Occurrence of Air Pollution Symptoms (Needle Tip Necrosis and Chlorotic Mottling) on Eastern White Pine in the Southern Appalachian Mountains

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ABSTRACT

The air pollution symptoms tip burn and chlorotic mottling were found on eastern white pine in about 23% of sampled stands in the southern range of this species in Virginia, North and South Carolina, Georgia, Tennessee, and Kentucky. Plantations had a higher percentage of trees affected than did natural stands. The percentage of stands with at least one symptomatic tree was highest in Kentucky (77%), followed by Tennessee (31%), and lowest in Georgia (10%). Elevation and percent slope were not correlated with incidence, but stands with symptomatic trees were most common on southwest aspects. Symptomatic trees had 49% less mean volume than healthy trees.

Common, ambient air pollutants adversely influence forest tree growth and productivity in some areas of the United States. In the San Bernardino Mountains in southern California, Miller and co-workers (19-21) reported severe growth losses in ponderosa (Pinus ponderosa Doug. ex Laws.) and Jeffrey (P. jeffreyi Grev. & Balf.) pines resulting from elevated ozone (O₃) concentrations, which are generated from precursor substances emitted in the Los Angeles Basin. Others (2,7,13,15,18,23-26) have likewise documented growth reductions in several eastern forest tree species exposed to ambient concentrations of O₃ in the Blue Ridge Mountains of Virginia.

For many years, eastern white pine's (P. strobus L.) sensitivity to O₃ and sulfur dioxide has been recognized (1-5,8,9,11,12). The most frequently observed needle symptoms associated with pollutant exposure are tip burn, chlorotic mottling, and chlorotic banding of needles (16). Air pollution injury on eastern white pine has been documented over a large geographic area, including Indiana and Wisconsin (27), Tennessee (5), New Hampshire (6), the Appalachian Mountains (13), Virginia (15), Virginia and North Carolina (24), and the southern Appalachians (3).

Eastern white pine shows significant genetic variation in response to pollutants such as O₃. In 1977, Gerhold (14) classified genotypes of eastern white pine as resistant (no symptoms), moderately resistant (some symptoms and growth loss), and sensitive (major symptoms and growth loss, with associated mortality). Berry and Hepting (5) reported that only 5.7% of the population they tested was resistant to O₃.

In 1979, Skelly et al (24) reported that 22, 67, and 11% of the eastern white pines in the southern Blue Ridge Mountains were resistant, moderately sensitive, and sensitive, respectively, to O₃. In many cases, the most sensitive genotypes were so severely affected that the authors concluded that these genotypes probably were being eliminated from the population.

Benoit et al (2) estimated growth losses of 15% for moderately sensitive trees and 25% for sensitive trees exposed to ambient O₃ concentrations, compared with tolerant trees, in the Blue Ridge Mountains of Virginia.

There is concern that atmospheric deposition may be affecting forest productivity in the southern United States. Pine growth reductions have been reported in much of the Southeast (22), and although the causes of these growth losses have not been determined, air pollution is viewed as a possible cause. The need therefore exists to assess the potential impact of O₃, the predominant phytotoxic air contaminant in the eastern United States, on forest trees in the Southeast. As an initial phase in this assessment, we surveyed symptoms typical of air pollution injury on eastern white pine in the southern portion of its natural range in Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. The objectives of the survey were: 1) to determine the incidence and distribution of needle tip

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Fig. 1. Percentage of eastern white pines with tip necrosis and chlorotic mottling in a six-state survey area.
burn and mottling in the study area, 2) to assess the potential growth loss on affected trees, and 3) to assess the possible correlation of site factors, such as slope, aspect, and elevation, with these symptoms.

The survey was designed to include only trees that had the typical air pollution symptoms of tip necrosis and chlorotic mottling. Where a cause other than air pollution could be identified, the tree in question was not tallied as having air pollution symptoms.

MATERIALS AND METHODS
During September through November 1985, 50 eastern white pines were examined on each of 201 sites systematically spaced across the natural range of this species in South Carolina, Tennessee, Virginia, North Carolina, Kentucky, and Georgia. Sample points were located on a map in a 24 x 24 km grid pattern. Every attempt was made to locate the white pine stand closest to the predetermined point on the map. All stands were located at least 40 m off a road and were not situated near major highways. The selected stands were at least 25% white pine and were of any age. The sampled trees had to have foliage that could be reached by hand (below 2.5 m) and that was fully exposed to the sun. The latter ensured that the foliage examined had been directly exposed to pollutants rather than to air filtered by other vegetation.

The current year’s foliage that could be reached from the ground by hand on each sample tree was examined for needle tip necrosis and chlorotic mottling. A tree was considered affected if 20% or more of its branches had some necrotic needle tips and chlorotic mottling. A stand was considered affected if at least one tree of 50 examined showed air pollution symptoms. Foliar symptoms resulting from other stresses, such as insects, winter fleck, mites, herbicides, salt injury, drought, and plant pathogens, were noted, but these symptoms were not considered indicators of air pollution damage. Only field diagnosis was used to assess needle symptoms. Damage such as drought injury and needle cast can mimic air pollution-caused tip burn injury on conifers. However, chlorotic mottling is a symptom unique to ozone injury on eastern white pine needles.

The following factors were recorded for each stand: slope, the nearest 1%, aspect as north, south, east, west, northwest, northeast, southeast, or southwest; elevation to the nearest 15.2-

Table 1. Distribution of tip necrosis and chlorotic mottling symptoms on eastern white pines within the species' natural range in a six-state area (1985)

<table>
<thead>
<tr>
<th>State</th>
<th>Plots in state</th>
<th>Plots with symptoms</th>
<th>Proportion of plots with symptoms (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky</td>
<td>13</td>
<td>7</td>
<td>77</td>
</tr>
<tr>
<td>Tennessee</td>
<td>32</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td>Virginia North</td>
<td>94</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Carolina North</td>
<td>45</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Carolina South</td>
<td>8</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Georgia</td>
<td>10</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 2. Distribution of tip necrosis and chlorotic mottling symptoms on eastern white pines in planted and natural stands

<table>
<thead>
<tr>
<th>Stand origin</th>
<th>No. of stands</th>
<th>Stands with symptoms (%)</th>
<th>Symptomatic trees (for all stands) (%)</th>
<th>Symptomatic trees (for stands with at least one affected tree) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted</td>
<td>125</td>
<td>28</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Natural</td>
<td>70</td>
<td>14</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>
occurrence of symptoms on southwest slopes may be associated with prevailing wind direction. These sites could also be more drought prone, which could affect tip necrosis but not chlorotic mottle. Even though many more paired trees were observed in the field, only 48 pairs of symptomatic or nonsymptomatic trees met the criteria of being on the same site, having the same age, and having foliage of the two trees touching. On the average, symptomatic trees were 0.7 m shorter and 2 cm smaller in diameter and contained 49% less cubic volume than unaffected trees (Table 4). Previous surveys have indicated that most eastern white pines are at least moderately sensitive to air pollution (2.27). In 1974, Skelly et al (24) reported that some eastern white pines had growth loss without visible symptoms. Because our nonsymptomatic trees may be growing slower than normal because of air pollution stress, our estimate of annual loss may be conservative. Also, sensitive trees that are showing symptoms may be of a genotype that naturally grows slower. The reported growth difference, therefore, may not have been caused by air pollution.

Most forest disease surveys involve a set of symptoms caused by a pathogen. These pathogens can be isolated to confirm the cause effect of the symptoms. In our survey, the cause of symptoms could not be delineated with certainty. Tip burn and chlorotic mottle were selected as the symptoms of air pollution. All attempts were made to eliminate trees when the cause of tip burn or mottle could be ascribed to another cause. Only when a tree clearly had tip necrosis and chlorotic mottle on the current year’s needles, and when another cause could not be found, was the tree considered to have air pollution symptoms.

This survey showed that trees that fit the classification were present in the southern part of the eastern white pine range in 1985. Symptomatic trees did not occur uniformly across the survey area but were found in definite high- and low-occurrence areas. No attempt was made to assess the reason for the pattern of occurrence or to determine if there was a correlation between sources of pollution and the observed symptoms. This survey was designed to map the occurrence and determine the percentage of trees affected. The percentage of trees affected was low (2-4%), and the pattern of incidence was not uniform.

ACKNOWLEDGMENTS

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LITERATURE CITED