CHANGES IN EASTERN WHITE PINE STANDS RELATED TO AIR POLLUTION STRESS

By

KARNOSKY D.F.
Cary Arboretum
Millbrook, N.Y

Summary

Fifteen eastern white pine (Pinus strobus L.) sample plots consisting of a total of 1523 trees were established within a 13 km radius of the Columbia Generating Station, a coal-burning power plant located 40 km north of Madison, Wisconsin, in 1971. The sample plots were made up of plantations with trees having uniform ages within each plantation but with trees ranging in age from 10 to 40 years old across the 15 plantations. Baseline study during 4 years before the 1054 MW power plant began operation in 1975 showed that some 10% of the white pine were affected to some degree by ambient air pollution as determined by the presence of needle tipburn and/or chlorotic dwarf symptoms in one or more years.

The most common type of air pollution symptom found in the baseline study was tipburn consisting of reddish brown dieback (0.1 to 3 cm in length) on needle tips. The severity of symptoms varied from tree to tree and from year to year. The most severely affected trees had stunted tops, short needles, poor needle retention, and were characteristic of an air pollution-induced syndrome called the chlorotic dwarf disease. Ambient sulfur dioxide (SO_2) and ozone (O_3) monitoring in the power plant vicinity revealed the presence of background levels of these two pollutants in the concentration ranges reported to injure genetically sensitive eastern white pine trees in controlled fumigations.

During the 5 years since the power plant began operation, there have been no detectable differences in the occurrence or severity of symptoms. With only a few exceptions, the same trees have shown symptoms after the plant began operation as before it started. However, mortality has reduced intermediate genotypes (those injured in 1 or 2 years of the 9 year study) by 4.7% and the sensitive genotypes (those injured in 3 or more years) by 10.4%. In comparison, only 2.0% of the tolerant trees have died during the course of the study. Most of the mortality of the sensitive genotypes was apparently due to their being slower growing and thus unable to compete for light, water, and nutrients with their neighboring trees. As a result, the white pine stands studied are gradually being dominated by air-pollution-tolerant genotypes.

Keywords: Pinus strobus, ozone, sulfur dioxide.

[1] Presented at the 11th International Meeting for Specialists in Air Pollution Damages in Forests. (IUFRO S 2.09) Graz, Austria, August 31 to September 6, 1980. This study was supported in part by Grant R803971, Environmental Protection Agency, and by the Wisconsin Public Service Corp., the Madison Gas and Electric Co., the Wisconsin Power and Light Co., and the College of Agricultural and Life Sciences, University of Wisconsin.

Introduction

Eastern white pine (*Pinus strobus* L.) is an important timber species in much of the eastern United States and southeastern Canada. It is also commonly planted by Christmas tree growers. Unfortunately, eastern white pine is very susceptible to injury from air pollutants. It is probably injured by air pollutants more than any other tree species (Gerhold, 1977). Near large sulfur dioxide (SO_2) pollution sources such as the ore smelters at Sudbury, Ontario and Copper Hill, Tennessee, eastern white pine has been eliminated from the vegetation within several miles of the emission sources. Under less severe conditions, however, it is only the sensitive genotypes, making up a small proportion of the population, that show symptoms of an air-pollution-induced stress.

The two most common symptoms of air-pollution-induced stress on eastern white pine that occur across the range of the species are those described as needle tipburn and chlorotic dwarf. Needle tipburn symptoms consist of reddish brown dieback (0.1 to 3 cm or more in length) on first year needle tips. Trees characterized as chlorotic dwarfs usually have foliage showing chlorotic mottling and have short needles, poor needle retention, and stunted tops. The two disease syndromes, needle tipburn and chlorotic dwarf, commonly occur on the same trees. There is evidence that these diseases are caused by exposure to low levels of SO_2 and ozone (O_3), alone or in combination (Dochinger *et al*., 1970; Costonis, 1970, 1971; Houston, 1974).

Trees suffering from needle tipburn and/or chlorotic dwarf tend to be slower growing than neighboring tolerant trees and so they are gradually eliminated from the population. This paper presents some quantitative data on the relative mortality rates of air-pollution-sensitive eastern white pine genotypes as compared to tolerant genotypes and discusses the future significance of this loss of a substantial portion of the variability in eastern white pine.

Materials and Methods

Because of its sensitivity to air pollutants, its economic importance, and its common occurrence in the study area, eastern white pine was chosen for a study of the environmental impact of a 1054 MW coal-burning power plant in Columbia County, Wisconsin. Permanent sample plots ranging in size from 20 to 355 trees per plot and totaling 1523 trees were established in 15 randomly chosen eastern white pine plantations within a 13 km radius of the Columbia Generating Station in 1971. These plots consisted of trees with uniform ages within each plantation but with trees ranging in age from 10 to 40 years across the 15 plots.

Sample plots were examined annually in late September or early October for the past 9 years and tipburn and chlorotic dwarf symptoms were recorded for each tree. In addition to the regular fall examinations, occasional inspections were made on sensitive trees during the summer months over the course of the study to observe and record symptom development.

The power plant began operation at 527 MW capacity in May, 1975 and the capacity was doubled in May, 1978. The plant now consumes over 9,000 tons of coal per day, and it burns low-sulfur Montana and Wyoming coal. The smoke stack height is 150 m for the first unit and 210 m for the second unit.

Levels of SO_2 at four sites, O_3 at one site, and particulates at one site have been continuously monitored since the spring of 1973. Levels of nitrogen oxides (NO and NO_2) have been continuously recorded for the past four years at one site.

Results

The baseline study during the 4 years before the plant began operation in 1975 showed that some 10% of the white pine trees were affected in some degree by ambient air pollution as determined by the presence of needle tipburn and/or chlorotic dwarf symptoms. The affected trees occurred randomly in the sample plots.

The most common type of air pollution symptom found in the baseline study was tipburn consisting of reddish brown dieback (0.1 to 3 cm in length) on first-year needle tips. The severity of symptoms varied from tree to tree and from year to year. The most severely affected trees had stunted tops, short needles, poor needle retention, and were characteristic of the chlorotic dwarf disease. However, chlorotic mottling of new needles, common to the chlorotic dwarf disease, did not occur. Tipburn symptom development usually began during the early summer when the new needles were elongating. Thus, trees began showing symptoms in early to mid June, and symptoms continued to develop throughout the growing season.

The first visible symptoms on elongating needles were pale chlorotic spots (less than 1 mm in size) localized on the stomatal face about 1 cm from the needle tip. These chlorotic spots eventually coalesced to form a yellowish to pinkish band across the needles. As the cells in this band died, a reddish brown necrotic area developed which spread to the needle tip. The dead needle tips usually turned grey by the beginning of the second growing season and they often broke off cleanly leaving a blunt and shortened needle.

Variations in symptom development within a tree also commonly occurred; the five needles within a single fasicle often showed a range of response from no visible injury to severe tipburn. Costonis (1970) has reported finding all stages of lesion development within a given fasicle following SO_2 exposure.

Air monitoring revealed the common occurrence of O_3 levels of 4.5 to 5.5 pphm for 1 to 3 hr during each growing season. The maximum 1 hr average for O_3 was 13 pphm. For SO_2, levels were generally less than for O_3. However, 1 hr SO_2 concentrations in the range of 2 to 4.5 pphm were fairly common during the study. A maximum of 11 pphm SO_2 for 1 hr was recorded on one occasion. These levels, while low in terms of air quality standards, have been shown to be within the range of concentrations of O_3 and SO_2 reported to injure genetically susceptible eastern white pine trees in controlled fumigations (Costonis, 1970, 1971, 1973; Dochinger et al., 1970; Houston, 1974).

With the exception of one site (site 9), there were no detectable differences in the occurrence or severity of tipburn symptoms during the 5 years after the power plant began operation. With only a few exceptions, the same trees had needle tipburn and/or chlorotic dwarf symptoms before and after the plant began operation. A more severe type of tipburn symptom was seen at site 9 during the second year after the plant began operation.

However, this was most likely caused by a fluctuating water table at this site during 1977 and 1978 and not by air pollution.

Trees were described as tolerant if they did not show any foliar symptoms during the 9-year study. Trees that had needle tipburn symptoms for only 1 or 2 years were classified as intermediate and those having needle tipburn symptoms for 3 or more years were listed as sensitive. The majority of the sensitive trees were also the most severely injured and could be described as having the chlorotic dwarf disease. Houston and Stairs (1973) found strong genetic control of variation of eastern white pine's response to SO_2 and O_3, alone and in combination.

During the course of the study it became apparent that the rate of mortality was different for the sensitive genotypes than it was for the tolerant individuals. The tree mortality rate due to natural causes, as opposed to that due to road construction or other man-related activities, was greater for the sensitive and intermediate genotypes than for the tolerant trees (Table 1).

Table 1--Mortality over a 9-year period of eastern white pine trees differing in air pollution sensitivity.

Air Pollution Sensitivity[1]	Original Number of Trees	Number That Have Died	Percent Mortality
Tolerant	1369	27	2.0 pct.
Intermediate	106	5	4.7 pct.
Sensitive	48	5	10.4 pct.
TOTALS:	1523	37	

[1]The sensitivity rankings were based on the following: tolerant trees did not have air-pollution-induced tipburn symptoms during the course of the study; intermediate trees had symptoms for 1 or 2 years; and sensitive trees had symptoms for 3 or more years.

Discussion

The most obvious effect of mortality of sensitive eastern white pine genotypes caused by air pollution is the slow selection against and gradual elimination of sensitive genotypes from the population (Miller and McBride, 1977). The loss of the sensitive genotypes prevents their future use in tree improvement efforts even though these genotypes may have valuable genes for form, growth rate, or insect and disease resistance in the future. Sensitive genotypes are also valuable as bioindicators of the presence of air pollutants. It is important that selections be made for both air-pollution-tolerant eastern white pine for planting in polluted areas and air-pollution-sensitive eastern white pine to serve as bioindicators and to preserve these genotypes for possible future breeding work.

Another consequence of the mortality of sensitive eastern white pine genotypes caused by air pollution is that surveys of older stands and plantings of eastern white pine in areas with long-term pollution problems may not accurately assess the impact of air pollutants on eastern white pine. The reason for this is that the sensitive genotypes would have died out of the population so that the remaining population would consist of tolerant trees. Surveys examining the impact of air pollutants on eastern white pine should include examination of young trees in nurseries, plantations, and/or Christmas tree farms. Surveys conducted using older eastern white pine trees should utilize more sophisticated measurements than needle necrosis to detect air pollution effects. Measurements of stem and diameter growth rates, needle length, needle retention, or biochemical processes such as photosynthesis, transpiration, or enzyme production must be used to detect impacts of air pollutants on older stands of eastern white pine in which the sensitive genotypes have died out.

Literature Cited

Costonis, A.C., 1970: Acute foliar injury of eastern white pine induced by sulfur dioxide and ozone. Phytopathology, vol. 60, pp. 994-999.

______________, 1971: Effects of ambient sulfur dioxide and ozone on eastern white pine in a rural environment. Phytopathology, vol. 61, pp. 717-720.

______________, 1973: Injury to eastern white pine by sulfur dioxide and ozone, alone and in mixtures. Eur. J. For. Path., vol. 3, pp. 50-55.

Dochinger, L.S., F.W. Bender, F.L. Fox, and W.W. Heck, 1970: Chlorotic dwarf of eastern white pine caused by an ozone and sulfur dioxide interaction. Nature, vol. 225, p. 476.

Gerhold, H.D., 1977: Effect of air pollution on *Pinus strobus* L. and genetic resistance. Ecological Research Series EPA-600/3-77-002. 45 pp.

Houston, D., 1974: Response of selected *Pinus strobus* L. clones to fumigations with sulfur dioxide and ozone. Can. J. For. Res., vol. 4, pp. 65-68.

__________ and G.R. Stairs, 1973: Genetic control of sulfur dioxide and ozone tolerance in eastern white pine. Forest Sci., vol. 19, pp. 267-271.

Miller, P.R. and J.R. McBride, 1975: Effects of air pollutants on forests. In: J.B. Mudd and T.T. Kozlowski (Eds.) Responses of plants to air pollution. Academic Press, New York. pp. 195-235.

Zeitschrift/Journal: Mitteilungen der forstlichen Bundes-Versuchsanstalt Wien

Jahr/Year: 1981

Band/Volume: 137_1_1981

Autor(en)/Author(s): Karnosky D. F.

Artikel/Article: Changes in eastern white pine stands related to air pollution stress 41-45