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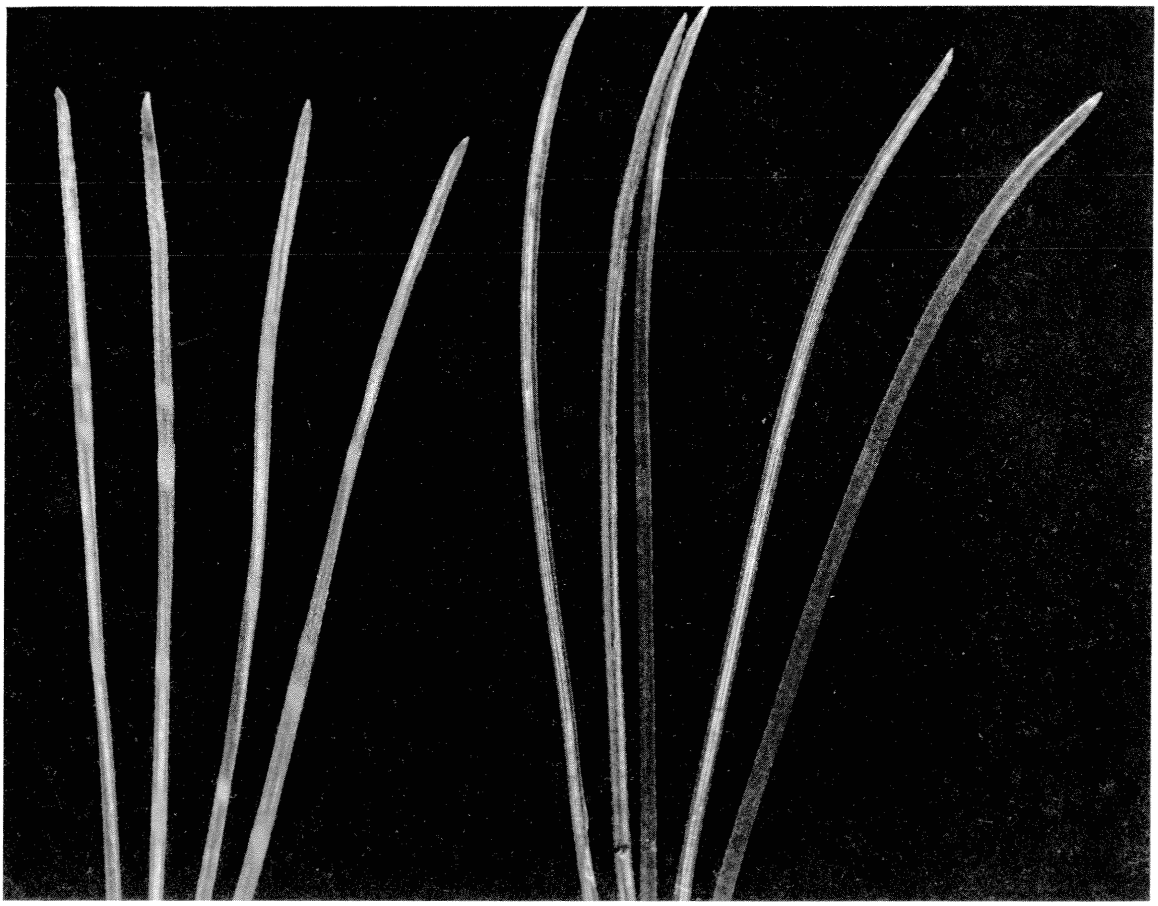
Needle Mottle in Eastern White Pine Seedlings: A Selective Parameter for Air Pollution Sensitivity



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Abstract

Positive correlations were established between morphological characteristics in eastern white pine seedlings and subsequent tolerance or sensitivity to air pollution 5 and 7 years after outplanting in Ohio plantations. Of 11 seedling variables, needle mottling was an accurate indicator of sensitivity or tolerance to air pollution. This characteristic, which may be genetically controlled, should allow for the detection and removal of sensitive white pines in the nursery during grading.

INTRODUCTION

QUANTIFYING GENETIC tolerance to air pollution is one of the more urgent priorities for forest management. Although large gene pools still exist for breeding, tree populations are constantly threatened and are being reduced by concentrations of ambient air pollutants. High levels of indigenous pollutants have damaged forest communities throughout the world (Dochinger 1971). Also, the adverse effects of long-term, ambient pollution over large expanses of forests are well documented (Dochinger 1972; Miller and Millican 1971).

Air pollution can create imbalances in the species composition of the plant community, which, in turn, may drastically influence the stability of the ecosystem. Although these changes are not totally understood, ambient pollution may change the genetic composition of the forest through the loss of intolerant genotypes, both by mortality and by impaired reproductive processes, such as flower production, pollen viability, and seed development (Houston and Dochinger 1977).

The variation in responses of trees to single and multiple pollutants is not completely understood. In conifers, genetic variation to injury by sulfur dioxide occurs in *Larix* Mill (Schonbach et al. 1964); by fluorides and sulfur dioxide in *Picea abies* (L.) Karst (Rohmeder et al. 1962; Rohmeder and von Schönborn 1968; Fer et al. 1972); by sulfur dioxide in *Pinus contorta* Dougl. (Enderlein and Vogl 1966); by fluorides and oxidants in *Pinus ponderosa* Laws. (Hepting 1964); by ozone and sulfur dioxide in *Pinus strobus* L. (Berry 1973; Dochinger et al. 1970; Houston 1974), and by fluorides and sulfur dioxide in *Pinus sylvestris* L. (Rohmeder et al. 1962; Vogl 1970).

Interspecific hybrids of *Larix* vary in sensitivity to sulfur dioxide (Enderlein et al. 1966) as do those of *Populus* L. to ozone (Jensen and Dochinger 1974) and to sulfur dioxide (Dochinger et al. 1972).

Intraspecific variation in sensitivity to ozone has been observed in *Acer rubrum* L. (Townsend 1974; Townsend and Dochinger 1974); to sulfur dioxide in *Picea abies* (Tzschacksch et al. 1969); to ozone and sulfur dioxide in *Pinus ponderosa* (Karpen 1970); to sulfur dioxide in *Pseudotsuga menziesii* (Mirb.) Franco (Enderlein and Vogl 1966); and to ozone and sulfur dioxide in *Platanus occidentalis* L. and in *Ulmus americana* L. (Santamour 1969).

This variation in sensitivity of tree species and populations to pollutants indicates significant genetic control. Therefore a program to select seedlings and seed sources of tolerant plants merits investigation. A preliminary step would be selecting for morphological, physiological, and biochemical markers. These genetic markers can be determined and classified only if quantitative or qualitative differences among plant populations can be measured.

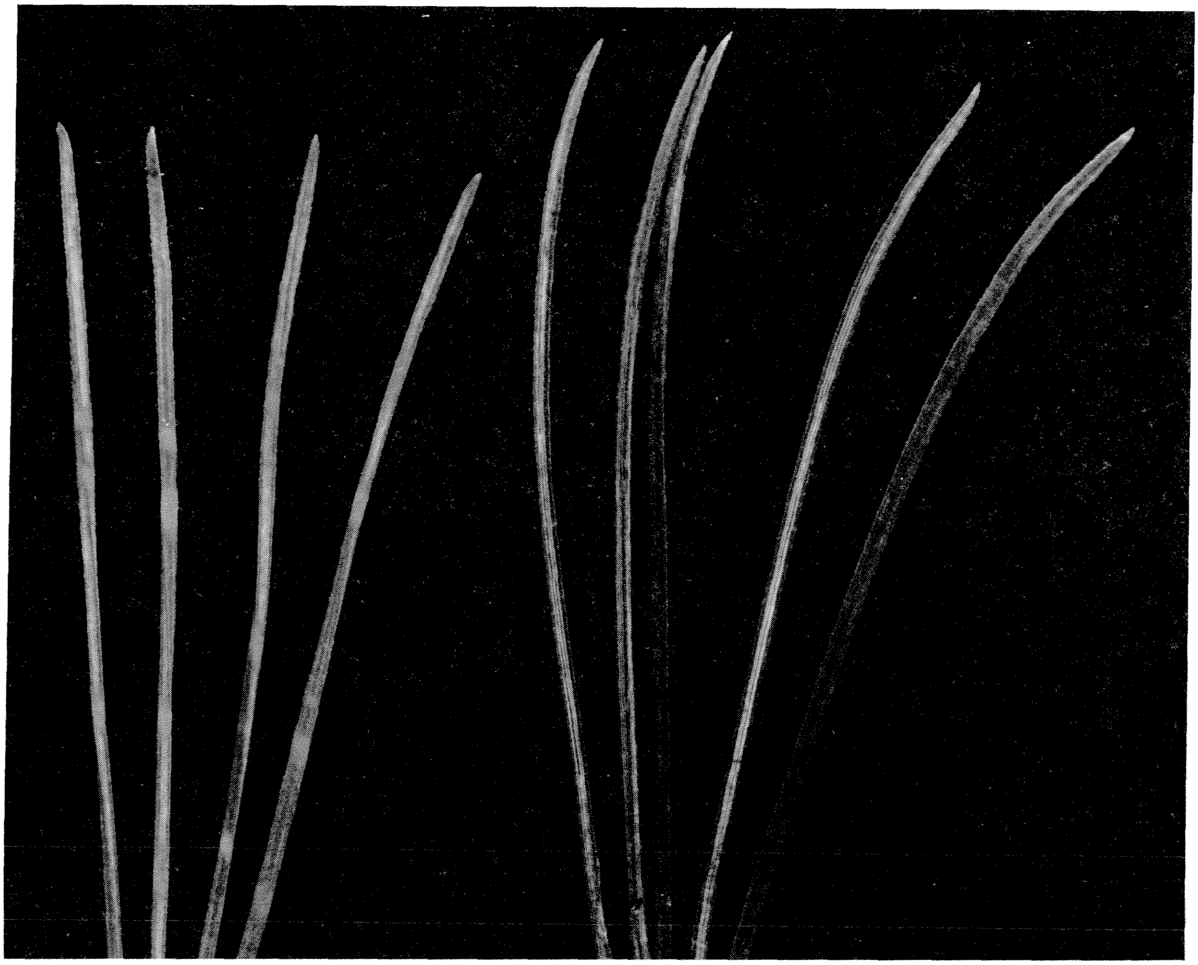
Our research on the sensitivity of white pine plants to air pollution suggested that mottling occurred on needles when sensitive trees were exposed to ambient pollution. Mottling was not observed when there were no pollutants in the vicinity of these white pines, but it reoccurred when they were again exposed to ambient pollution. Therefore we decided to determine the relationship between needle mottle and other morphological characteristics and tolerance to air pollution in seedlings of eastern white pine after outplanting. This paper reports on the responses of two eastern white pine plantings to ambient pollution over a 12-year period.

METHODS

In the first phase of the study, 2–0 seedlings of eastern white pine from state forest nurseries in Marietta and Zanesville, Ohio, were examined for chronic mottling of current-year needles (Fig. 1). Chronic injury was defined as irregular patterns of yellow discoloration (with indefinite margins) that occurred on both the abaxial and axial surfaces of the leaf.

Each seedling was rated for 11 characteristics: degree of foliage mottling; needle length; reten-

Figure 1.—Needle mottle is visible on a pollution-sensitive white pine fascicle, but not on the tolerant specimen.



tion of first-year needles; current-year needle defoliation; necrotic spotting; needle tip necrosis; needle tip yellowing; presence or absence of juvenile foliage (Fig. 2); number of buds in terminal shoot; presence or absence of vestigial buds; and presence or absence of stalked buds (Fig. 3).

Foliage mottling was scored: 0 (none); 1 (less than 25 percent); 2 (25 to 50 percent); or 3 (greater than 50 percent). Needle length was scored: 0 (less than 1 inch); 1 (1 to 2 inches); or 2 (greater than 2 inches). The number of buds was scored: 0 (less than 3), or 1 (greater than 3). The remaining variables were scored: 0 (no), or 1 (yes).

We selected 400 plants, 200 with mottling and 200 without mottling. Seedlings were planted randomly in a plantation in the Blue Rock State Forest in southern Ohio during the spring of 1963. In the immediate vicinity of Blue Rock State Forest are several sources of stack gases, including 500,000 and 1,000,000-kilowatt electric power plants. For all trees, ratings for survival and sensitivity to air pollution were recorded each year for 5 years.

The second phase of the study was begun in 1968 when an additional planting was made in the Blue Rock State Forest. In each of 20 randomly chosen rows we planted 10 seedlings of 2-0 white pines—with and without mottling. Similar data for these trees were collected each September for 7 years.

Figure 2.—Morphological characteristic of juvenile foliage on white pine.

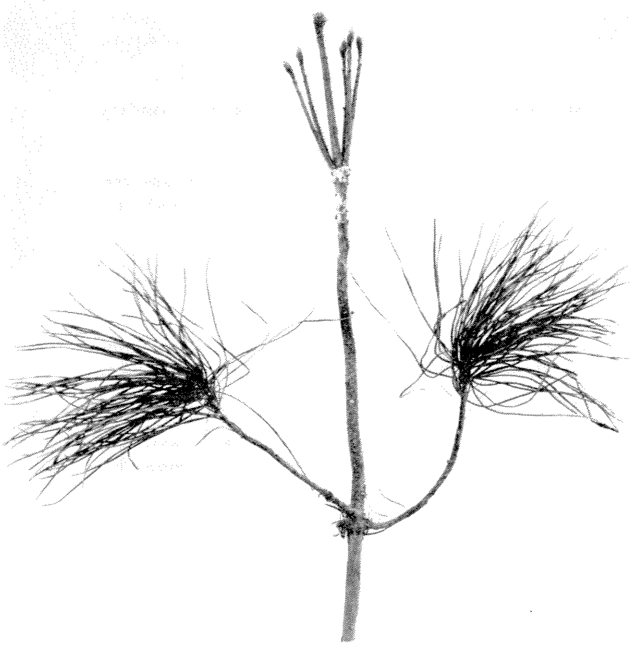


Figure 3.—Morphological characteristic of stalked buds on white pine.

RESULTS AND DISCUSSION

A nonparametric classification technique was used to relate white pine individuals to measured seedling characteristics (Cochran and Hopkins 1961). The presence or absence of mottling on the seedlings was an excellent criterion for measuring sensitivity to ambient concentrations of air pollutants in white pine trees in Ohio plantations.

5-year planting

The value for each variable in Table 1 represents the proportion of white pine seedlings—originally designated as tolerant or sensitive—that remained

Table 1.—Percentage of white pine seedlings, originally designated as tolerant or sensitive to air pollution, that remained tolerant or sensitive 5 years after outplanting.

Characteristic	White pine seedlings	
	Tolerant	Sensitive
Foliage mottling		
None	95	—
Less than 25%	4	21
25 to 50%	1	50
Greater than 50%	—	29
Needle length		
1 inch	2	8
1 to 2 inches	55	84
Greater than 2 inches	43	8
Current-year needle retention		
Yes	34	—
No	66	100
Current-year needle defoliation		
Yes	99	99
No	1	1
Necrotic spotting		
Yes	67	12
No	33	88
Needle necrosis		
Yes	94	82
No	6	18
Needle tip yellowing		
Yes	39	48
No	61	52
Juvenile needles		
Yes	100	93
No	—	7
Number of buds		
Less than 3	98	86
More than 3	2	14
Stalked buds		
Yes	31	37
No	69	63
Vestigial buds		
Yes	100	99
No	—	1

tolerant or sensitive to air pollution 5 years after outplanting. During the first year, 59 seedlings did not survive—40 in the tolerant group and 19 in the sensitive group. These seedlings were not included in the final tabulation because responses to air pollution were not apparent at the time of death; also, survival patterns did not indicate significant differences between the two groups. Of the 181 surviving plants designated as sensitive because of mottling, 173 remained sensitive. However, all of the 160 surviving seedlings without needle discoloration remained tolerant.

7-year planting

For the 7-year planting, we observed similar responses to air pollution. All of the 100 tolerant white pines remained tolerant (including five plants that died during the study). In the sensitive group, 97 of 100 seedlings with mottled foliage remained sensitive to air pollution (including five that died during the study).

On the basis of results for both studies, it seemed reasonable to classify all white pine seedlings with no mottling as tolerant and those with mottling as sensitive to atmospheric pollution. This conclusion nullified the necessity of considering the remaining 10 variables because the results would not have markedly affected the accuracy of predictions of plant performance.

The similarity in values for mottling between white pine seedlings and forest trees indicates that the nursery stage is an excellent one for identifying genetic differences in sensitivity to air pollution. Since nursery seedlings are exposed to fairly uniform conditions, sensitive individuals can be removed during grading. And widespread sublethal and lethal concentrations of air pollution coupled with extreme sensitivity of white pines to these levels allow the detection and removal of sensitive pines. Cooperation among research specialists, commercial nurserymen, forest managers, and arborists would be required to apply these techniques successfully.

The use of these techniques require selection for morphological, physiological, and biochemical markers. These genetic markers must be tested by controlled laboratory fumigation regimes and by field exposure to ambient pollution. The merits of laboratory study are considerable, but ultimate decisions on plant performance must be determined in the field before practical recommendations can be made.

Field plantings may present difficulties in measuring the impact of air pollution. All factors must be evaluated in testing promising phenotypic and genotypic characteristics. The interactions of hereditable factors of the plant with its total environment must be evaluated as possible variations in response to pollution. Finally, traditional factors such as stem form and volume must be considered in selecting for tolerance to air pollution in a long-term breeding program.

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