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# Cation Deficiencies in Needles and Fine Roots of Pitch Pine in Seoul Metropolitan Area

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# 首都圈地域에서 리기다소나무 잎과 잔뿌리 속의 陽이온 不足

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## ABSTRACT

The contents of major elements were determined in current-year and previous-year needles and fine roots of pitch pine (*Pinus rigida*) at 33 sites in Seoul and its vicinity. Contrary to Ca and Al in needles, N, P, Mg and K contents in current-year needles were higher than those in previous-year needles. The N, P, K and Al contents in current-year needles in Seoul were not significantly different from those in rural areas. In contrast, Ca and Mg contents in needles in Seoul were significantly lower than those in suburbs and rural areas. The N/Ca and N/Mg ratios in needles in urban Seoul were higher than those in rural areas. Mg contents in fine roots in soil of 0~5 cm depth increased along with distance from the center of Seoul, while Al contents in fine root in soil of 5~10 cm depth decreased along with distance from the center of Seoul. Al contents in fine roots in soil layer in Seoul and suburbs were higher than those in rural areas. Al contents in fine roots in litter layer were 1/3 ~ 1/2 times lower than those in soil layer for all areas. Al content in fine roots in deep soil was higher than that in top soil. Therefore growth decline of pitch pine in Seoul and suburbs was thought to be caused by Ca and Mg deficiency in plant tissues and Al toxicity to fine roots. Abnormal vertical distribution of fine roots of pitch pine in Seoul and its vicinity were interpreted as the result of growth reduction of fine roots by Al toxicity in deep layer of acid soil.

**Key words**: Al toxicity, Cation deficiencies, Fine root, Needle, N/Mg ratio, Pitch pine, Urban area

## INTRODUCTION

Rhyu *et al.* (1994) reported the growth decline and the abnormal vertical distribution of fine roots in pitch pine in Seoul and its vicinity, and they suspected accelerated soil acidification caused by acidic diposition as an important factor for the growth decline of pitch pine. On acidic soils plant growth can be limited by Mg, Ca and K deficiency and Al and Mn toxicity. Matzner *et al.* (1986) reported that a large proportion of dead or living fine roots were distributed in top soil layer in acidic soil, which was similar to the abnormal vertical distribution of fine roots in Seoul(Rhyu *et al.* 1994). Besides, low cation contents, high Al content and nutrient imbalance in plant tissue were reported as the cause of growth decline of trees in areas polluted by acidic precipitation (Zech *et al.* 1985). Therefore we suspected that growth decline and superficial rooting in pitch pine in Seoul were caused by soil acidification becasue acid rain precipitated in Seoul for decades (Rhyu 1994).

The purpose of this study was to investigate the relationship between growth decline and ions contents of needles and fine roots in pitch pine in Seoul and its vicinity.

## METHODS

Thirty-three sites of pitch pine forests were selected in Seoul, its vicinity and rural areas within 60 km radius from the center of Seoul (Fig. 1). The characteristics for 33 sites studied were described by Rhyu *et al.* (1994). At each site twigs of three to five trees were sampled from top branches with fishing pole and a hook and combined into one composite sample. At each site fine roots (roots $<$ 2 mm in diameter) were sampled at distance of 60 cm from stems of five trees. All fine roots in litter layer were sampled with litter in quadrats of 100 $cm^2$ with the pruning shear and those in soil layer were sampled at two soil depths of 0~5 cm and 5~10 cm with soil corer (4.5 cm in diameter and 5 cm in length).

Twigs were lightly washed with tap water in order to remove particles deposited on the needle surface, and needles were separated into current-year and previous-year needles. Fine roots were separated from litter and soil, then washed completely by running water. The washed needles and fine roots were dried at 80℃ for 72 hr. They were ground with a grinder (Janke & Kunkel Model MFC S1), sieved with a 1 mm mesh sieve, and used for chemical analysis. Plant materials were digested by mixed acid ($Se + Li_2SO_4H_2O + H_2O_2 + H_2SO_4$) (Moore and Chapman 1986). Nitrogen in needles was determined by a modified micro-Kjeldahl method (Jackson 1967). Phosphorus in needles was determined by ascorbic acid method (APHA 1989). Aluminium in needles and fine roots was determined by Erichrome cyanine R (ASA 1982). Calcium, magnesium and potassium in needles and fine roots were determined by atomic absoption spectrophotometer (M-901).

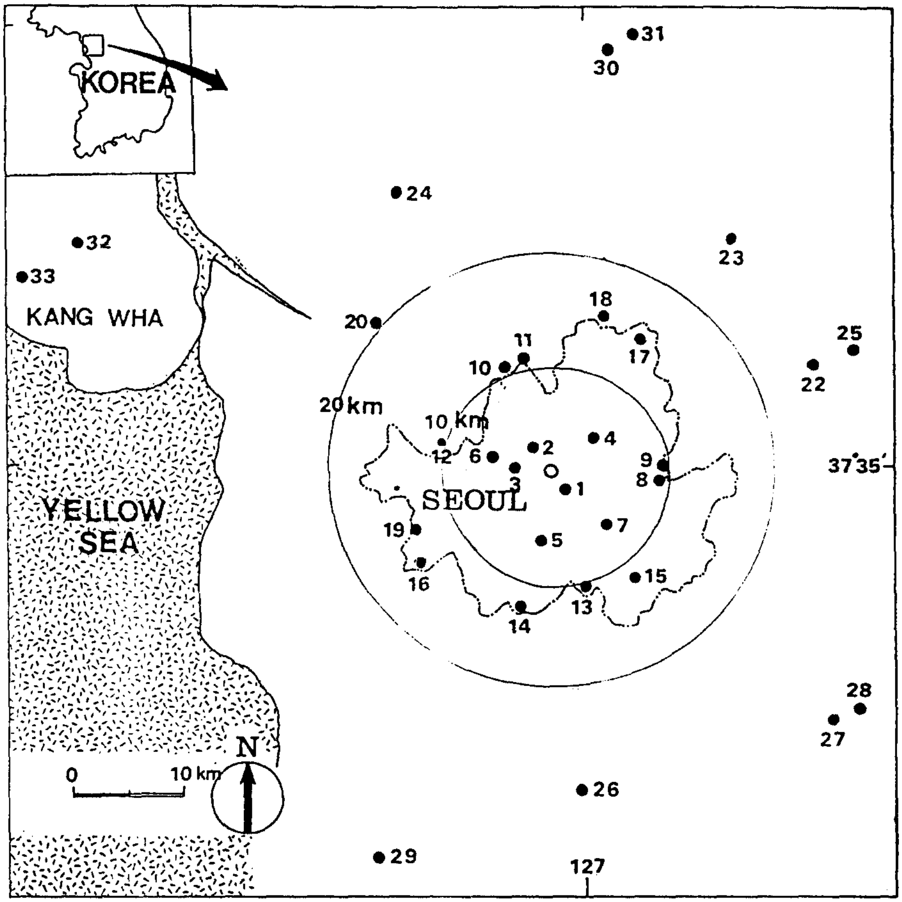


**Fig. 1.** Map showing 33 sampling sites in and near Seoul metropolitan area.

To make regional comparisons, we split all samples into 3 geographic regions; 1) urban Seoul which included all sites within a radius of 10 km from the center of Seoul, 2) suburbs which included those within a radius between 10 km and 20 km from the center of Seoul, and 3) rural areas which included those within a radius between 20 km and 60 km from the center of Seoul (Fig. 1).

## RESULTS

### Ion contents in current-year and previous-year needles

Major ion contents of current-year and previous-year needles were presented in Table 1. Contrary to Ca and Al in needles, N, P, Mg and K contents in current-year needles were higher than those in previous-year needles (Table 1). Therefore Ca and Al were thought to be accumulated in old needles, but N, P, Mg and K to be translocated to new needles

**Table 1.** Content of major inos in previous-year and current-year needles of pitch pine sampled in fall December, 1990 at Mt. Nogosan (site 11), Mt. Youngmasan (site 21), Mt. Jukyeopsan (site 23), Mt. Chilbosan (site 26), and Mt. Taiwhasan (site 28). Numerals in parentheses indicate standard deviations

| Needle age | Ion content in needles (mg /g) | | | | | |
|---|---|---|---|---|---|---|
| | N | P | Ca | Mg | K | Al |
| Current year | 14.55<br>(2.15) | 0.96<br>(0.18) | 2.42<br>(0.24) | 1.04<br>(0.29) | 3.81<br>(0.73) | 0.37<br>(0.09) |
| Previous year | 12.70<br>(1.93) | 0.80<br>(0.04) | 3.80<br>(0.98) | 0.91<br>(0.11) | 2.88<br>(1.43) | 0.45<br>(0.09) |

from old needles before needle fall (Oren *et al.* 1988, Goaster *et al.* 1990 /1991).

### Comparison of N, P and K in needles among the different areas

N contents in current-year needles ranged 11.8 ~ 17.5 mg /g for all 33 sites, and average N contents in Seoul, its vicinity and rural areas were 15.1, 15.1 and 14.2 mg /g, respectively (Fig. 2). N contents in needles were not different among the areas. Average P

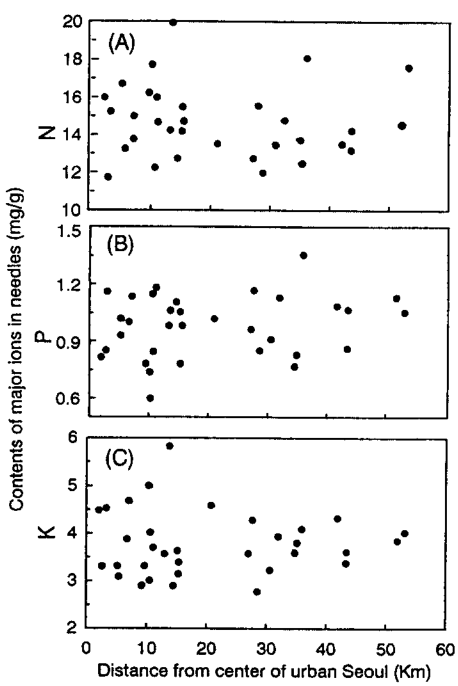


**Fig. 2.** Changes of N (A), P (B) and K contents (C) of pitch pine needles along distance from the center of Seoul.

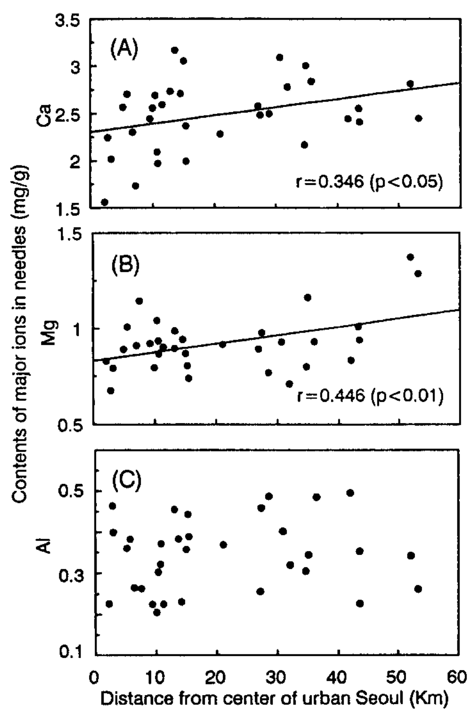


**Fig. 3.** Changes of Ca (A), Mg (B) and Al contents (C) of pitch pine needles along distance from the center of Seoul.

contents in the three areas were 0.94, 0.98 and 1.02 mg/g, respectively (Fig. 2). While N was not greatly different among the araes, P in needles in Seoul had the tendency to be lower than that in rural areas. Average K content in needles was not different among the three areas (Fig. 2).

### Comparison of Ca, Mg and Al in needles among the different areas

Average Ca contents in needles in Seoul, its vicinity and rural areas were 2.24, 2.54 and 2.61 mg/g, respectively, and increased along with distance from the center of Seoul (Fig. 3). Average Mg contents in the three areas were 0.89, 0.90 and 0.97 mg/g, respectively, and increased along with distance from the center of Seoul (Fig. 3). The Ca and Mg contents in urban Seoul were lower than those in rural areas. Differences in Ca and Mg contents in needles among the three areas were statistically significant. Average Al contents in needles in Seoul, its vicinity and rural areas were 0.31, 0.35 and 0.37 mg/g, respectively (Fig. 3). Al contents in Seoul had the tendency to be lower than that in suburbs and rural areas, but differences in Al content in needles among the three areas were not statistically significant.

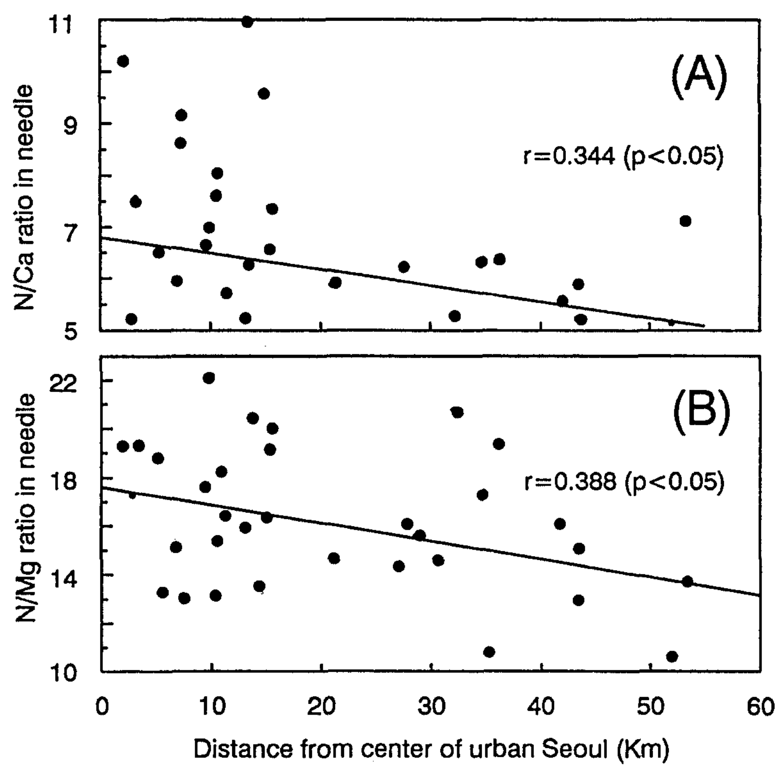


**Fig. 4.** Changes of N/Ca (A) and N/Mg ratio (B) of pitch pine needles along distance from the center of Seoul.

**Comparison of N/Ca and N/Mg ratio in needles among the different areas**

Average N/Ca ratio in needles in Seoul, its vicinity and rural areas were 6.96, 6.07 and 5.51, respectively, and decreased along with distance from the center of Seoul (Fig. 4). N/Mg ratio in the three areas were 17.3, 16.86 and 15.12, respectively, and decreased along with distance from the center of Seoul (Fig. 4). The N/Ca and N/Mg ratio in needles in urban Seoul were higher than those in rural areas.

**Comparison of Ca, Mg and Al in fine roots among the different areas**

Average Ca contents in fine roots in litter layer and is soils were not different among three areas (Fig. 5). However, Ca contents in fine roots in litter layer seemed to be a little higher than those in soil layer. Unlike Mg content in fine roots in litter layer and soil of 5~10 cm depth, Mg contents in fine roots in soil of 0~5 cm depth was lower in urban Seoul than that in rural areas and increased along with distance from the center of Seoul (Fig. 5). Mg content in fine roots in litter layer was not different from that in fine roots in soils of two depths. Average Al content in fine roots in litter layer and in soil of 0~5 cm depth was not different among the three areas (Fig. 5). Al contents in fine roots in soil of 5~10 cm depth in Seoul, suburbs and rural areas were 7.13, 7.02 and 5.43 mg/g, respec-

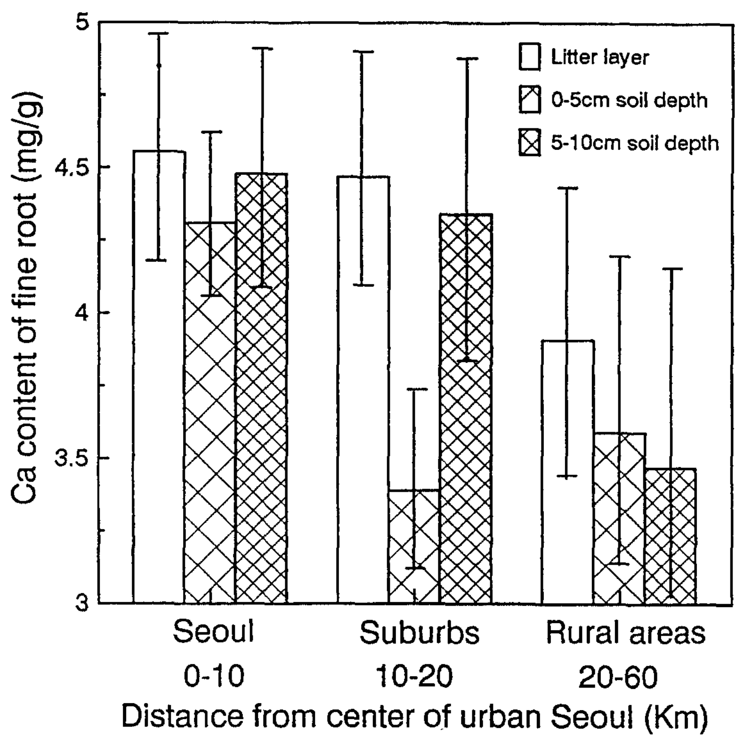


**Fig. 5.** Regional comparison of Ca content of fine roots of pitch pine grown in litter layer, top soil (0~5 cm depth) and subsoil (5~10 depth).

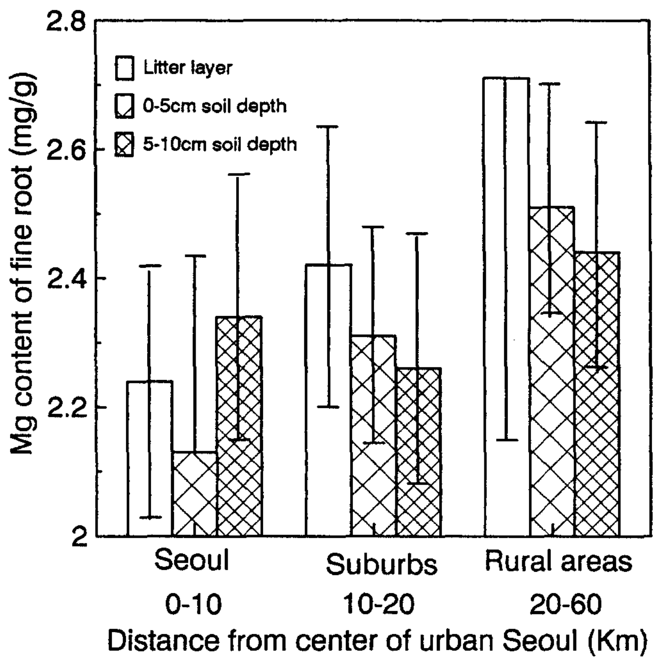


**Fig. 6.** Regional comparison of Mg content of fine roots of pitch pine grown in litter layer, top soil (0~5 cm depth) and subsoil (5~10 depth).

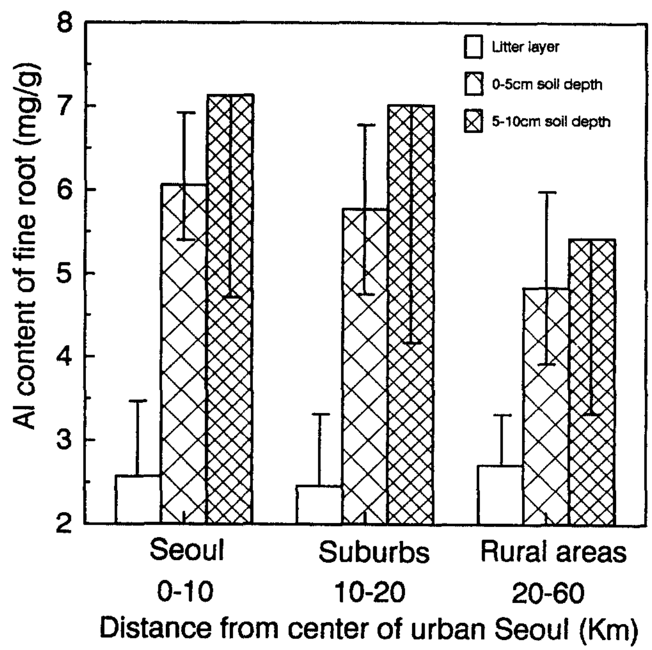


**Fig. 7.** Regional comparison of Al content of fine roots of pitch pine grown in litter layer, top soil (0~5 cm depth) and subsoil (5~10 depth).

tively, and decreased along with distance from the center of Seoul. Al content in Seoul and suburbs was higher than that in rural areas. Al content in fine roots in litter layer was 1/3 ~ 1/2 times lower than those in soil layer for all areas. Al content in fine roots in deep soil layer was higher than that in fine roots in top soil layer. Besides, Al content in fine roots in soil layer was about 20 times higher than that in needles.

## DISCUSSION

### Cation deficiencies and growth decline of pitch pine in Seoul

Contrary to other ions in needles, N contents in needles in Seoul was a little higher when compared with those in rural areas, indicating that growth decline of pitch pine in Seoul and its vicinity was not caused by nitrogen deficiency (Zech *et al.* 1985). Higher N contents in needle in Seoul were thought to be the result of increase in nitrogen oxides in the atmosphere of Seoul (Rhyu 1994, Roelofs *et al.* 1985). Low P contents in needles in Seoul were thought to be the change of available P to insoluble P in acid soil (Mengel and Kirby 1982). In addition, growth decline of pitch pine in Seoul was not caused by K deficiency or excessive Al in needles because Al and K contents in needle were not different among the three areas.

The Ca and Mg contents in needles in Seoul, however, were lower than those in rural areas. Growth decline of pitch pine in Seoul, therefore, might be caused by deficient Ca and Mg, because basic cations often were reported as deficient ions for plants in acid soil (Zech *et al.* 1985). Especially, Mg deficiency was frequently reported as a causal factor of forest decline in central Europe, Canada and China (Zottle *et al.* 1989, Zech *et al.* 1990/1991). Recently Office of Forestry (1986~1988) investigated the properties of forests and soils in Seoul, industrial complex and control area, and reported that the reduction of tree growth in Seoul was greatly affected by air pollutants and acid soil showing low pH and high content of soluble Al.

Increase in the ratio of N/Ca or N/Mg in needles was often regarded as one factor among the causes of forest decline in northern Europe (Roelofs *et al.* 1985, Kadza 1990). Such ion imbalance in plant tissues make plants unable to cope with environmental stresses (Willison 1990, Dueck *et al.* 1990/1991). One of the predisposing factors for growth decline of pitch pine can be soil acidification in Seoul and its vicinity, too.

### Al toxicity and abnormal vertical distribution of fine roots in Seoul

Like Mg in needles, Mg content in fine roots in Seoul was lower than that in suburbs and rural areas, but Ca contents were not different among the three areas. Ca content in fine roots in litter layer seemed to be a little higher than that in soil layer. This result indicated that fine roots can sufficiently absorb nutrients in litter layer as they do in soil layer. Unlike Mg, Al contents in fine roots in Seoul and suburbs, however, were higher than those in rural areas. In addition, Al content in fine roots in litter layer was much lower than those in soil layer for the three areas. As fine roots entered deeply into the soil layer, Al contents in fine roots increased. This result was explained by the fact that soluble Al in soil increased with soil depth, and that Al absorbed by fine roots were accumulated in root tissues (Joslin *et al.* 1988). High Al contend in fine roots inhibited the growth of fine root. Growth of fine roots, therefore, was slow in deep soil layer where soluble Al was high in acid soil. Al content in litter layer, however, was relatively lower than those in soil layer. Even when Al is in litter layer, Al is combined with organic acid and become insoluble. Insoluble Al is not toxic to plants (Suthipradit *et al.* 1990, Kretzschmar *et al.* 1991). Fine roots in acid soil, therefore, can ascend in to litter layer to absorb nutrients if moisture is sufficient because of sufficient nutrients and little soluble Al in litter layer. The above assumption was verified indirectly by the fact that amount of fine roots was low in deep layer of acid soil compared with vertical distribution of fine roots in unpolluted rural areas (Rhyu *et al.* 1994). Abnormal vertical distribution of fine roots in Seoul and suburbs, therefore, was thought to be caused by high content of soluble Al and low content of basic cations in acid soil.

In conclusion, the growth of pitch pine in Seoul and suburbs might have been reduced due to the superficial rooting, Altoxicity and deficient cations (Ulrich 1990).

## 적 요

수도권과 그 주변 지역의 33 지소의 리기다소나무 숲에서 리기다소나무 잎과 잔뿌리의 주요 이온의 함량을 정량하였다. 잎 속의 N, P, K 및 Mg 함량은 전년도 잎에 비해 당해년도 잎속에 높았지만, Al과 Ca은 그 반대였다. 잎 속의 N, P, K 및 Al 함량은 지역간의 차이가 없었지만, Ca과 Mg 함량은 전원지에 비해 도심지에서 낮았다. 그러나 잎 속의 N/Ca와 N/Mg의 비의 값은 전원지보다 도심지에서 컸다. 표토 잔뿌리 속의 Mg 함량은 도심으로부터 거리가 멀어짐에 따라 증가하였으나, 심층토 잔뿌리 속의 Al 함량은 그 반대였다. 토양층 잔뿌리 속의 Al 함량은 도심지보다 전원지에서 낮았다. 토양층 잔뿌리 속의 Al 함량은 낙엽층의 잔뿌리에 비하여 2~3배 높았다. 그리고 표토보다 심층토에 존재하는 잔뿌리 속에 Al 함량이 높았다. 그러므로 수도권 지역에서 리기다소나무의 생장감소는 조직 속의 Ca과 Mg 부족, N/Ca과 N/Mg 비의 증가 및 잔뿌리 생장에 대한 Al 독성에 있었다. 그리고 수도권 지역에서 잔뿌리의 비정상적인 분포는 산성토양에서 Al 독성에 의한 잔뿌리의 생장 감소가 그 원인으로 해석된다.

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