Mun and Whitford(1990) reported that resin ammonium values were strongly affected by soil water regime. In this study, however, content of NH_4-N showed

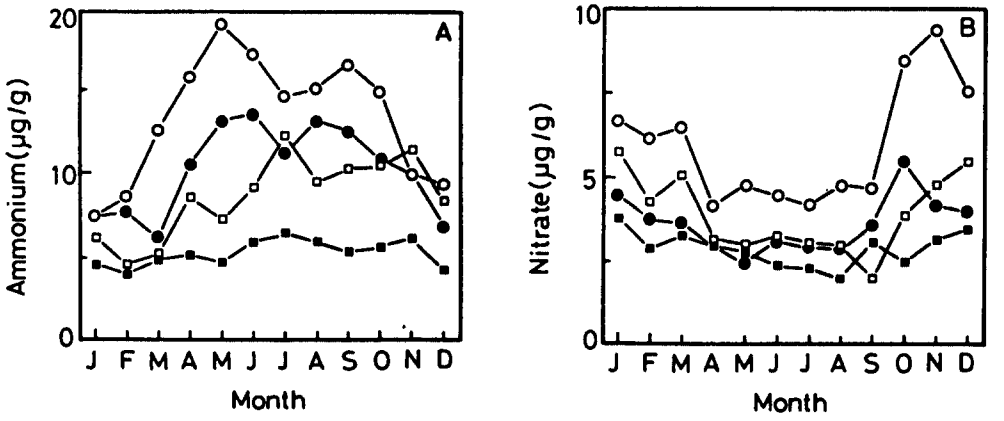

Fig. 2. Seasonal patterns of ammonium nitrogen(A) and nitrate nitrogen(B) in the oak and pine stands. Legends are the same with Fig. 1.

a peak when the soil moisture content low, which suggest that some other factors, rather than soil moisture, are important for nitrogen mineralization in this temperate region. Since the process of nitrogen mineralization is governed by soil microorganisms, the effect of soil temperature on nitrogen mineralization must be considered. Nitrogen mineralization may not have taken place actively in winter from December to February in the study areas because the soil temperatures at 10cm depth were below zero in this period(Fig. 3). The amount of mineral nitrogen produced in field soils of oak and pine stands during 1yr(sum of the each value minus the value of January) were 71.1 and 31.8mg/kg soil, respectively. The quantities of mineral nitrogen in this study sites were similar with the results by Matson and Vitousek(1981), Vitsek and Matson(1985) and Sasser and Binkley(1989).

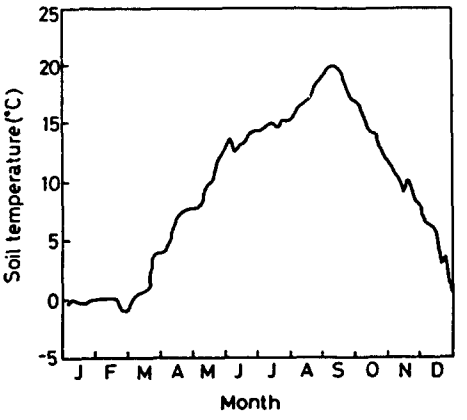

Fig. 3. Seasonal variation in soil temperature at 10cm depth. Temperature reading was done around midday.

Mineral nitrogen production

Physico-chemical properties of soils used in incubation experiment were quite different between oak stand and pine stand(Table 1). Soil texture in oak and pine stands were classified into loam and sandy loam, respectively. The latter was more acidic than the former. Content of NH_4-N was significantly higher in oak stand than in pine stand, however, NO_3-N were similar between the two stands.

The quantities of NH_4-N and NO_3-N mineralized during incubation were greater in soils of oak stand than those in pine stand(Table 2). This may be due to the higher organic matter and total nitrogen in the former than in the latter, and the difference in soil texture between the soils of two stands. Herlihy(1979) reported that the quantity of inorganic nitrogen in the optimum moisture treatment was greater in the loam(122mg/kg soil) than in the loamy sand(35mg/kg soil). Initial content of NH_4-N in oak stand was 12.6 μg/g soil. The quantity of ammonium-N mineralized increased during the first half incubation, and showed a maximum 28.5 μg/g soil at 5th week(2.3times of initial quantity). Thereafter, it decreased, but maintained higher than initial quantity till at the end of the incubation. Nitrate-N production also showed the same pattern with that of NH_4-N. Initial content of NO_3-N was 6.5 μg/g soil. NO_3-N increased to 36.2 μg/g soil at 5th week(5.6 times of initial quantity).

Table 2. Content of nitrogen mineralized during soil incubations

Stand		Incubation periods, weeks								
		0	1	2	3	4	5	6	7	8
		mg mineralized N/kg soil								
Oak	NH_4-N	12.6	13.1	18.4	23.7	20.2	28.5	22.1	18.4	16.1
	NO_3-N	6.5	11.2	15.6	19.3	35.1	36.2	30.2	25.3	20.7
Pine	NH_4-N	5.3	4.6	7.5	13.2	15.3	11.5	16.7	16.1	9.3
	NO_3-N	5.1	6.2	8.5	7.4	13.4	12.7	10.6	11.7	11.5

Seasonal pattern of NH_4-N and NO_3-N in oak stand showed that the former was consistently higher than the latter(Fig. 2). In the incubation experiment, however, production of NO_3-N was greater than that of NH_4-N(Table 2). The low values of NO_3-N of the field soil in the growing season indicate that considerable amount of NO_3-N produced in this oak stand might be uptaken by plants, and leached downward in the soil(Kim, 1976). Although absolute amount of mineral nitrogen produced in pine stand was lower than in oak stand, patterns of mineralization were similar at both stands. The amount of NH_4-N and NO_3-N produced in soils of oak and pine stands during two-months incubation(sum of the each value minus initial value) were 59.7 and 141.6mg/kg soil(total 201.3mg/kg soil), and 51.9 and 41.2mg/kg soil(total 93.1mg/kg soil), respectively. The higher production of inorganic nitrogen in soils of oak stand may be due to the differences of soil pH, texture, organic matter and total nitrogen(Harmsen and van Schreven, 1955). The results of this study were greater than those by Herlihy(1979).

토양성질이 상이한 상수리나무 군집과 리기다소나무 군집에서 연중 무기질소의 동태와, 실험실에서의 배양실험을 통해 각 토양의 무기질소의 생산량을 조사하였다. 토양은 8주 동안 배양하였으며 배양기의 온도는 35±0.3℃로 유지하였다. 토양의 수분, 유기물, 전질소 및 무기질소의 함량은 상수리나무 군집이 리기다소나무 군집에 비해 높았다.

배양기간 동안에 암모니아태 질소와 질산태 질소의 생산량은 상수리나무 숲에서 토양 1kg당 59.7mg과 141.6mg, 리기다소나무 숲에서 각각 51.9mg과 41.2mg으로 나타났다. 상수리나무 숲 토양이 리기다소나무 숲 토양에 비해 무기질소 생산량이 많은 것으로 전자가 후자에 비해 토양 pH와 토성이 질소의 무기화에 적합하고, 유기물 함량과 전질소 함량이 높은데 기인하는 것으로 해석되었다.

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