

VARIATION IN AIR POLLUTION TOLERANCE AND GROWTH
RATE AMONG PROGENIES OF SOUTHERN APPALACHIAN WHITE PINE

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ABSTRACT.--Two-year-old open-pollinated progenies from 13 pinus strobus stands in Georgia, North Carolina and Tennessee were planted in three different physiographic regions of Tennessee. About 30,000 progenies, representing 129 families, were evaluated after five growing seasons in the field. Variation in growth rate of trees from different stands were highly significant. Progenies from the three Cumberland Mountain stands consistently grew fastest in the three test locations. Also, these progenies had darker green and longer needles than progenies from the other stands, indicating greater resistance to SO₂-damage from nearby coal-burning steam plants. Within most stands there were mother trees which produced progeny that grew significantly faster and had longer, darker green needles than progeny from other mother trees in the same stand. Estimates of narrow-sense heritability for height growth varied from 0.20 to 0.33. By selecting the best individual progenies from the best families in the best stands estimated gains in juvenile height growth varied from a minimum of 20 percent to a maximum of 73 percent. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 80-86, 1978,

INTRODUCTION

Several studies indicate that eastern white pine (Pinus strobus L.) from the Southern Appalachians may outgrow trees of local origin in both the Northeast and Midwest (Funk 1965 King and Nienstaedt 1969; Garrett et al. 1973). Seed-source tests in southern locations indicate a clinal variation pattern associated with source latitude (Genys 1968; Sluder and Dorman 1971; Thor 1974). The gradual reduction in progeny growth with increasing latitude of the source does not preclude locally adapted ecotypes. That such ecotypes do indeed exist at the southern limit of the species range is suggested by the large amount of variation in progeny height of sources from between latitude 35° and 36° North (Thor 1974).

In addition to the observed geographic variation patterns there is experimental evidence for genetic differences among individual white pines for both sulfur-dioxide tolerance and growth rate. Broad-sense heritability estimates for sulfur-dioxide tolerance tend to be high (Houston and Stairs 1973) while narrow-sense heritability estimates for juvenile height growth are low (Kriebel et al. 1972; Thor 1974).

The wide variation in height growth of trees from different stands in the extreme southern end of the species range suggested that more intensive sampling from this part of the white pine range would be necessary to capitalize on the apparent ecotypic variation. Also, estimates of variation among trees and narrow-sense heritability estimates for air pollution tolerance and growth rate would be valuable in eastern white pine breeding programs. One such study was established in 1970 with open-pollinated progenies from 13 stands in Georgia, North Carolina, and Tennessee. Two-year-old seedlings representing 129 open-pollinated families were planted in four physiographic regions of Tennessee. Five-year height measurements were obtained from about 30,000 progenies in three of these plantations.

HEIGHT GROWTH

Differences in growth rate of trees from different stands in the Southern Appalachians were highly significant. Trees from stands in three East Tennessee counties (Anderson, Morgan, and Scott) consistently grew fastest in the three test locations (Table 1). On the Highland Rim, progenies from these three stands grew 25 percent faster than progenies from the three North Carolina stands. However, these differences in growth between North Carolina and local sources were small compared to differences observed at the Cumberland Mountain test site; at this location trees from local stands (Anderson, Morgan, and Scott Counties) had a height superiority of 53 percent over those from North Carolina. Differences of this magnitude indicate that in addition to the north-south clinal variation pattern there has been considerable ecotypic differentiation in the extreme southern part of the species range.

TABLE 1. Mean height (in feet) of white pine progenies from 13 stands after five growing seasons in three locations.

Stands		Location of Test Plantations		
County	State	Great Valley	Cumberland	Mt. Highland Rim
Monroe	TN	4.44	5.68	5.47
Polk	TN	4.71	6.65	5.74
Fanin	GA	4.74	5.81	5.72
Cherokee	NC	3.92		4.86
Madison	NC	4.62	4.66 5.07	5.52
Cocke	TN	4.51	5.80	5.52
Unicoi	TN	4.83	6.29	5.82
Unicoi	TN	4.80	6.20	5.78
Transylvania	NC	3.59	4.27	4.63
Carter	NC	4.10	5.16	4.71
Scott	TN	4.81	6.75	6.02
Morgan	TN	5.14	7.34	6.29
Anderson	TN	5.63	7.36	6.52
		<u>4.72</u>	<u>6.05</u>	<u>5.63</u>

Ten to 15 percent of the total variation in height observed in individual plant tions was accounted for by stands (source of seed). An additional 5 to 7 percent of height variation was contributed by differences among half-sib families. Within most stands there were families that grew significantly faster than other families (Figure 1). This variation among families within stands is reflected in the estimates of narrow-sense heritability, varying from 0.20 to 0.33. By selecting the best individual progenies from the best families it is possible to make gains of about 20 percent in juvenile height growth. Such gains may, of course, be added to any gains realized by using seed from the best stands. Thus, the gain in mean juvenile height growth from one generation- of selection will be about 20 percent above the mean height of unselected progeny from the best seed sources. The maximum gain will be between 45 and 73 percent above the height of progeny from the poorest Southern Appalachian sources.

AIR POLLUTION TOLERANCE

Several coal-fired steam plants in East Tennessee emit large amounts of sulfur dioxide and have been held responsible for the killing or damaging of forest stands and Christmas tree plantations. In stands destroyed by high levels of sulfur dioxide, individual trees with no apparent damage have been observed. That this resistance is genetically controlled has been confirmed in clonal tests. Since white pines for most uses are propagated by seed (sexually) rather than by cloning (asexually) it is desirable to determine the narrow-sense heritability for resistance to sulfur dioxide damage. One progeny test in the fall-out area of the Bull Run Steam Plant in the Great Valley is giving this information.

Two continuous sulfur dioxide monitoring stations, both located about one mile from the progeny test plantation near Bull Run Steam Plant, recorded hourly averages for April, May, and June 1974. During this period hourly averages ranged from less than 1 to 10 parts per hundred million (pphm). A great number of progenies from some of the 90 open-pollinated families represented in this plantation showed symptoms of air pollution damage (yellow, short needles and/or tip burn) when evaluated in December 1974. Even though it was not possible to distinguish between needle damage from ozone and sulfur dioxide there is no evidence that ozone levels sufficiently high to produce needle damage were present in the area. On the other hand, the recorded levels of SO_2 were ample to cause the observed symptoms; Costonis (1973) found that exposures of SO_2 -sensitive eastern white pine ramets to sulfur dioxide at a concentration of 5 pphm for 2 hours was sufficient to induce necrosis of new needles.

In this plantation the progenies from stands in Anderson, Morgan, and Scott counties, originating from the airsheds of two steam plants, had longer, darker-green needles than progenies from other stands in the Southern Appalachians (Table 2). Also, trees from Polk and Monroe counties in Tennessee and Fannin County in Georgia had a high "needle index" indicating that the proximity of these stands to the Cooperhill smelting operations has resulted in removal of the most susceptible genotypes from these populations.

Table 2. Thirteen white pine stands ranked according to needle color and needle length of progenies growing near Bull Run steam plant in the Great Valley.

Stand No.	Stand Location	Color ^{a)} Score	Needle Length cm.	Needle Index ^{c)}
13	Anderson Co., Tenn.	3.07	7.52	3.28
11	Scott Co., Tenn.	3.03	7.50	3.22
2	Polk Co., Tenn.	3.00	7.31	3.00
3	Fannin Co., Ga.	2.94	7.00	2.63
12	Morgan Co., Tenn.	2.85	7.81	3.35
1	Monroe Co., Tenn.	2.73	7.18	2.60
8	Unicoi Co., Tenn.	2.70	7.08	2.47
5	Madison Co., N.C.	2.64	7.07	2.40
4	Cherokee Co., N.C.	2.52	6.81	2.02
10	Carter Co., Tenn.	2.36	7.32	2.36
7	Unicoi Co., Tenn.	2.30	7.13	2.11
6	Cocke Co., Tenn.	2.22	7.00	1.91
9	Transylvania Co., N.C.	1.62	5.69	0.00

^{a)} Each tree was rated 1 for greenish-yellow, 2 for yellow-green, 3 for bluish-green, and 4 for greenish-blue.

^{b)} Vertical lines connect sources not significantly (5 percent level) different in color rating according to the new Duncan's multiple range test.

^{c)} Combined value for needle color and needle length.

The variable needle length is a metric character. However, needle colors were obtained by visual ratings and assumed only four discrete values. Inspection of frequency distributions of both these variables suggested that they were normally distributed. The analysis of variance indicated that the variation due to families within stands was significant for both variables while only the stand component was significant for needle color. Variance components for the two needle characteristics are presented in Table 3.

Table 3. Components of variance (in percent) for needle color and needle length.

Variance Component	Needle Color	Needle Length
Replication	7	7
Stand	7	2
Family Within Stand	14	7
Replication X Stand	0	1
Replication X Family Within Stand	72	83
Total	100	100

Since the needle data were obtained as plot means no estimate of within-plot variance was available and the resulting heritability estimates, $h^2 = 0.64$ for needle color and $h^2 = 0.32$ for needle length, must be considered as upper limits.

Cross-products analyses, based on plot means, were performed among the variables needle color, needle length, and total height at five years. Highly significant positive correlation coefficients were obtained at both the stand level and family within stand level. When the narrow-sense heritability estimates for needle traits and total height are considered with the correlation among these characteristics it appears that advances in breeding for resistance to sulfur dioxide damage may be attained. Selection may be made in test plantations which are exposed to high levels of sulphur dioxide; the best individual trees from the best families within the best stands may be selected based on either total height or needle characteristics or a combination of both.

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