C-2.3 Effects of Acid Rain on Crops and Agricultural Environments

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Abstract Photosynthetic response of leaves to acid rain varied among plant species. Decrease of photosynthetic rate with acid rain was mainly based on the decrease of chlorophyll content of leaves. Dry weight in most crops except rice reduced with simulated acid rain in the case that its acidity was more than pH 3.0. The results suggest that current ambient levels of rain acidity in Japan may not affect the growth and yield of most crops. Experiment on the combined effect of ozone and acid rain on the visible injury of plants also supported this suggestion. Soil column leaching experiments with simulated acid rain revealed that exchangeable base is the major source of buffering capacity of soils, and Al dissolution occurs at less than 3% of base saturation. Influences of plant roots, soil respiration and percolation rate should be considered to estimate acid-base budget of soils. Acid neutralizing capacity (ANC) values of 51 irrigation water ranged from 139 to 2,135 μ eq/l. These values suggest a small probability of acidification in irrigation water.

Key Words Acid rain, Photosynthesis, Indicator plant, Buffering capacity

1. Introduction

In recent years, acid rain was widely observed in the world and often damaged vegetation and the environment. In agriculture, it is also feared that bad influences of acid rain to crops, their cultivated environment, matter cycle and so on will occur. Hence, urgent study in this field is indispensable.

2. Research Objective

To establish the countermeasure, clarification of action mechanism of acid rain in crops, evaluation of the influences to agricultural environment and selection of indicator plants are the main objectives of the present study.

3. Methods, Results and Discussion

(1) Effect of Acid Rain on Physiological Activity of Leaves

The effect of acid rain on the physiological activities of the leaves in 10 species of crops and weeds was investigated in 1-2 weeks after spraying simulated acid rain of pH 2.5-3.5.

Plant species tested were divided into three groups according to the photosynthetic response to simulated acid rain. Photosynthesis in radish and kidney bean leaves decreased significantly when acid rain under pH 3.0 was sprayed. In the case of white clover and Philadelphia fleabane leaves, it decreased when acid rain under pH 2.5 was sprayed, but did not show any significant decrease in buckwheat, tall fescue, southern crabgrass, common lamb's-quarters and *Polygonum lapathifolium* leaves.

Respiration increased in the leaves of all species when acid rain of pH 2.5 was sprayed.

Chlorophyll content of the leaves which was sprayed with acid rain decreased in the species tested except tall fescue and southern crabgrass. A positive correlation was observed between the relative chlorophyll content, that is, the ratio of the chlorophyll content of the treated leaves to that of the control leaves, and the relative photosynthetic rate which was calculated as mentioned in the case of relative chlorophyll content.

(2) Effect of Acid Rain on Growth and Yield of Crops

The effect of acid precipitation on the yield of agricultural crops is of great concern. Many experiments have been performed concerning the effect of simulated acid rain on the growth and yield of agricultural crops, mainly in USA throughout 1980's. The results suggested that acid rain would not cause yield reduction in any agricultural crop when the pH of rain is above 3.0[1].

In Japan, however, attempts to assess the effects of acid rain on crops have been limited[2] although the rain in Japan is acidified to similar pH level in North America and Europe. In this study, we exposed eight species of agricultural crops, radish, spinach, bush bean, turnip, carrot, chingen-sai, lettuce and paddy rice, to simulated acid rain at pH 5.6 to 2.5 throughout their growing period. The aim of these experiments was to determine the relationship between the pH of rain and growth reduction in plants and to compare the sensitivity of some crop species to acid rain.

All the plants exposed to simulated acid rainfalls at pH 3.0 or below produced visible injury on the leaves. Severeness of the visible injury varied with species to species and also varied depending on leaf ages or growth stages. In many cases in this study, visible injury was more severe at early stages of growth than at later stages, which resulted in the growth reduction at early stages of growth in the case of plants exposed to simulated acid rain at pH 2.7 and pH 2.5 compared with pH 5.6. The relationships between the simulated rain acidity (H+ concentration) and dry weight of whole plant at harvestable stage are shown in Fig.1, in radish and bush bean as examples. In all cases, treatment at pH 3.0(1 mM/l) or less acidity did not significantly affect the dry weight of whole plant at harvestable stage. In the case that the acidity of simulated rain was more than pH 3.0, dry weight reduced except in rice. In the case of rice, there was no reduction in yield even at pH 2.5. The most remarkable reduction was observed in radish.

These results suggest that current ambient levels of rain acidity in Japan, where annual mean pH value is about 4.6, may not affect growth and yield in main species of crops.

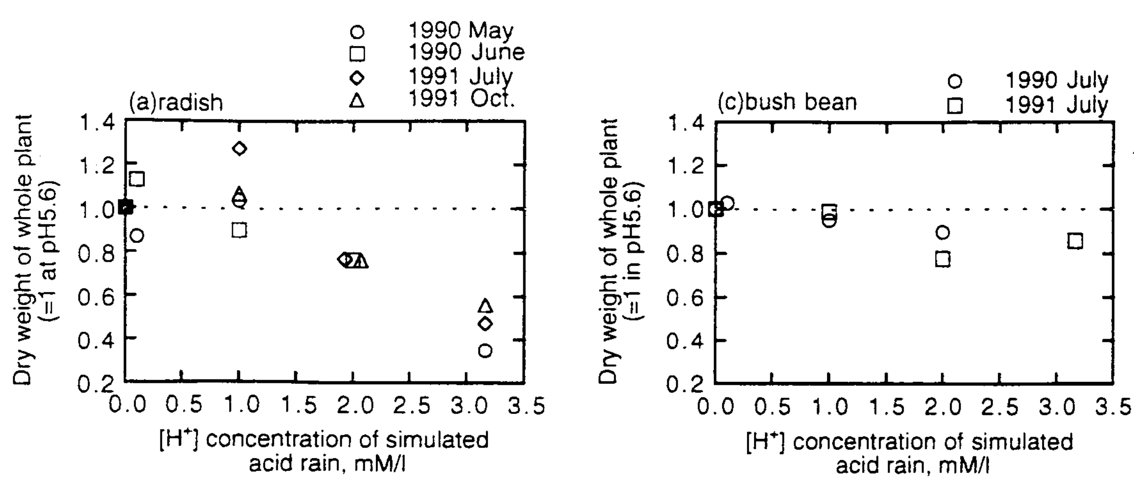

Fig.1. The relationship between simulated rain acidity and relative dry weight of whole plant of radish and bush bean.

(3) Combined Effect of Ozone and Acid Rain

An experiment was performed to determine the combined effect of ozone (O_3) and acid rain on the visible injury of weed and crop plants.

Four species both weeds and crops, which are relatively sensitive to acid rain, were exposed to 0.0, 0.05, 0.10 or 0.15 ppm of O_3 for 8 hr day^{-1} for three days and then 10 ml day^{-1} of simulated acid rain at pH 5.6, 3.5, 3.0, 2.5 or 2.0 were sprayed for three days. The visible injury rate of these leaves were measured.

The threshold concentration of O_3 for appearance of visible injury was between 0.10 and 0.15 ppm. Although injured leaf area was expanded by the exposure of acid rain, the interaction between O_3 and rain pH was not significant. In all of the plants, percentage of the injured leaf area (ILA) of the leaves that had not exhibited O_3 injury, increased drastically at the exposure of pH 2.0 acid rain. Analysis of variance showed that the interaction between O_3 and pH was not significant except for *Arthraxon hispidus* and *Brassica* spp. though the effects of both O_3 and rain pH were significant in most plants. ILA of a few plants such as *Oplismenus undulatifolius* and *Perilla ocymoides* increased at the exposure in the acid rain of pH 2.5 because of the previous exposure of O_3, indicating that O_3 stress affected the induction of visible injury by acid rain to some extent. These results suggest that there is little possibility that plants will be injured by the short-term exposure of O_3 and acid rain at the current ambient levels.

(4) Buffering Capacity of Farm Soils

Soil column leaching experiments with simulated acid rain were conducted to investigate mechanism of soil acidification and buffering capacity of soils.

Saturated and unsaturated column leaching experiments were conducted on 3 types of cropland soils (allophanic Ando soil, non-allophanic Ando soil, and Red-yellow soil). Simulated acid rains (pH 3.00 or 4.00) consisted of equal moles of sulfuric acid, nitric acid, and clouric acid. Simulated acid rain was applied at 20 mm/h, 100mm/day, and 5 days/week, onto saturated soil columns, and at 38mm/h or 7.5mm/h onto unsaturated soil columns. The moisture of unsaturated columns was kept close to field condition by applying tension.

Al was dissolved from allophanic Ando soil and Red-yellow soil columns during saturated leaching with pH 3 simulated rain. Dissolution of Al was also observed in upper layer of non-allophanic Ando soil column. From the amount of eluted cations or soil analysis, base saturation at which Al dissolved was estimated as 0.3% , 3.0%, and 1.8-3.6% for allophanic Ando soil, Red-yellow soil, and non-allophanic Ando soil, respectively. It is inferred, therefore, that exchangeable base is the major source of buffering capacity of soils, and Al dissolution occurs at less than 3 % of base saturation.

Allophanic Ando soil adsorbed about 50% of sulfate ions in pH 3 simulated rain, whereas other soils adsorbed only 20% . These facts indicate high sulfate-adsorbing capacity of allophane. With pH 4 simulated rain, however, more than applied amount of sulfate was leached from allophanic Ando soil. It is supposed that adsorbed sulfate was leached by solution with low concentration of sulfate because allophanic Ando soil had large amount of initially adsorbed sulfate. Therefore, initial sulfate content and sulfate concentration in liquid phase should be taken into account when evaluating buffering capacity due to sulfate adsorption by allophanic Ando soil.

Base cations were leached several times more than applied acid from non-allophanic Ando soil with pH 4 simulated rain, and the amount of them was influenced by leaching rate. The excess cations are supposed to be leached by carbonic acid produced in the soil. It is understood, therefore, that carbonic acid has a large effect on cation leaching from soils, and that production of carbonic acid varies on percolating rate. Carbonic acid is also produced by plant roots in natural environments, so the influences of plant roots, soil respiration, and percolating rate should be considered to estimate acid-base budget of soils.

(5) Buffering Capacity of Irrigation Water

Alkalinity, pH and the concentration of main dissolved elements in 51 irrigation water were measured to evaluate acid buffering capacity of irrigation water for paddy fields.

Measured pH values ranged from 6.79 to 8.50 and were higher than lower limit of standard.

End point for determining acid neutralizing capacity(ANC) was decided to be pH 6 at which titration curve rapidly declines.

ANC values ranged from 139 to 2,135 μeq/l and the average value was 502 μeq/l. ANC tended to be smaller in Tohoku than that in other regions. ANC of four irrigation water with carbonate bedrock in catchment area showed higher level.

100μeq/l of ANC corresponded to pH 4 of acid rain in water lodging period. In this respect, measured ANC values suggest a small probability of acidification in irrigation water.

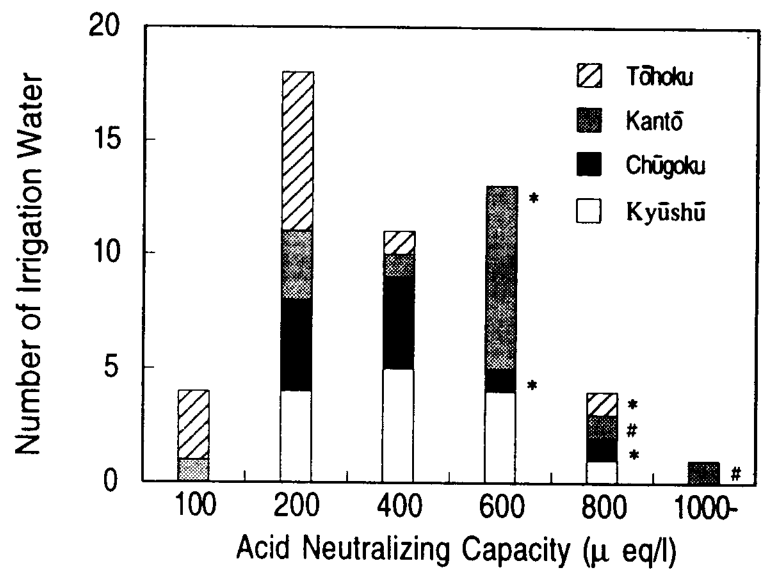

Fig.2. Histogram of acid neutralizing capacity of irrigation water.
*: These had areas with carbonate bedrock in catchment area.
#: These catchment areas were large and urbanized.

4. References

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