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Litterfall, Decomposition, and Nutrient Dynamics of Litter in Red Pine (*Pinus densiflora*) and Chinese Thuja (*Thuja orientalis*) Stands in the Limestone Area

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石灰岩地域 소나무림과 측백나무림의 落葉生産, 分解 및 窒素와 燐의 動態

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ABSTRACT

Litterfall, decomposition, and dynamics of N and P in decomposing litter were investigated for 2 years in red pine (*Pinus densiflora*) and Chinese thuja (*Thuja orientalis*) stands in the limestone area. Average litterfall in red pine and Chinese thuja stands were 4,535 kgDM ha^{-1} yr^{-1} and 5,010 kgDM ha^{-1} yr^{-1}, respectively. Seasonal litterfall in red pine and Chinese thuja stands showed peaks in November. Concentrations of N and P in the needle litter were lowest in the winter when the greatest litterfall occurred, and highest in the summer when the least litterfall occurred. However, those in Chinese thuja scale leaf litter showed little seasonal variation. Amount of N and P returned to the forest floor through litterfall were 29.02 kgN ha^{-1} yr^{-1}, 2.81 kgP ha^{-1} yr^{-1} for red pine stand, and 31.06 kg N ha^{-1} yr^{-1}, 2.86 kgP ha^{-1} yr^{-1} for Chinese thuja stand, respectively. After 21 months elapsed, needle and Chinese thuja scale leaf litterbags lost 34.8% and 32.5% of the initial weight, respectively. N concentrations in the docomposing needle and Chinese thuja scale leaf litter decreased by 19% and 30%, respectively, after 1 month elapsed, and then gradually increased to exceed the initial concentration after 9 months elapsed in both of them. P in needle and Chinese thuja scale leaf litter decreased by 54% and 57% of the initial concentration, respectively, after 1 month elapsed. Unlike N, P concentration in the decomposing litter did not exceed that of initial ones. Net immobilization period of N and P in decomposing litter did not occur over the study period.

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INTRODUCTION

Litterfall and decomposition of litter are the major pathway for the supply of plant nutrients (Fogel and Cromack, 1977; Jorgensen *et al.*, 1980). In recent years many workers have attempted to quantify the rates of litterfall and its subsequent decomposition for understanding the transfer of litter mass and minerals to the floor in forest ecosystems (Meentemeyer, 1978; Duffy *et al.*, 1985; Sharma and Ambasht, 1987; Lowman, 1988; Blair *et al.*, 1990), and uncovered that many factors such as climate, edaphic, soil biota and organic chemical composition of the litter can affect decomposition rates (Meentemeyer, 1978; Swift *et al.*, 1979; Vossbrinck *et al.*, 1979; Berg *et al.*, 1982; McClaugherty *et al.*, 1984). In a mesic, oak-dominated forest floor, about 60% of the nutrients was returned through litterfall (Carlisle *et al.*, 1966). In Korea, Kim and Chang (1965), Chang and Chung (1986) and Chang *et al.* (1990) have studied production and decomposition of litter using Olson's negative exponential decay model (Olson, 1963). However, there is a few works using litter trap and litterbag method (Kim and Chang, 1989; Mun and Yoo, 1992).

We have initiated a long-term research project in August 1989 for the purpose of studying the structure and function of ecosystems in limestone areas of Korea. The purpose of the present study is to quantify production and decomposition of litter as a basic data set for the nutrient cycling in a red pine (*Pinus densiflora*) and Chinese thuja (*Thuja orientalis*) stands occurring in the limestone areas.

METHODS

Litter production

The site description, basic climatic data and community structure of the study area, located at Maep'o near Tanyang, Ch'ungbuk Province, have been described in detail by Kim *et al.* (1990). Litterfall was measured at every two months intervals over 2 years, from November 1989 to December 1991, in a red pine and a Chinese thuja stands, respectively. Beginning in November 1989, litter was collected from ten 50×50 cm litter traps placed on each plot. Collected litter was sorted into leaves and twigs etc. in the lab, oven-dried at 80℃ for 72 hrs and weighed. Subsamples were ground with grinding mixer to pass through a 20 mesh screen for chemical analysis.

Litterbag preparation

Pine needle and Chinese thuja scale leaf litter which turned brown were collected from the branches at abscission in the autumn of 1989 from a red pine and a Chinese thuja forest, respectively. They were brought to the lab and dried to constant weight for two days at 80℃ oven. The litterbags of 12×12 cm in area were made of terylene net with a mesh size of 1 mm. Each litterbag enclosed about 5 g of litter. Aluminum tags were attached to every litterbags giving the exact weight of the litter enclosed. Needle litterbags and Chinese thuja scale leaf litterbags were laid flat on the pine forest floor and Chinese thuja forest floor, respectively, on February 23, 1990. They were fastened to the ground with an aluminum nail.

Litterbag retrieval and chemical analysis

Five litterbags of each species were retrieved and brought to the lab after 1, 3, 6, 9, 12, 15, 18 and 21 months. They were gently washed with tap water to remove adhering soil particles and weighed after drying to constant weight at 80℃ oven. Weight loss and release of nutrients during litter decomposition were determined by measuring remaining weight and nutrient concentration of litter in the litterbags. Weight loss of remaining litter was expressed as % of initial sample weight.

Samples were ground in a laboratory mill equipped with 1 mm screen for chemical analysis. Total-N was determined by microkjeldahl method, and P was determined by a wet digestion method (Allen *et al.*, 1974). The concentrations of N and P of the remaining litter in litterbags were multiplied by the fraction of the litter weight remaining, and this product was expressed as % remaining of the original content of each nutrient.

RESULTS AND DISCUSSION

Litterfall

Litterfall in the red pine and Chinese thuja stands occurred throughout the year with a marked seasonal variation (Fig. 1). It was the minimum in summer and the maximum in winter at both stands. Seasonal pattern of litterfall showed little difference year by year. Annual litterfall in the red pine stand was 4,050 kgDW ha^{-1} in 1990 and 5,020 kgDW ha^{-1} in 1991, which varied significantly from year to year. That in Chinese thuja stand was 4,950 kgDW ha^{-1} in 1990 and 5,060 kgDW ha^{-1} in 1991.

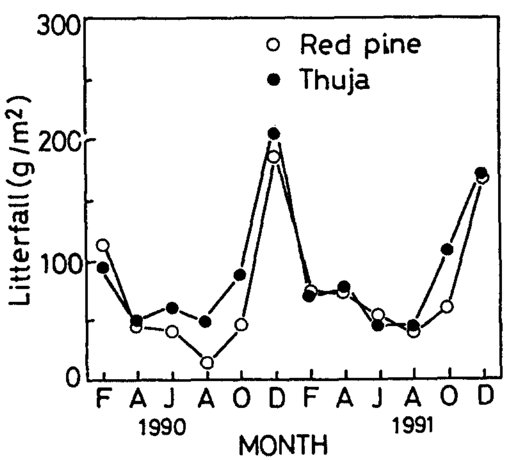

Fig. 1. Seasonal litterfall in red pine stand(open circle) and Chinese thuja stand(closed circle) in the study area.

Kim and Chang (1989) reported that annual litterfall in *P. rigida* plantation was 6,044 kg ha^{-1}, which was greater than our result. Annual needle litterfall in slash pine plantations increased with stand age to a peak of 4,450 kg ha^{-1} at age 15, then declined in the older stands (Gholz *et al.*, 1985). After canopy closure, foliage bio-

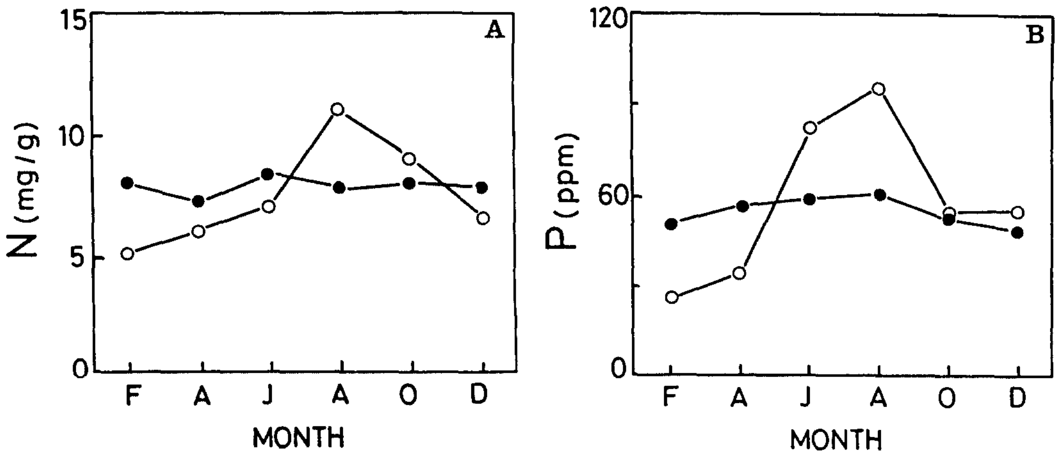

Fig. 2. Seasonal changes of nitrogen and phosphorus in the litter of red pine(open circle) and Chinese thuja(closed circle) as a function of time elapsed.

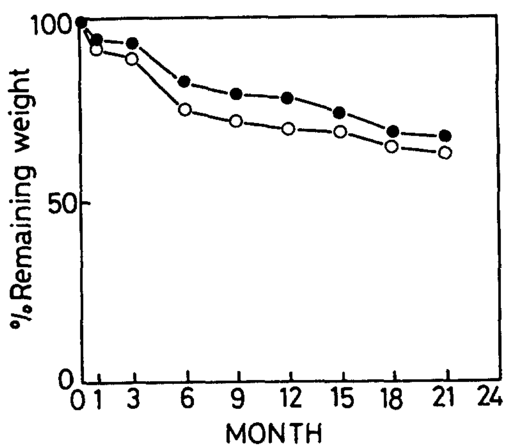

Fig. 3. Percentages of dry weight remaining in decomosing litter of red pine(open circle) and Chinese thuja(closed circle) as a function of time elapsed.

mass declined somewhat in the older stands, which was paralleled by a decline in needle litterfall (Switzer and Nelson, 1972; Wiegert and Monk, 1972). Unfortunately, there was no available data for comparison with our litterfall data of Chinese thuja stand.

N and P concentrations in litterfall

N concentration in needle litter was the lowest in the winter (5.5 mgN g^{-1}) when the greatest litterfall occurred, and highest in the summer (12.0 mgN g^{-1}) when the least litterfall occurred. However, N concentration in Chinese thuja scale leaf litter showed no significant seasonal pattern (Fig. 2A). P concentration in needle litter also showed the same seasonal pattern with that of N (Fig. 2B). It showed a peak in August (100 ppm), and a sink in February (26 ppm). P concentration in Chinese thuja scale leaf litter showed a slight increase in August, but the seasonal pattern was not conspicuous. Gholz *et al.* (1985) also reported similar results in needle litter in the slash pine plantation, although the period of maximum and minimum litterfall differed from this site. Amount of N and P returned to the forest floor through litterfall were 29.02 kgN ha^{-1} yr^{-1}, 2.81 kgP ha^{-1} yr^{-1} for red pine stand, and 31.06 kgN ha^{-1} yr^{-1}, 2.86 kgP ha^{-1} yr^{-1} for Chinese thuja stand, respectively.

Weight loss during litter decomposition

Weight losses from the needle and Chinese thuja scale leaf litter continued steadily over 2 years, but the former was always greater than the latter, in spite of similar pattern (Fig. 3). After 1 year, needle and Chinese thuja litterbags lost 30% and 22% of the initial weight, respectively. After 21 months, remaining weight of needle and Chinese thuja scale leaf litter was 65.2% and 67.5% of initial weight, respectively. Weight loss was greater in the first year than second year in both species. This may be due to the fact that most of the water soluble fractions in litter leached out during the first year (Berg *et al.*, 1980; Yavitt and Fahey, 1986; Sharma and Ambasht, 1987). Kim and Chang (1989), Mun and Yoo (1992) also reported that needle litter (*P. rigida* and *P. thunbergii*) lost 30% and 34% of initial weight, respectively, during first year in noncalcareous site. Needle litter of ponderosa pine and slash pine, however, lost 20% and 15%, respectively, during the first year (Klemmedson *et al.*, 1985, Gholz *et al.*, 1985). Such differences among needle litters would result from litter quality and site factors such as soil moisture, air temperature, rainfall pattern, and soil microfauna (Mentemeyer, 1978; Vossbrinck *et al.*, 1979; Berg *et al.*, 1980). Mun and Yoo (1992) reported that the black pine needle litter lost 66% of the initial weight after 18 months and 71% after 24 months elapsed in noncalcareous site. Decomposition of black pine needle litter in the noncalcareous site was much faster than that of red pine needle litter in the calcareous site. Litterbags retrieved from the limestone site were drier than those in nonlimestone site, and density of soil microarthropods (mites and springtails) also was higher in the former than that in the latter (Mun and Kim, unpublished). These results emphasize that the site characteristics such as microclimatic, edaphic, and biological factors are quite important for litter de-

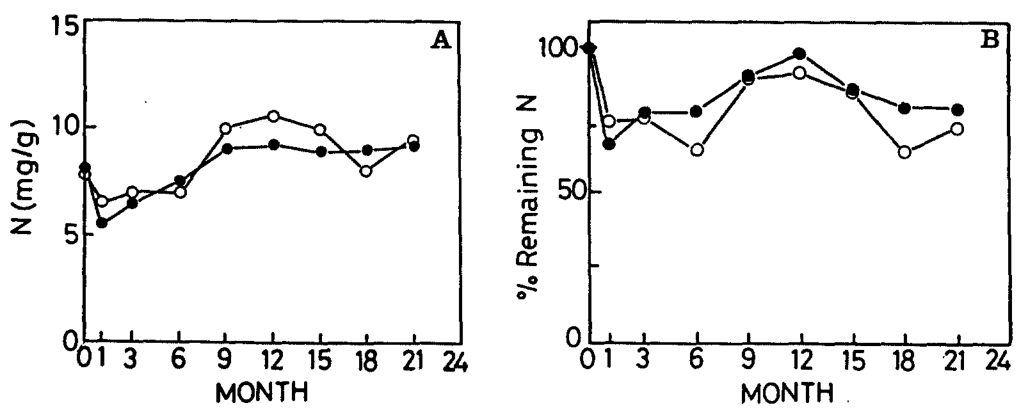

Fig. 4. Changes of nitrogen concentration(A) and percent of remaining nitrogen(B) in litter of red pine(open circle) and Chinese thuja(closed circle) as a function of time elapsed.

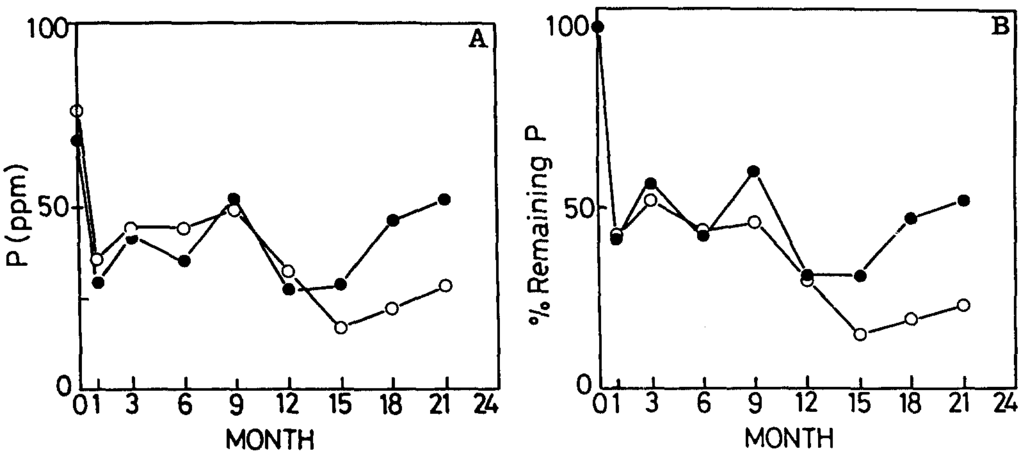

Fig. 5. Changes of phosphorus concentration(A) and percent of remaining phosphorus (B) in litter of red pine(open circle) and Chinese thuja(closed circle) as a function of time elapsed.

composition processes (Fogel and Cromack, 1977; Vossbrinck *et al.*, 1979; Berg *et al.*, 1982; Blair *et al.*, 1990).

Dynamics of N and P during litter decomposition

N concentration in both decomposing litter decreased significantly after 1 month elapsed (Fig. 4A). Initial N concentrations of needle and Chinese thuja scale leaf litter were 8.0 mg g^{-1} and 7.8mg g^{-1}, and they decreased to 6.5mg g^{-1} and 5.5mg g^{-1}, respectively, after 1 month elapsed. Thereafter, N concentration gradually increased till 12 months elapsed in both litter. N concentration in the decomposing black pine needle in noncalcareous site increased significantly after 1 month elapsed (Mun and Yoo, 1992). Such difference was likely to be due to the difference of weight loss pattern of the decomposing litter between the calcareous and noncalcareous sites as mentioned above. A number of authors (Anderson, 1973; Berg and Theander, 1984; Gholz *et al.*, 1985; Kelly and Beauchamp, 1987) have reported that N concentration of decaying litter increased with time in various kinds of litter. The major sources of increased nitrogen are from the N-fixation by microorganisms(Olsen, 1932), precipitation, dust and insect frass (Bocock, 1964). Percentages of remaining N in decomposing litter showed a similar pattern in both litter (Fig. 4B). There was no net N immobilization period in both litter in calcareous site over the study period, although N immobilization in the needle litter of black pine occurred till 6 months elapsed (Mun and Yoo, 1992).

Initial P concentration of decomposing needle and Chinese thuja scale leaf litter were 76 ppm and 68 ppm, and then decreased to 35 ppm and 29 ppm, respectively, after 1 month elapsed (Fig. 5A). Klemmedson *et al.* (1985) have also reported that P concentration in decomposing needle litter decreased with time elapsed. However, Schlesinger (1985), Kelly and Beauchamp (1987) have reported that P concentrations in decomposing chaparrel shrub foliage, and upland oak and mesic mixed-hardwood leaf litter increased with time, respectively. P in the decomposing black pine needle in noncalcareous site also increased steadily with time elapsed (Mun and Yoo, 1992). Percentages of remaining P in both decomposing litters showed a similar pattern with that of nitrogen. Net release of P occurred throughout the study period (Fig. 5B). After 21 months elapsed, the needle and Chinese thuja scale leaf litter lost 75% and 50% of the initial P, respectively.

摘 要

석회암 지역에 발달되어 있는 소나무림과 측백나무림에서 낙엽의 생산량, 분해량, 그리고 낙엽 분해에 따른 질소와 인의 동태를 조사하였다. 낙엽 생산은 연중 계속되었으나 두 지역 모두 11월에 그 값이 최대로 나타났다. 2년 동안의 연평균 낙엽 생산량은 소나무림에서 4,535 kgDW ha^{-1}, 측백나무림에서 5,010 kgDW ha^{-1} 이었다. 소나무 낙엽의 질소와 인 함량은 낙엽 생산량이 최소인 여름에 가장 높았으나 측백나무 낙엽은 계절적인 변화가 두드러지지 않았다. 낙엽을 통해 연간 임상에 회수되는 질소와 인은 소나무림에서 29.02 kgN ha^{-1}, 2.81 kgP ha^{-1}, 측백나무림에서 31.06 kgN ha^{-1}, 2.86 kgP ha^{-1}인 것으로 조사되었다. 21개월 후 소나무와 측백나무의 낙엽은 각각 처음 무게의 34.8%, 32.5%가 소실되었다. 분해과정에 있는 낙엽의 질소와 인 함량은 초기에는 감소하나 점점 증가하였다. 21개월의 낙엽 분해과정에서 질소와 인 모두 순 부동화 (net immobilization) 기간은 없었다.

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