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Histological Damage and Growth Inhibition of *Pinus densiflora* around the Metropolitan Area of Seoul

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수도권 주변 소나무의 조직피해와 생장억제

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ABSTRACT

Histological damage and growth inhibition of *Pinus densiflora* were analysed in different areas around the Metropolitan area of Seoul; urban (heavily polluted), suburban (lightly polluted), and rural (unpolluted) areas. Soil properties of each area were also investigated.

Contact angles of water droplet on needle leaves growing in polluted areas were lower than that in unpolluted area. Transpiration rates of needle leaves growing in polluted areas were more rapid than that in unpolluted area. These results represented that needle leaves growing in polluted areas were more susceptible to water deficit than that growing in unpolluted area was. Growths of annual ring of *Pinus densiflora* growing in polluted areas were lower than that in unpolluted area. On the other hand, soil pH in polluted areas was lower than that in unpolluted area. That is, the former was more acidified than that the latter was. Ca and Mg contents in polluted areas were lower than that in unpolluted area, while Al contents in polluted areas were higher than that in unpolluted area. These soil properties revealed that the effects of acid precipitates in urban and suburban areas were severer than that in rural area.

Key words: *Pinus densiflora*, Acid precipitates, Histological damage, Transpiration rate, Soil acidification.

INTRODUCTION

Pollutants discharged in the air are fallen in a state of wet deposits mixed with rain, snow, fog, and so on or in a state of dry deposits, such as solid and gas of their original forms. All of those air pollutants are altogether called as acid precipitates (Freedman 1986, Smith 1990). Those acid precipitates had already destroyed aquatic ecosystems of many regions in Europe and North America and in recent years their effects appearing as a forest decline in many regions of the world (Freenman 1986, Smith 1990). Soil acidification, ozone pollution, soil nutrients deficiency, excessive nitrogen supply, and multiple stressors hypotheses were suggested as causal factors of forest decline according to environmental condition of each region. But general conclusion on main causes of forest decline was not obtained yet (Freedman 1986, Smith 1990, Rhyu 1994).

Effects of acid precipitates on plants would be shown in 2 patterns. The one is direct effect and the other is indirect one originated from changes of soil properties (Smith 1990, Rhyu 1994, Lee 1996). Direct effects occur from erosion of epicuticular wax on leaf surface and loses of nutrients and water from those injured tissues. Initial symptom of those direct effects is shown in reduction of contact angle of water droplet on leaf surface (Boyce and Berlyn 1988) and in increase of transpiration (Mengel *et al.* 1989). Moreover direct effect induce growth inhibition and leading to forest decline (Omasa *et al.* 1985, Freedman 1986, Mengel *et al.* 1989, Smith 1990, Rhyu and Kim 1994a, b, c, d).

Loses of nutrients from acidified soil, nutrients deficiency of plant, increase of toxic Al, and inhibition of plant growth from those factors are known as indirect effects (Freedman 1986, Smith 1990).

In this way acid precipitates could be involved directly or indirectly in forest decline syndromes. In *Pinus densiflora* stands around the Metropolita area of Seoul changes of floristic composition originated from poor crown development was reported (Lee 1996). Change of floristic composition was shown in the notable increase of shade intolerant species, such as *Styrax japnica, Sorbus alnifolia,* and so on. Such a change indicating retrogression of succession would be estimated as a type of forest decline syndrome (Lee 1996).

The cause of poor crown development in this area was suspected to the water deficit caused by 1) the increase of transpiration through epicuticular injury by acid precipitates, and 2) the decrease of water absorption through growth inhibition or abnormal distribution of fine roots in acidic soil (Rhyu 1994, Lee 1997). Both cuticle damage and growth inhibition of fine roots would be influenced on the water status of *P. densiflora* and led to poor growth.

In this study, we aimed to clarify the direct effects of acid precipitates on *P. densiflora* and changes of soil properties around the Metropolitan area of Seoul, in which the effect of acid precipitates have been continued for a long time and the effect is also severe.

STUDY AREAS AND METHODS

We selected the study areas referring to Rhyu and Kim (1994d) who carried out similar study to this. Study areas were divided into urban area, within 10 km, suburban area, 10 to 30 km, and rural area, more than 30 km according to the distance from the urban center of Seoul. The selected areas are Mt. Inwang as urban area, Mt. Surak as suburban, and Paju as rural area (Fig. 1). All sites selected were similar in topography, parent rock, and vegetational state excluding distances from the urban center.

P. densiflora growing in all of these study areas was selected as sample plant to investigate the direct effects of acid precipitates. To get plant samples in field, 5 plots, 10m × 10m area, were selected in each study area and 3 individuals were selected in each plot. From the selected individuals, branchs with needles were sampled to estimate effects of acid precipitates on leaf tissue and annual ring cores were collected to measure effect on growth. Degree of damage was measured by contact angle of water droplet on the needle leaf (Boyce and Berlyn 1988),

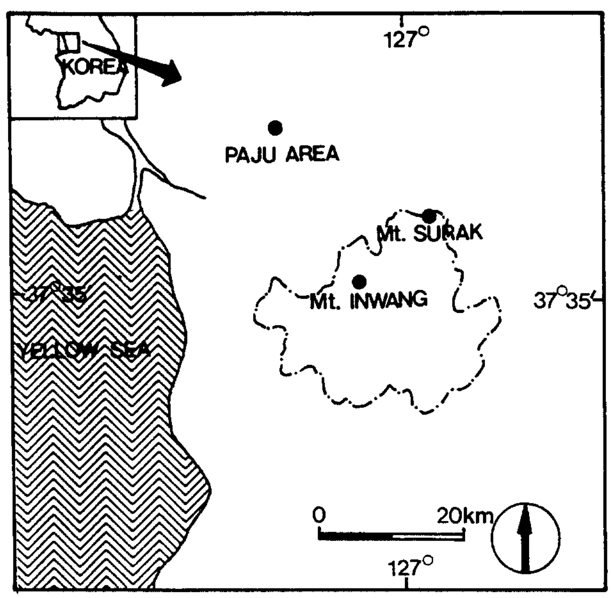

Fig. 1. Map showing the sampling sites.

cuticular transpiration (Mengel *et al.* 1989), and growth of annual ring.

Contact angle of water droplet dropped by microsyringe on the needle leaf was measured by graduator installed in dissecting microscope. Amount of water used to measure contact angle was 1 μl. Cuticular transpiration was determined by measuring the water loss that occurred from excised needles in incubator condition (25℃) according to the lapsed time after detachment from branch. Cut surface in excised needles was covered with parafilm to prevent water loss from this surface. Needles were weighted with a chemical balance and loss of weight was regarded as water loss. Growth of annual ring was measured by vernier calipers under 40× dissecting microscope. Soil samples were collected in pure *P. densiflora* stands distant more than 200m from human settlements or roads. Soil was sampled within 5cm from soil surface. pH was measured by pH meter after shaking soil mixed with distilled water by ratio of 1:5 for 1 hour. The contents of exchangeable Ca, Mg, and Al were measured by ICP (Inductively Coupled Plasma atomic emission spectroscopy, Shimazu ICPQ-1000) after extraction by ammonium acetate (CH_3COONH_4) solution of pH 4 (Al) and 7 (Ca and Mg).

RESULTS AND DISCUSSION

Histological damage on needles

Comparisons in contact angles of water droplet on needles sampled in urban, suburban and rural areas was shown in Fig. 2. Contact angles of current year needle leaves in urban, suburban, and rural areas were 65.0±3.7°, 72.2±2.5°, and 79.5±5.2°respectively. Those on 2 year-old needle leaves were 63.2±3.9°, 61.7±2.4°, and 72.5±4.0°, respectively. That is, contact angle on the needles of *P. densiflora* grown in urban area was lower than those on needles grown in suburban and rural areas and contact angles on 2 year-old needles were lower than that on current year ones. Differences between urban area and both suburban and rural areas in current year needle leaves were siginificant at 1% level and that between suburban area and rural area was significant at 5% level. In 2 year-old needle leaves, difference between urban area and suburban area was not significant but those between rural area and both urban and suburban areas were significant 1% level.

Kim *et al.* (1994) clarified that contact angle was proportional to visible damage and inversely to the wax content of needles by analysing the relationships between contact angle and plant damage in study areas different in distance and topography from the pollution source in Daesan industrial complex. Lee *et al.* (1998) reported that contact angle on needles of *P. densiflora* seedlings was lowered in proportion to amount and acidity of simulated acid rain treated. On the other hand,. Steubing and Fangmeier (1991) showed that contact angle on plant leaves exposed to mixed gas of SO_x, O_3 and NOx was lower than that exposed to single state of above mentioned gases. These results indicated that contact angle was closely related to the degree of pollution damage. Judging

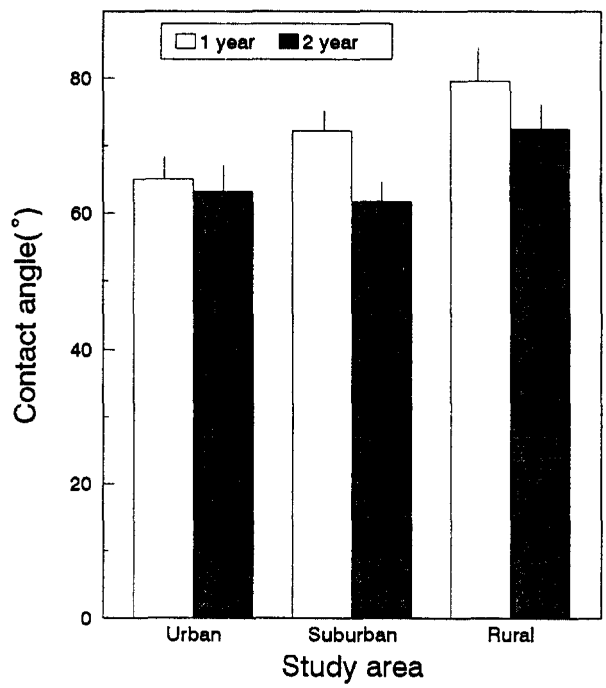

Fig. 2. Contact angle of water droplet on current year and 2 years old needle leaves of *Pinus densiflora* in urban, suburban and rural area.

from those results low contact angle on *P. densiflora* needles in urban and suburban areas comparing with that in rural area might be originated from the effect of acid precipitates.

Transpiration rate

In the equations showing relationship between change in fresh weights of needle leaves and the lapsed times after detatchment from branch, regression coefficients were −0.21, −0.19 and −0.19 in urban, suburban, and rural areas, respectively (Fig. 3). That is, transpiration rate of needle leaves grown in urban area was more rapid than those in rural and suburban areas. Rhyu and Kim (1994d) reported that transpiration rate of pitch pine (*P. rigida*) needle leaves sampled in urban area of Mt. Kwanak was more rapid than that in rural area of Paju. Lee *et al.* (1988) reported that the lower pH of simulated acid rain was, the more rapid transpiration of *P. densiflora* needle leaves was. They clarified that such a rapid transpiration was originated from epicuticular degradation of needle leaves by simulated acid rain. On the other hand, Mengel *et al.* (1989) showed that transpiration rate of plant leaves exposed to acid fog was more rapid than that of control plot. From those results we estimated that the difference of transpiration rate among study areas would be related to the effects of acid precipitates.

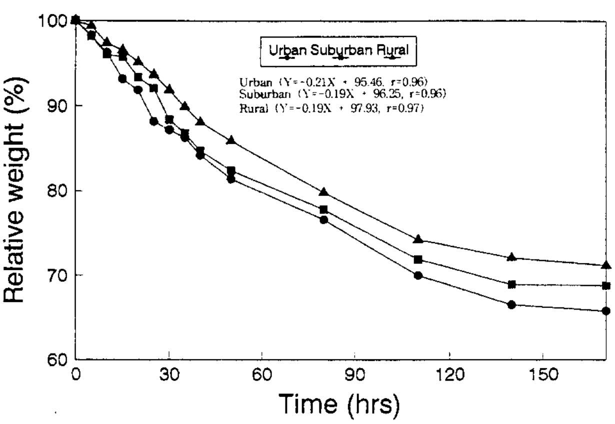

Fig. 3. Changes of relative water content in needle leaves of *Pinus densiflora* growing in urban, suburban, and rural area with the lapse of time after detachment from branch.

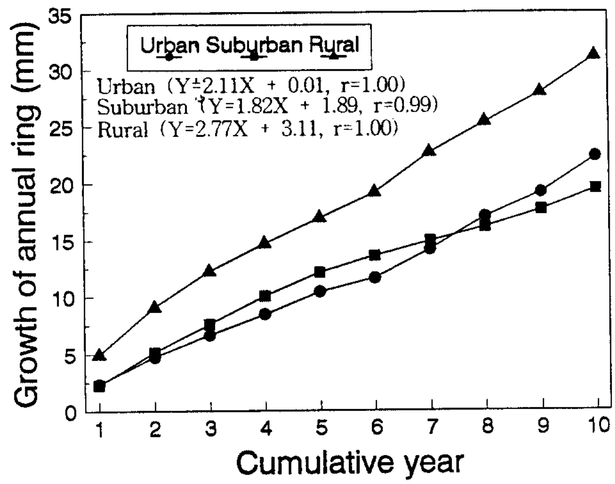

Fig. 4. Growths of annual ring of *Pinus densiflora* in urban, suburban, and rural area.

Growth of annual ring

Growth coefficient of annual ring was the highest in rural area and those in urban and suburban areas were similar to each other as 2.11, 1.82 and 2.77 in urban, suburban, and rural areas, respectively (Fig. 4). That is, growth of annual ring in rural area was more rapid than those in urban and suburban areas. Growth of annual ring is related to many environmental factors. Lee (1993) investigated growth of annual ring in relation to air pollution and competition with other individuals in population. Lee (1995a,b) studied with reference to gap formation in *P. densiflora* forest and Rhyu (1994) reported growth of pitch pine in terms of air pollution and soil acidification around the Metropolitan area of Seoul. In addition, Park and Yadav (1998) examined growth of annual ring as means monitoring climatic change by green house effect.

Soil properties of study areas

Soil properties investigated in study areas were shown in Table 1. pH, and Ca and Mg contents in

Table 1. Soil properties of study areas

Study areas	pH	Ca (ppm)	Mg (ppm)	Al (ppm)
Urban area	4.62±0.19	219.0±15.5	28.3±3.1	287.5±96.3
Suburban area	4.65±0.21	239.3±23.4	31.0±2.6	271.5±82.4
Rural area	4.93±0.25	285.3±24.8	49.0±4.1	134.5±64.0

polluted urban and suburban areas were lower than that in unpollted rural area. On the other hand, Al contents in urban and suburban areas were higher than that in rural area. That is, soils of urban and suburban areas were more severely acidified and deficient in nutrients (Ca and Mg) than that of rural area was. It can be explained that such a soil acidification was originated from acid precipitates and nutrient deficiency and toxicity of soil were from soil acidification (Rhyu and Kim 1994 a,b,c, Rhyu 1994). Changes of those soil properties would impose unfavorable effects on plant growth. In addition, higher content of Al in urban and suburban areas might also influence adversely on plant growth inhibiting ion absorption (Truman *et al.* 1986, Bengtsson *et al.* 1988, Roy *et al.* 1988) and cell division (Cronan *et al.* 1989).

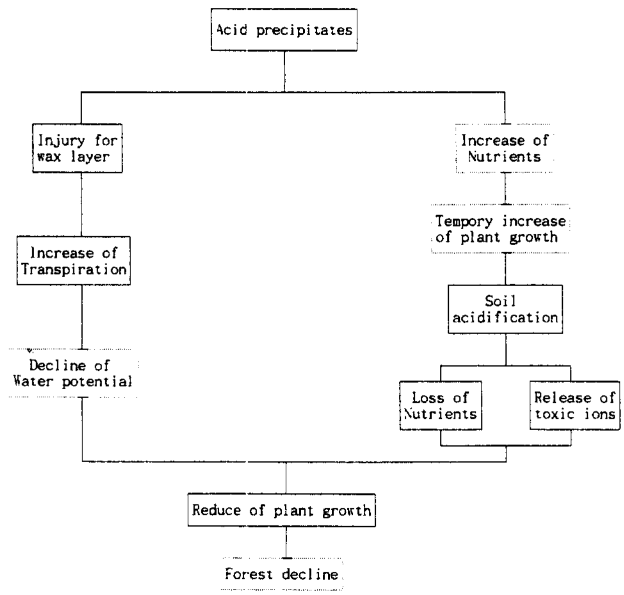

Fig. 5. Diagram showing the mechanism of forest decline caused by acid precipitates. Solid boxes results measured in this study and dotted boxes show predicted ones.

CONCLUSION

Results obtained from this study were summarized in Fig. 5. As was shown in Fig. 5, acid precipitates can affect both plants and soil. Their effects on plants result in injury for wax layer. In this study we certified that needles in urban area were more severely injured than those in suburban and rural areas were. On the other hand, evidence on injury of needle also can be found in increase of transpiration rate. For example, transpiration rate on needles in urban area was more rapid than those in suburban and rural areas.

Similar results were also obtained in SO_2 exposure experiment (Lee and Bae 1991). Decrease of water potential by those serial processes might be operated to inhibit growth of *P. densiflora* in polluted area considering that plant growth is closely related to water potential (Lee and Kim 1987, Salisbury and Ross 1992). On the other hand, changes of soil properties also can induce water deficiency. For example, increased Al in urban and suburban soils causes inhibition of growth of fine root and abnormal distribution of root system, which aggravate water status of plant (Rhyu and Kim 1994d, Lee 1997) That is, both direct and indirect effects induce water deficiency, water status is closely related to growth and existence of plant (Lee 1997).

적 요

서울시와 그 주변지역을 심하게 오염된 도심지역, 약하게 오염된 주변지역 및 오염되지 않은 전원지역으로 구분하고 각 지역에 생육하는 소나무를 대상으로 침엽의 조직피해와 연륜생장을 분석하여 산성강하물이 식물에 미치는 영향을 밝혔다.

침엽위에서 물방울의 접촉각은 도심지역에서보다 전

원지역에서 높았다. 오염지역에서 자란 접촉각이 낮은 침엽의 증산속도는 비오염지역에서 자란 침엽의 증산속도보다 빨랐다. 오염된 도심과 주변지역에서 자란 소나무의 연륜생장은 오염되지 않은 전원지역에서 자란 소나무의 생장보다 느렸다. 한편, 토양의 pH는 도심과 주변지역에서 전원에서보다 낮아 전자에서 후자보다 토양의 산성화가 많이 진행되었음을 보여주었다. 심하게 산성화된 도심과 주변지역 토양의 Ca과 Mg함량은 약하게 산성화된 전원지역 토양의 것보다 낮았다. 한편, 도심과 주변지역 토양의 Al함량은 전원지역 토양의 것보다 높았다.

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