Atmospheric Quality, Soil Acidification and Tree Decline in Three Korean Red Pine Forests

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ABSTRACT: Although a forest damage of large area due to air pollution has not yet been found in Korea, declines of Korean red pine (Pinus densiflora Sieb. et Zucc.), the most common coniferous species, have been locally reported. To evaluate the effect of air pollution and acid deposition on the forests, SO2 concentration, acid load, soil pH and tree decline were monitored for 13 years from 1988 to 2001 in Namson, Doowang and Gyeongsan with the gradient of air pollution. During the study period, annual mean SO2 concentration in Namson, Doowang and Gyeongsan were 14 ppb, 13 ppb and 6 ppb, respectively. Annual mean acid loads in Namson and Doowang were three to four times more than that in Gyeongsan. As respected, forest surface soils in Namson and Doowang were acidified to pH 4.1 and 4.3, whereas that in Gyeongsan showed normal value as pH 5.4. On the other hand, decline degrees of Korean red pines in Namson and Doowang in both 1996 and 2001 were higher than those in Gyeongsan. It is reasonable that the severer tree declines in Namson and Doowang could be closely related with the higher air pollution, acid load, and the effects (possibly Ca deficit and Al toxicity) of soil acidification.

Key words: Forest damage, Pinus densiflora, SO2, Soil pH, Tree decline.

INTRODUCTION

Air pollution is a common phenomenon occurring in heavily urbanized or industrialized regions throughout the world. The impacts of dry and wet acid depositions and soil acidification on tree vitality are the subject of comprehensive scientific discussions. Over the past thirty years in Europe and North America, many of evidences of the negative impact of air pollution on different forests in regional or local scale have been announced (Johnson and Siccarana 1983, Mackenzie and Mohamed 1989).

Korea also has been experienced the increase in air pollution since the 1970s incipient industrialization like such many countries. Korean red pine is a common coniferous species and important tree in both terms of economy and ecology. Recently the acceleration of soil acidification and the visible tree damage in forest ecosystem have been documented, especially in red pine forest of urban and industrial regions (Kim 1996, Lee et al. 1998, Lee and Park 2001). Lee(1998) reported that Korean red pine seedlings grown in artificially acidified forest soil showed nutrition deficit and reduced growth rate.

This study was carried out to clarify the effect of air pollutants and acid deposition on the Korean red pine forests by monitoring ambient SO2 concentration, soil chemistry and tree decline degree from 1988 to 2001 in three red pine forests under different atmospheric quality.

MATERIALS AND METHODS

The study sites selected along the gradient of atmospheric pollution are located at Namson in Seoul (37° 40'N 126° 58'E), Doowang in Ulsan (35° 33'N 129° 19'E), and Gyeongsan (37° 50'N 128° 25'E) in Hongcheon. The parent rock is Granite, Mudrock and Granitic gneiss in the above mentioned site order.

To obtain the site-specific estimation of air pollution, monthly ambient SO2 concentration was measured by colorimetric analysis, and pH (TOA HM-40V) and major inorganic cations (IC, Waters 590) and anions (IC, Sykam S-1121) of wet-only rainfalls collected daily were determined. And annual mean of rainfall pH and ion concentrations was calculated by weighting rainfall volume to the ion concentration. The ion composition of rainfall was presented only for the rainfalls collected from 1996 through 2001. Surface soils at 0–15cm depth in the red pine forests were measured for pH(H2O) and base saturation as main buffering factors to acid deposition. Also tree decline classified into four degrees (0–3) was determined by integrating defoliation and leaf

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discoloration rate on 20 sample trees a site both in 1996 and 2001.

**RESULTS**

**Ambient SO₂**

The annual mean concentrations of SO₂ in Namsan, Doowang and Gyeongsang 1988 to 2001 were 14(9.7) ppb, 13(6.0) ppb and 6(2.1) ppb, respectively. SO₂ concentrations of all regions were lower than 19 ppb of IUFRO international standard (Mayer 1985). There was a trend in SO₂ concentration, particularly in Namsan and Doowang (Fig. 1). For Namsan, SO₂ concentration dramatically decreased from 1989 to 1995. SO₂ concentration in Doowang, however, significantly increased from 1988 to 1994, and then decreased to 2001. On the other hand, Gyeongsang did not show noticeable change over the period.

**Rainfall acidity**

The annual mean pH of rainfall from 1988 to 2001 was 5.0(0.3), 4.9(0.2), and 5.5(0.2) in Namsan, Doowang and Gyeongsang, respectively. The rainfall pH within the period increased in Namsan. Similar result was also found in Doowang from 1993 to 2001 (Fig. 2). However, Gyeongsang did not show any change in the rainfall pH like the SO₂. The recovery of rainfall acidification in two air-polluted regions may be attributed to the above mentioned decreasing SO₂. Based on 2001 shown the highest rainfall pH during study period, acid rain (pH < 5.6) in Namsan amounted for 58% of the total measured rainfall and 92% in Doowang, but less than 25% in Gyeongsang.

For Namsan and Doowang, hydrogen(H+) and sulfate(SO₄²⁻) concentrations in rainfall were three to four times higher than those of Gyeongsang (Table I). As expected, sulfate and nitrate are believed to be dominant acidic anions affecting rainfall acidity. In this way, the annual mean acid loads in Namsan and Doowang from 1988 to 2001 averaged 0.09(0.06～0.18) and 0.11(0.03～0.16) kmol H⁺ ha⁻¹ yr⁻¹, respectively, but only 0.03(0.02～0.03) kmol H⁺ ha⁻¹ yr⁻¹ in Gyeongsang.

**Soil acidification**

Surface soil at 0～15cm depth in 1996 and 2001 averaged pH 4.1, pH 4.3 and pH 5.4 in Namsan, Doowang and Gyeongsang, respectively (Fig. 3). Also, base saturation as a buffering part of mineral soil to acid input was 10.0%, 14.5% and 85.6% in above regional order. Potential forest impacts from Al stress by soil

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**Table 1. Annual volume-weighted mean concentrations (μmol/L) of cations and anions in rainfall from 1996 to 2001. Mean values with same letter are not significantly different at the probability level <0.01. Samples are 237, 231 and 179 in Namsan, Doowang, and Gyeongsang, respectively.**

<table>
<thead>
<tr>
<th>Region</th>
<th>H⁺</th>
<th>NH₄⁺</th>
<th>K⁺</th>
<th>Na⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>SO₄²⁻</th>
<th>NO₃⁻</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namsan</td>
<td>9.4b</td>
<td>66.9b</td>
<td>20.5a</td>
<td>29.3b</td>
<td>36.8c</td>
<td>9.4b</td>
<td>30.1b</td>
<td>32.3a</td>
<td>28.3b</td>
</tr>
<tr>
<td>Doowang</td>
<td>13.8a</td>
<td>67.8ab</td>
<td>16.6b</td>
<td>61.7a</td>
<td>48.4a</td>
<td>14.0a</td>
<td>45.4a</td>
<td>25.6b</td>
<td>52.5a</td>
</tr>
<tr>
<td>Gyeongsang</td>
<td>3.3c</td>
<td>70.1a</td>
<td>19.0a</td>
<td>29.5a</td>
<td>40.4b</td>
<td>10.3b</td>
<td>20.2c</td>
<td>19.1c</td>
<td>22.1c</td>
</tr>
</tbody>
</table>
under base saturation less than 15% of effective cation exchange capacity.

And Korean red pines in two regions showed higher decline degree than those in Gyeangsan. It is empirically true that increasing tree decline can occur in acidic soils at less than pH 4.5 especially for vulnerable forest. Ulrich(1989) proposed that abnormal tree decline was induced by acid deposition and soil acidification. And for Europe and North America, forest declines or damages have been noticed in heavily urbanized or industrialized areas (Johnson and Siccama 1983, Mackenzie and Mohamed 1989).

Consequently, we can find out any regional pattern or correspondence between atmospheric quality, soil acidification and tree decline for three Korean red pine forests. However, we have to discover more various non-natural affecting factors and clarify the effects of natural stress like meteorological fluctuation on tree condition (Lindgren et al. 2000).

LITERATURE CITED


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