C-2.1 Dynamic Analysis of Acid Deposition in Sugi Forests and Prediction of its Effect on Forest Growth

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Abstract; The decline of Sugi forest in the Kanto and Kansai plains was investigated in dynamics of acid deposition, tree ecophysiology and soil buffering capacity for elucidating the decline mechanism and to predict the influence of acid deposition to the forests.

More remarked declination was observed for the old and tall trees, and trees which were isolated or grown in forest edges. The decline was displayed to be still continuing.

pH and chemical composition of precipitation, throughfall and stemflow were determined to characterize the acid deposition into forests in quantity and quality. Acidification of stemflow and soils near trunk of Sugi were clarified.

The methods for measuring emission of nitrogenous and sulfurous compounds from forest floor were established.

From the exposure experiment to artificial acid rain, Sugi was judged not to be damaged by the present precipitation. It was found that Sugi has small tolerance against water deficit because of its rapid transpiration rate and high resistance of water flow in plant body. This physiological characteristics of the tree were presumed to be associated with the decline. Air temperature in summer was related significantly with the decline.

The contents of Al and K in the needles of declined Sugi were high and low, respectively.

Buffering reaction of soil was exibited to consist of four different steps; i.e. carbonate at pH 6, salt adsorption at pH 6, cation exchange at Ph 5 and aluminum at pH 4. Surface soil was weaker in buffering than subsoils in most forest soils.

1. Introduction

Atmospheric pollution especially of acid deposition has been claimed to be a major cause of forest decline in Europe and north America. In Japan, decline of Sugi (*Cryptomeria japonica*) forests. The cause of the decline has not be identified yet, but acid deposition are widely observed. Effects of acid depositon on terrestrial ecosystems are chronic and accumulative. Thus, it is urgently required to estimate and evaluate the effect of acid deposition on forest on the basis of environmental, ecological and plant physiological analyses.

2. Research Objectiv

In order to make clear of the declining mechanism of Sugi forests, the environmental factors, dynamics of acid precipitation in forest ecosystems, physiological characteristics of Sugi and buffering capacities of soils are to be studies, and required methods for the study will be newly developed. The methods for predicting and assessing the effects of acid deposition on Sugi forests will be developed based on the results which will be obtained in the study mentioned above.

3. Research Methods

(1) Dynamic analysis of nitrogen and sulfur in forest

Chemical composition of precipitation, throughfall and stem flow were analyzed. Soil acidification and chemical characteristics of soil water around Sugi (*C. japonica*) trees were examined.

Nitorgen and sulfur contents in Sugi foliar were measured, and the absorbed amounts of these elements in stands were estimated.

Measurement systems of nitrogen and sulfur compounds emitted from soil surface were developed.

(2)Analysis of the mechanism of *C. japonica* forests decline related with acid precipitations

The direct effects of exposure to acid rain and ozone on growth and physiology of Sugi seedlings were studied.

Possible causes of the Sugi decline were discussed based on the analysis of ecophysiology and site condition.

Uptake rate of nutrients by Sugi seedlings was measured by hydroponical cultivation.

The influence of acid rain on soil animals and fungi was examined. Floral differentiation and seed germination of Sugi affected by acid rain were as well investigated.

Ring samples of Sugi trees from polluted areas were analyzed aiming at elucidating the influences of environmental impacts on Sugi trees.

Soil buffering capacity was discussed by an experimental study using soil column and artificial acid rain.

(3)Development of prediction technique

The declination of Sugi stands was discussed in terms of environmental and physiological aspects. Soil buffering capacity was evaluated.

4.Results and discussion

(1) Dynamic analysis of nitrogen and sulfur in forest

The pH and chemical composition of precipitation, throughfall and stem flow of Sugi stands in Kanto district were characterized. The stem flow pH of old Sugi was always lower in comparison with the corresponding precipitation or throughfall. Nutrient concentrations of stem flow increased by 10 to 100 times as it flowed downward along the trunk. The soil pH and the concentration of chemical components near trunk was much lower and higher than that of the further points, respectively. High concentration of water soluble Al was detected in soil solution from near trunk at a heavily damaged Sugi stand.

The methods for measuring emission of nitrogenous and sulfurous compounds from forest floor were established.

A direct and automatic measurement system of nitrogen oxide in ambient air was developed by using gas chromatography equipped with a non-radioactive electron capture detector. The N_2O flux from soils under Sugi forest was measured continuously by using a gas chromatography and open chamber system. The N_2O flux changed depending on the

weather condition. The following formulas were obtained between N_2O flux rate (Y; $mgN/m^2/sec$) and average air temperature (X; C).

Non-rainfall day; Y=10.2X-79.8 (r=0.868), Rainfall day; Y=17.2X-113.8 (r=0.842). The total amount of N_2O flux was estimated to be 363.8 g/ha by formulas mentioned above and weather data.

Sulfur gas flux from soil was measured by a closed chamber method. Suffer gas in the sample was enriched cryogenically with liquid nitrogen under low air pressure condition. Sulfur gases were analyzed by a gas chromatography equipped with a FPD detector. Fluxes of CH_3SCH_3, CS_2 and COS were detected from Sugi forest soil. Annual gas fluxes from the atmosphere to the soil were $0.8mgSm^{-2}yr^{-1}$.

(2)Analysis of the mechanism of C. japonica forests decline related with acid precipitations

No visible injuries were observed for Sugi seedlings treated with acid mist of pH 3.5 and 4.5, and even combination treatment of ozone and pH 2.0 mist gave no visible injuries. Net photosynthesis and stomatal conductance were slightly increased by the treatment with pH 3.5 and 4.5 mist, whereas they were accelerated markedly by the combination treatment of pH 2.5 mist and ozone.

Annual reports on air pollution in Japan suggests that NO_2 level was almost constant (0.020-0.028 ppm) from 1970 to 1990, and SO_2 level decreased gradually from 0.057 ppm to 0.010 ppm during the 25-year period before 1990 around Tokyo bay, one of the highly polluted area in Japan. The highest concentration of O_3 was 0.39 ppm in 1975; however not higher than 0.23 ppm in 1990 in Japan. Annual mean pH of wet deposition was nearly constant ranging from 4.3 to 5.6 in resent years in Japan.

From the experiments and the status of air pollution and wet deposition in the Kanto plains of Japan, we could not clarify the causes of declination of Sugi tree in connection with wet acid deposition and air pollution.

Maximum values of leaf conductance and mean values of total resistance to water flow in the SPAC of Sugi were higher than those of other tree species. Stomatal closure was observed markedly under the condition of low leaf water potential, which depressed daytime apparent photosynthesis rate on a fine day. Morphological characteristics such as high apparent specific weight of sun twigs in the upper crown suggested the frequent water stresses during daytime in tall Sugi trees. These results suggest that tall Sugi trees suffer severe water deficit under the condition of high atmospheric vapor demand and soil drying.

Saturation deficit of the atmosphere in the Kanto plains has increased gradually,and yearly precipitation has decreased science 1950's. On the other hand, the decline of large Sugi trees have been observed science 1960's. This coincidence between climatic change and the decline will lead to the hypothetical presumption that the decline of Sugi in the Kanto plain might not be associated with acid rain, but with ecophysiological characteristics of the species with the low resistance against drying.

Sugi declined seriously in the areas with dry and hot summer. Mean monthly temperature in August was related most significantly with the decline, while degree of stamping and isolation, and concentrations of NO_2 and oxidant affected the decline less significantly.

The surface soil near the trunk of Sugi was found to have been acidified in many sites, but the effect of soil acidification on the decline was not evident.

Exposure of young plants of five different Sugi clones to simulated acid rain resulted in the reduction of floral differentiation. The extent of reduction differed among the five clones. Acid rain did not affected seed germination of Sugi seriously.

The concentrations of Al and K in the needles of declined Sugi were high and low,

respectively. Aluminum in hydroponics did not inhibit the growth of Sugi seedlings at 10ppm.

The distribution of soil organisms did not related with Sugi declination. However, the population of sulfur-oxidizing fungi in the Sugi bark was high in polluted sites, and low in non-polluted ones. This suggests that Sulfur-oxidizing fungi will be an effective bioindicator for pollution.

The structure of Sugi ring samples from polluted area indicated that ring width and maximum density of wood were suitable indications to estimate the influences of acid deposition on the tree. The decline of Sugi was the severest in 1970s, and its growth is recovering in recent years.

By an experimental study using soil column and artificial acid rain, it was showed that soil has four steps of buffer reaction; i.e. carbonate at pH 6, salt adsorption at pH 6, cation exchange at pH 5 and aluminum at pH 4. To estimate soil buffering capacity, anion exchange capacity are to be added to cation exchange capacity. Volcanic ash soils which contain plenty of allophane have strong buffer capacity. Once cations become deficient to anion in soil solution, aluminum starts eluting and lowers pH. Surface soils are weaker in buffering than subsoils in most forest soils. Acidic soils which widely distributed in Japanese forests might be weak against acid deposition.

(3)Development of prediction technique

Based on the research conducted, it was judged that the declination of Sugi stands,which have been observed in plains of the urban vicinity area, was not caused directly by the effect of acid rain, though some different hypotheses on mechanism of the declination have been proposed by different workers. Although the air pollution has been relieved recently in comparison with 1970's, the Sugi stands are still declining. It is considered that polluting substances will be loaded and accumulated increasingly in forest ecosystems, and the soils will be acidified at higher magnitude in future. Environmental change by urbanization will create the unsuitable condition for Sugi to survive. Thus, it is reasonable to assume that the declination of Sugi will continue as ever. More intensive monitoring and research on forest declination and environment are required for conserving the forest.