EFFECTS OF SULFUR DIOXIDE AND NITROGEN DIOXIDE ON VEGETATION

Progress Report

for Interim Period 1 June 1978 - 30 September 1978

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INTRODUCTION

DOE Contract EE-77-S-02-4368 was initiated on 1 June 1977. Because of a probable transfer of funds between DOE and EPA that would affect this contract, renewal was for the period 1 June 1978 to 30 September 1978. This report summarizes progress for that period.

A major disruption to this program occurred because of the move of the Boyce Thompson Institute from Yonkers, NY to Cornell University in Ithaca, NY. The major part of the move occurred during the period of this contract extension. Because facilities were not completed in Ithaca, all laboratory and field studies were conducted in Yonkers.

Effects of NO₂ on the Phytotoxicity of SO₂.

Two soybean cultivars, Beeson and Hark, were selected for field studies based on the results of short-term exposures to SO₂ in controlled environment chambers. Beeson was found to have considerably more acute damage than the Hark when both were exposed to 3 ppm SO₂ for four hours.

These two cultivars were planted in field plots on 5 June 1978 in 10 hexagonal arrays with 10-inch spacing between plants as shown below. Therefore each plant except those in the outermost positions

had six neighboring plants 10 inches apart. This design was used to minimize problems associated with competition for light, water, and nutrients and perhaps other environmental or biotic variables which might bias the results. Ten field plots were enclosed in open-top chambers. Any potential position effect within the chamber was reduced by alternating sections of each cultivar within each chamber.

The soybeans were exposed to charcoal filtered air with or without added pollutants from 19 July until harvest.

The following treatments were made in duplicate: control (filtered air); 0.2 ppm SO₂; 0.2 ppm SO₂ + 0.2 ppm NO₂; 0.6 - 0.8 ppm SO₂; and 0.6 - 0.8 ppm SO₂ + 0.2 ppm NO₂. The exposures were maintained for 4 hours per day from approximately 1000 to 1400 hours for 13 days from 15 August through 9 September 1978.

Leaf symptomology indicated that a few leaves had acute SO₂ injury in all of the chambers exposed to the higher concentrations of SO₂. Bronzing of some of the leaves was also evident in the chambers with the higher SO₂ plus NO₂ concentrations. By the end of the experiment, the plants in the chambers with the higher SO₂ plus NO₂ and higher SO₂ alone had the most chlorotic leaves (chronic SO₂ injury). The plants exposed to the low SO₂ plus NO₂ concentrations also had a large amount of chlorosis while the plants in the low SO₂ alone and the control chambers had some chlorotic older foliage. In general, the plants in the SO₂ alone and the control chambers were much greener than the plants in the other chambers.

The soybeans were harvested on 19-20 September and the outer plants (guard plants) in each chamber were discarded. The following variables were then determined for each plant: number of full pods,

total number of pods, number of seeds, and seed dry weight.

The highest seed dry weights of all treatments for both cultivars were found in the controls. Significant differences in yield (seed dry weight) were found between the control and all treatments in Hark. Also a significant difference between the yields for the control and the high SO₂ plus NO₂ treatments was found in Beeson. For both cultivars, SO₂ plus NO₂ reduced yield greater than SO₂ alone at the higher levels of SO₂ used. In contrast to the short-term exposure experiments, Hark was more susceptible to all of the treatments than was Beeson.

Interactions of Air Pollutants, Plants, and Plant Pathogens

During the past few years, research has been conducted on effects of air pollutants on incidence and severity of plant diseases. There are two major questions to be answered: 1) Does exposure to an air pollutant modify disease development, i.e., will increases in concentrations of pollutants increase or decrease the risk due to plant disease? and 2) Does infection by a plant pathogen modify the host's response to air pollutants? Information that results from these studies should contribute to the formation of meaningful air quality standards and increase the accuracy of risk prediction.

Diseases caused by fungi have been shown to be increased or decreased in incidence and severity, depending on the particular pollutant-plant-fungus combination. Studies of the effects of low concentrations (0.1 to 0.15 ppm) of sulfur dioxide on southern corn leaf blight (caused by Helminthosporium maydis) and wheat stem rust (caused by Puccinia graminis) have shown that fewer infections are formed on plants exposed to the pollutant than on plants exposed to

pollutant-free air. Analysis of other parameters, such as sulfur content of plants, plant dry mass, and spore germination did not indicate significant interactions of the pollutant and pathogens.

Research in other laboratories has shown that virus infected plants often respond differently to some air pollutants than do healthy plants. Little is known, however, about the effects of air pollutants on the development of virus diseases. Three systems were chosen for study: pinto bean and southern bean mosaic virus (SBMV), tomato and tobacco mosaic virus (TMV), and maize and maize dwarf mosaic virus (MDMV). In all cases, plants were exposed to low concentration of sulfur dioxide (0.1 to 0.2 ppm) for five to eight days. In both SBMV and MDMV, the virus titer was higher in exposed plants, and in particular, in plants exposed after inoculation. Titer of TMV was not affected by pollutant exposure. In the case of MDMV, the percentage of infection and the resultant disease severity was increased when plants were exposed to sulfur dioxide after inoculation.

We conclude from these results that pollutants do interact with plant pathogens, and that under certain conditions, these interactions could be significant. Further studies are planned to investigate pollutant effects on additional host-parasite combinations and possible effects of air pollutants on the epidemiology of plant diseases in the field.

Effects of SO₂ on Plant-Insect Interactions

Studies of the effects of SO₂ on plant-insect interactions progressed nearby on schedule. The development and mortality of Mexican bean beetle larvae on SO₂-fumigated or control Phaseolus vulgaris was examined in two replicated tests using laboratory-reared

insects. Total development time as well as that of each larval stadium was the same on both fumigated and control plants. Also, there were no significant differences in survivorship by larval stage or total mortality. Leaf disc assays showed no effect of SO₂-fumigation on feeding preference.

Studies comparing growth, development, and fecundity of the laboratory colony with field-collected beetles were continued. After 3 generations in the laboratory, the "field" beetles laid an average of 31% fewer eggs/day on pinto beans than the laboratory colony. Conversely, although neither colony did well on soybeans, the "field" colony had a shorter preoviposition period and laid more eggs/day with a higher viability than the laboratory colony. Clearly, the quality of the insect colony must be considered carefully in future experiments. Towards this end, a colony has been established from field-collected beetles and arrangements made for annual infusion of field beetles into the colony.

Analysis of needles from mature trees of Norway spruce, blue spruce, and white pine indicated that little variation occurs between branches of the same tree, but considerable variation can be expected between individual trees of the same species. However, when small, potted balsam fir and white spruce trees were subjected to the same analysis, noticeable variation was found between branches of the same tree. Changes also occur in needle composition as the growing season progresses. In balsam fir, the bornyl acetate content increased from an average of 1.5% in buds to 15% in old needles, whereas the α -pine content decreased from an average of 20% to 10% in the same tissues.

Mode of Action and Metabolism of SO₂ in Plants

Individual corn and soybean plants were exposed to several concentrations of SO₂ to produce uptake isotherms (rate of uptake at various concentrations). A teflon-lined exposure chamber was used to reduce surface adsorption to a minimum. Teflon-coated pots without plants were exposed in the chambers and within five minutes the SO₂ concentration of the chamber outflow was equal to that of the inflow. Therefore any deviation of chamber outflow to inflow SO₂ concentration when the plant was in the chamber was attributed to uptake and surface adsorption by the plant.

Leaf resistance values were determined for all of the leaves on the plants with the aid of a Lambda diffusion porometer. These measurements were made to follow changes in stomatal aperture and hence the capacity of the plants for uptake of the SO₂.

It was found that for both corn and soybean that the SO₂ uptake was linear over a range of concentrations tested from zero to 3 ppm. The SO₂ uptake was linear over this concentration range only when leaf resistances were constant and the exposure times were short. The plants were maintained under conditions of high soil water content and high relative humidity and illuminated with 2000 fc from fluorescent lights for at least one hour before exposure to induce wide stomatal apertures. Under these conditions, the uptake of the SO₂ appeared to follow Fick's first law of diffusion.

Ethylene and ethane evolution from leaf homogeantes of soybean, corn, pinto bean, cotton, and lettuce subjected to various concentrations of sodium bisulfite was measured as an indication of injury to the tissues. Although ethylene evolution increased with

increasing concentrations of bisulfite in the homogenate, the increase in ethane evolution was found to follow the increase in bisulfite much better. Furthermore, the ethane evolution continued to increase up to 10 mM bisulfite while ethylene evolution sometimes ceased at a bisulfite concentration of 5mM. These reactions were found to be independent of light but did not occur in tissues which had been killed by boiling (which indicates that the bisulfite effect which produced the ethylene and ethane is dependent on living tissues).

Leaf homogenates of six cultivars of soybean were placed in distilled water or 5 mM sodium bisulfite solutions and after incubation for 1 hour in light, ethylene and ethane evolution were measured. All of these cultivars had been previously screened for susceptibility to acute SO₂ injury. It was found that the cultivar most resistant to SO₂, Hark, also showed the least amount of ethylene and ethane evolution.

The increased production of ethane and ethylene raises the prospect that bisulfite and, by extension, SO₂, peroxidizes the polyunsaturated fatty acids of the membrane lipids and destroys the compartmentalization of the plant cells. It is possible that species resistant to SO₂ have a larger pool of natural antioxidants or a lower amount of polyunsaturated fatty acids.

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Dated January 15, 1979

Boyce Thompson Institute
(Applicant)

(Signature of Director, Administrative-
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