Korean J. Ecol., 26(2): 87~89, 2003

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

Lee, Choong Hwa*, Seung-Woo Lee, Young-Kul Kim and Jae-Hyoung Cho

Korea Forest Research Institute, Seoul 130-712, Korea

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, SO_2 concentration, acid load, soil pH and tree decline were monitored for 13 years from 1988 to 2001 in Namsan, Doowang and Gyebangsan with the gradient of air pollution. During the study period, annual mean SO_2 concentration in Namsan, Doowang and Gyebangsan were 14 ppb, 13 ppb and 6 ppb, respectively. Annual mean acid loads in Namsan and Doowang were three to four times more than that in Gyebangsan. As respected, forest surface soils in Namsan and Doowang were acidified to pH 4.1 and 4.3, whereas that in Gyebangsan showed normal value as pH 5.4. On the other hand, decline degrees of Korean red pines in Namsan and Doowang in both 1996 and 2001 were higher than those in Gyebangsan. It is reasonable that the severer tree declines in Namsan 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*, SO_2, 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 Siccama 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 SO_2 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 Namsan in Seoul (37° 40'N 126° 58'E), Doowang in Ulsan (35° 33'N 129° 19'E), and Gyebangsan (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 SO_2 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 ionic 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(H_2O) 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

* Author for correspondence ; Phone: 82-2-961-2557, Fax: 82-2-961-2551, e-mail: hwa21@foa.go.kr

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

RESULTS

Ambient SO_2

The annual mean concentrations of SO_2 in Namsan, Doowang and Gyebangsan 1988 to 2001 were 14(9.7) ppb, 13(6.0) ppb and 6(2.1) ppb, respectively. SO_2 concentrations of all regions were lower than 19 ppb of IUFRO international standard (Mayer 1985). There was a trend in SO_2 concentration, particularly in Namsan and Doowang (Fig. 1). For Namsan, SO_2 concentration dramatically decreased from 1989 to 1995. SO_2 concentration in Doowang, however, significantly increased from 1988 to 1994, and then decreased to 2001. On the other hand, Gyebangsan 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 Gyebangsan, respectively. The rainfall pH within the period increased in Namsan. Similar result was also found in Doowang from 1993 to 2001 (Fig. 2). However, Gyebangsan did not show showed any change in the rainfall pH like the SO_2. The recovery of rainfall acidification in two air-polluted regions may be attributed to the above mentioned decreasing SO_2. 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 Gyebangsan.

For Namsan and Doowang, hydrogen(H^+) and sulfate(SO_4^{2-}) concentrations in rainfall were three to four times higher than those of Gyebangsan (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 Gyebangsan.

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 Gyebangsan, 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

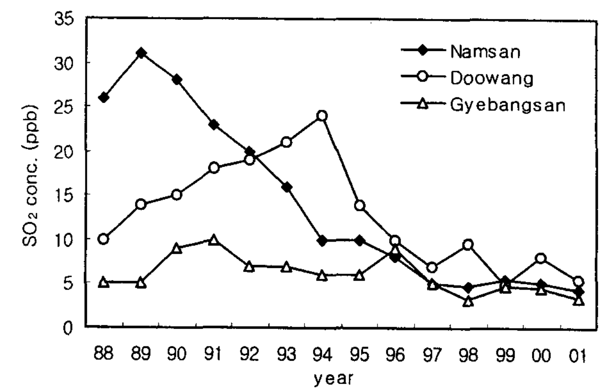

Fig. 1. Annual mean concentration of ambient SO_2 in three regions, 1988 to 2001.

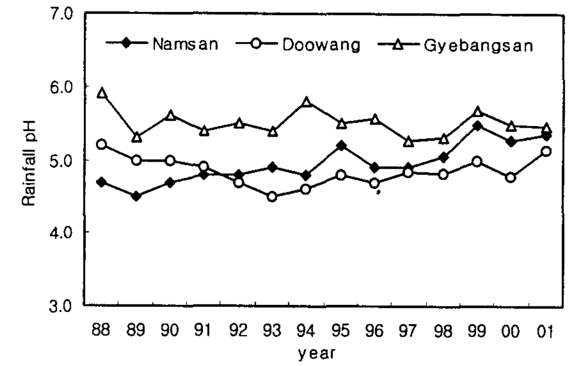

Fig. 2. Annual mean pH of rainfall in three regions, 1988 to 2001.

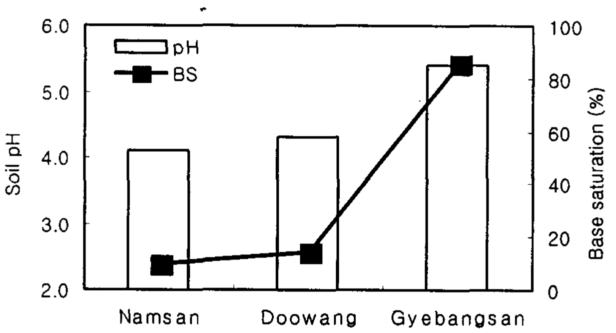

Fig. 3. pH and base saturation of surface soil at 0~15cm depth in three Korean red pine forests. Data are average values of 1996 and 2001, and BS is base cations ratio of effective CEC.

Table 1. Annual volume-weighted mean concentrations (μmolc/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 Gyebangsan, respectively

Region	H^+	NH_4^+	K^+	Na^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	Cl^-
Namsan	9.4b	66.9b	20.5a	29.3b	36.8c	9.4b	30.1b	32.3a	28.3b
Doowang	13.8a	67.8ab	16.6b	61.7a	48.4a	14.0a	45.4a	25.6b	52.5a
Gyebangsan	3.3c	70.1a	19.0a	29.5a	40.4b	10.3b	20.2c	19.1c	22.1c

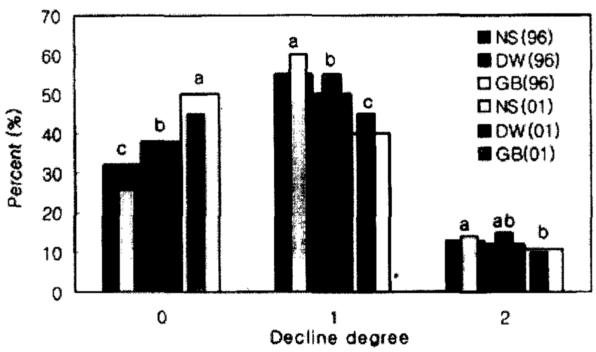

Fig. 4. Decline degree of Korean red pines in three regions, 1996 and 2001. NS, DW and GB note Namsan, Doowang and Gyebangsan, respectively. Decline degree 0; <10% defoliation and 10~25% discoloration, degree 1; 0~10% defoliation and 25~60% discoloration or 10~25% defoliation and discoloration, and degree 2; 0~10% defoliation and >60% discoloration, 10~25% defoliation and >25% discoloration or 25~60% defoliation and 10~25% defoliation, respectively. Mean values with same letter are not significantly different at the probability level <0.01.

acidification can happen at less than 15% of base saturation (Cronan and Grigal 1995).

Tree decline

As shown in Fig. 4, the red pine in Namsan, Doowang and Gyebangsan showed 68%, 62%, and 51% of decline degree 1 (beginning decline phase) and 2 (moderate decline phase) in 1996, and 74%, 70%, and 55% in 2001, respectively. The higher decline degree ($p<0.01$) in two air-polluted regions could be likely induced by higher air pollution, great acid load, and much lower soil pH as well, despite the average age of the sample trees was similar to those in Gyebangsan.

DISCUSSION

In air-polluted Namsan and Doowang from 1988 to 2001, annual mean SO_2 concentrations were two times greater than that in Gyebangsan. The decreased SO_2 in two regions after the mid-1990s is believed to be due to the desulfurizing facilities and expansive use of fuels with lower sulfur (Kim 1996). Although there was the recovery of rainfall acidification for the period, annual mean acid loads in two regions were three to four times higher than that in non-polluted Gyebangsan. Abrahamsen *et al.*(1994) concluded that acidic deposition is likely to bring about increased nutrient imbalance in Norwegian forest ecosystems.

Surface soils in two air-polluted forests were very acidic (pH 4.1~4.3) and had very low base saturation (10~14.5%). They are under threshold of base cation deficit and Al toxicity as soil acidification stress, which could be detrimental to the tree vitality. Cronan and Grigal(1995) reported that Al stress was observed 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 Gyebangsan. 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

Abrahamsen, G., A.O. Stuanes and B. Tveite. 1994. Long-Term Experiments with Acid Rain in Norwegian Forest Ecosystems, Ecological Studies. Springer-Verlag, 337 p.

Cronan, C.S. and D.F. Grigal. 1995. Use of Calcium/Aluminum ratios as indicators of stress in forest ecosystems. J. Environ. Qual. 24: 209-226.

Johnson, A. H. and T. J. Siccama. 1983. Acid deposition and forest decline. Environ. Sci. Technol. 17: 294-305.

Kim, Y.K. 1996. Luftschadstoffsituation in Waldgebieten in Südkorea, Centralblatt für das gesamte Forstwesen 113(1): 39-49.

Mackenzie, J.J. and T.E. Mohamed. 1989. Air pollutions toll on forests & crops. Yale University Press. 376 p.

Mayer, W.H. 1985. Luftverunreinigungen und Waldsterben. 123 p.

Lee, C.H. 1998. Effects of soil acidification on growth and nutrient status of *Pinus densiflora* seedlings. J. Korean Forestry Society 87(4): 611-619.

Lee, C.S., J.H. Kil and Y.H. You. 1998. Historical damage and growth inhibition of *Pinus densiflora* around the Metropolitan area of Seoul. Kor. J. Eol. 21(2): 125-131.

Lee, S.W. and G.S. Park. 2001. Experimental assessment of forest soil sensitivity to acidification(I)-Application of prediction models for acid neutralization responses. J. Korean Forestry Society 90(1): 133-138.

Lindgren, M., M. Salemaa and P. Tamminen. 2000. Forest condition in relation to environmental factors, In E. Mälkönen (Eds), Forest condition in a changing environment, Kluwer Academic Publishers, pp. 142-155.

Ulrich, B. 1989. Forest decline in ecosystem perspective. In Proceedings of international congress on forest decline research. pp. 21-41.

(Received January 13, 2003 ; Accepted April 11, 2003)