WHITE PINES FROM THE SOUTHERN APPALACHIANS

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Abstract.--Four different studies of variation in eastern white pine were evaluated. After five years in the field 45 percent of all seed source variation in height was accounted for by latitude. In addition to the strong clinal variation pattern there is evidence that at the southern limit of the species range locally adapted ecotypes are present. Two independent estimates of narrow sense heritability (h^2 = 0.11 and 0.14) indicate that improvement in height growth may be made by a combination of stand and individual tree selection.

Additional keywords: Height growth, clinal variation, heritability, provenance, progeny test, *Pinus strobus*.

Eastern white pine (*Pinus strobus* L.) is not a very important timber species in Tennessee, ranking behind three southern pines and a number of hardwoods. However, approximately two million white pine seedlings are planted each year, a large number of them for production of Christmas trees and landscaping material.

In the past, seed was purchased from the lowest bidder, regardless of origin. Following a complete disaster in the nursery with seedlings of New York origin procurement of seed was limited to the Southern Appalachian Region. Such discrimination was based on convincing evidence of superior survival and growth in provenance tests. This superiority of southern seed sources may be used to support the old rule of thumb about use of local seed. On the other hand, a large amount of evidence (Funk 1965; King and Nienstaedt 1969; Garrett *et al*. 1973) indicates that white pines from the Southern Appalachians outgrow local trees in both the Northeast and Midwest.

Sluder and Dorman (1971) tested a large number of sources in three southern locations (Georgia, North Carolina and Virginia). Ten-year height data showed a clinal variation pattern associated with the latitudes of the sources. The authors also suggested that there was experimental evidence for genetic differences in growth rate among individual white pine trees. Estimates of heritability for height of three-year-old seedlings support this notion (Kriebel *et al*. 1972). Even though the heritability estimates were low (from .16 to .28) and had dropped considerably from those obtained at ages one and two, the authors suggest that the generally high additive variance makes it possible to select for early height growth.

The purpose of this paper is to present some of the work with eastern white pine carried out in Tennessee over the last ten years. Four different studies will be evaluated, starting with simple seed source tests and ending with a more sophisticated heritability test.

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SEED SOURCE TESTS

The establishment of five seed source tests in 1960 was prompted by the indiscriminate seed procurement practices prevailing in Tennessee. After five growing seasons fire destroyed one plantation in the Cumberland Mountains; the other four are still intact and ten-year results are presented in Table 1. Survival and growth were excellent in all plantations except in the southwest Tennessee location which is far outside the species range and has a climate not generally considered suitable for white pine. Trees of a northern source (Pennsylvania) in particular did not survive the hot summers in this location, but even in the coolest location (Cumberland Plateau at 2000 ft. elevation) these trees of northern origin had greater mortality than those of Southern Appalachian sources. Low survival and poor growth of the Pennsylvania (Sullivan County) trees were also recorded in the Cumberland Mountain location before this plantation was destroyed.

In addition to the obvious inferiority of a northern seed source this simple test pointed out that there probably is much variation among sources from the Southern Appalachians and that the "local" East Tennessee source used in this test was inferior to the Western North Carolina source with regard to height and diameter growth (Table 1). This result suggested that more detailed investigations of the variation within the Southern Appalachian region were needed.

Table 1.--Survival, height and diameter in four Tennessee provenance tests at age ten.

	Provenance					
Location	E. Tenn.	W.S.C.	W.N.C.	Ky.	S.W.Va.	Pa.
	Percent Survival					
S.E. Tenn.	84	79	77	68		
Middle Tenn.	92	92	97	84		
Cumberland Plateau	98		92		97	71
S.W. Tenn.	66		86	65	77	16
Mean	85		88			
	Total Height, feet					
S.E. Tenn.	17.2	19.3	18.9	18.0		
Middle Tenn.	19.5	20.5	20.7	19.8		
Cumberland Plateau	14.4		16.7		15.8	12.3
S.W. Tenn.	10.8		18.1	14.8	14.5	
Mean	15.5		18.6			
	DBH, inches					
S.E. Tenn.	2.9	3.4	3.5	3.6		
Middle Tenn.	4.1	4.4	4.5	4.1		
Cumberland Plateau	2.5		3.0		2.9	2.0
S.W. Tenn.	1.6		3.1	2.7	2.5	
Mean	2.8		3.5			

THE PILOT STUDY

Since only a small amount of seed was available for this study of Southern Appalachian white pine and limited amount of detailed information was anticipated we considered this test a pilot study. Such a study may, for a small investment, give some general information valuable in planning of more comprehensive studies.

A total of 103 seed lots were obtained from Dr. J. W. Wright of Michigan State University. Only 88 lots yielded a satisfactory number of 2-0 seedlings; 22 were seed source collections with seeds mixed from several mother trees within a given stand. The other 66 lots were collections from single mother trees, but some of these were in groups and could be pooled for seed source analysis. The 2-0 seedlings were produced during the 1966-67 seasons and in 1968 the 88 seedling lots were planted in a randomized block design with ten replications on the Highland Rim in Middle Tennessee. Each plot consists of four trees in a row.

During the first two years considerable mortality occurred in this plantation, mainly caused by heavy competition and poor soil drainage. Survival following five growing seasons in the field averages only 56 percent, but varies from a low of 33 percent to a high of 80 percent. Provenance data for 26 white pine stands are given in Table 2, where stands are ranked according to mean total height of the progenies. The vertical lines to the extreme right indicate which sources are not significantly different from one another (at the 5 percent level). The three best sources are significantly taller than the poorest eleven; the median height for the three best sources is 4.81 feet while the median for the eleven poorest is only 3.07 feet. All but one of the eleven poor sources came from Virginia or West Virginia; apparently, in Tennessee we can insure ourselves against poor seed lots by excluding such "Northern" imports.

A regression analysis indicated that 45 percent of all seed source variation in height was accounted for by latitude. Since a considerable amount of variation was still unaccounted for, additional variables, such as elevation and number of frost-free days of the source, were added in a multiple regression analysis. However, the equations derived did not account for a significantly greater amount of the variation than the simple regression equation with latitude as independent variable.

Six of the stands (sources) were represented in this study by open-pollinated progenies from five mother trees. Height at age five was analyzed on an individual progeny basis; the resulting data are presented in Table 3. In addition to the highly significant stand effect the family variance component was significant but of much less relative importance. Using the standard formula for determination of narrow sense heritability, the estimate of h^2 is 0.11 for juvenile height growth. This estimate is much lower than those obtained by Kriebel *et al*. (1972) and is a reflection of the relatively low family variance and the high within plot variance component.

Table 2.--Average survival and height of 26 white pine provenances after five years in the field.

Seed Source			Percent	
County	State	Latitude	Survival	Mean ht., ft.[a]
Union	Ga.	34°43'	80	5.04
Burncombe	N.C.	35°30'	58	4.81
Caldwell	N.C.	35°50'	70	4.69
Yancey	N.C.	35°45'	65	4.44
Rabun	Ga.	34°54'	55	4.40
Carter	Tn.	36°20'	48	4.31
Burke	N.C.	35°50'	70	4.26
Rabun	Ga.	34°52'	70	3.94
Burke	N.C.	35°51'	35	3.74
Botetcourt	Va.	37°31'	78	3.71
Pocahontas	W.Va.	38°10'	63	3.58
Pleasants	W.Va.	39°25'	56	3.57
Pocahontas	W.Va.	38°20'	64	3.57
Greenbriar	W.Va.	37°58'	60	3.57
Rabun	Ga.	34°49'	50	3.56
Rockingham	Va.	38°42'	58	3.41
Braxton	W.Va.	38°45'	50	3.33
Macon	N.C.	35°06'	56	3.24
Greenbriar	W.Va.	38°00'	54	3.14
Greenbriar	W.Va.	38°00'	53	3.11
Greenbriar	W.Va.	37°50'	33	3.07
Wetzel	W.Va.	39°30'	52	3.06
Montgomery	Va.	37°14'	48	2.99
Alleghany	Va.	37°48'	44	2.76
Pocahontas	W.Va.	38°07'	47	2.75
Augusta	Va.	38°20'	50	2.75

[a] Vertical lines connect sources not significantly (5 percent level) different in height according to Duncans multiple-range test.

Table 3.--Components of variance from analysis of five-year height of open-pollinated progenies from five mother trees from each of six stands.

Source of variation	d.f.	Mean square	Variance component	V.C.%
Stand	5	28.93***	.138	9
Replications	9	9.48***	.068	5
Rep X Stand	45	1.28	.009	1
Family within stand	24	2.64*	.023	2
Rep X fam/stand	198	1.71***	.154	10
Within plot	431	1.09	1.094	73
Total	712		1.486	100

*** Significant at .1 percent level.
* Significant at 5 percent level.

PROGENY TEST

In 1961 a selection breeding program for resistance to air pollution damage was initiated. A total of 35 trees were selected in Morgan County, an area where a large proportion of the white pines had been killed by sulphur dioxide from a coal-burning power plant. Even though some consideration was given to growth rate and pruning ability, trees were mainly selected on the basis of color and length of the needles: dark green or blue-green, long needles were used as the most important criteria. A grafted seed orchard was established in an area where most of the native white pines had been killed by air pollution. The grafted trees remain healthy and several ramets have produced seed; however, since pollen production in the orchard has been poor it is assumed that fertilization to a large extent is the result of pollen transport for relatively long distances.

The first progeny test for this orchard was established with two-year-old seedlings. Thirteen half-sib families and one commercial check were included in a randomized block design with ten replications. Total height was measured two years after establishment (Table 4). It is gratifying that the commercial check trees had the slowest growth rate, but since these trees were of a different geographic source than the orchard trees we cannot claim a general superiority for our selections. On the other hand progenies of some clones were significantly better than those of others; the growth rate of clone 51 progenies is particularly impressive. Additional progeny tests are now being established in other locations to get the information needed for successful roguing of this orchard.

Table 4.--Height of open-pollinated progenies of 13 clones and one commercial check two years after field planting.

Parent	Progeny Height, feet [a]
51	2.54
78	2.23
71	2.21
74	2.17
70	2.12
77	2.10
55	1.96
67	1.93
56	1.90
75	1.88
76	1.78
73	1.74
57	1.63
Check	1.54

[a] Vertical lines connect sources not significantly (5 percent level) different in height according to Duncans multiple-range test.

HERITABILITY TEST

Seed for this study was collected from 13 stands in Georgia, North Carolina and Tennessee (Table 5). Cones were collected from ten randomly selected dominants and codominants. Preliminary selection of stands was completed in 1962, but several promising cone crops were attacked by insects (Conophthorus spp.); in some stands four consecutive crops were destroyed. As a result, a total of five years passed before all 13 stands had been sampled.

Table 5.--Location of stands used for seed collection in the Oak Ridge heritability test ranked according to average height following five growing seasons.

Stand No.	County	State	Lat. N.	Long. W.	No. Fam.	% Surv.	Height, ft.[a]
13	Anderson	Tenn.	36°00'	84°20'	9	68	5.63
12	Morgan	Tenn.	36°05'	84°30'	7	57	5.14
7	Unicoi	Tenn.	36°00'	82°30'	6	51	4.83
11	Scott	Tenn.	36°15'	84°35'	6	53	4.81
8	Unicoi	Tenn.	36°10'	82°20'	8	51	4.80
3	Fannin	Ga.	34°45'	84°10'	6	66	4.74
2	Polk	Tenn.	35°00'	84°30'	10	71	4.71
5	Madison	N.C.	35°55'	82°50'	8	59	4.69
6	Cocke	Tenn.	35°50'	83°15'	5	43	4.51
1	Monroe	Tenn.	35°20'	84°10'	10	62	4.44
10	Carter	Tenn.	36°20'	82°05'	3	52	4.10[b]
4	Cherokee	N.C.	35°05'	84°10'	10	49	3.92
9	Transylvania	N.C.	35°20'	82°45'	2	40	3.59[b]

[a] Vertical lines connect sources not significantly (5 percent level) different in height according to Duncans multiple-range test.

[b] Data not included in analysis of variance or Duncan Test.

Two-year-old seedlings were planted during the winter of 1970 in four different physiographic regions of Tennessee (West, Middle, Cumberland and Great Valley). A total of 42,600 progenies representing 129 open-pollinated families were planted in randomized block designs with 10-tree family rows as treatment plots. After five growing seasons in the field only two plantations are in good condition; about half the trees died in the West Tennessee plantation and 5 of the 10 replications in the eastern Great Valley plantation were destroyed by fire.

In the fall of 1974, five-year height measurements are scheduled, but only measurements from the remaining five replications at Oak Ridge in the Great Valley could be analyzed in time for this Conference.

The average height of each stand is based on only five replications and a variable number of families per stand. Since only two families were present from stand 9 and three from stand 10 these data were omitted from the analysis of variance. The other 11 stands were represented with from five to ten families each for a total of 85 open-pollinated families. The Duncan Multiple Range Test (Table 5) indicates that the progeny from stand 13 was superior to those from all other locations. This result definitely supports the theory of local superiority since stand 13 is located within a few hundred yards of the Oak Ridge plantation site. The relatively good performance of the nearby Morgan and Scott County sources also supports the notion that at this low elevation (800' above sea level) East Tennessee sources perform well. While older seed source tests (Table 1) indicate that Western North Carolina sources are superior in Tennessee, the Oak Ridge test ranks two such sources lowest.

The analysis of variance (Table 6) for the Oak Ridge data gave results similar to those of the Highland Rim data (Table 3). The relative magnitude of the variance components ranked in the same manner in both locations. Stands (seed sources) accounted for seven percent while families within stands only accounted for three percent of the total variation. Assuming that the open pollinated families were half-sibs, the narrow sense heritability for juvenile height growth was calculated to be 0.14, somewhat greater than estimated from the Highland Rim data and more in agreement with data published by Kriebel et al. (1972).

Table 6.--Components of variance from analysis of five-year height of 85 open-pollinated progenies from a total of 11 stands.

Source of variation	d.f.	Mean square	Variance component	V.C. %
Stand	10	46.65***	.197	7
Replications	4	46.34***	.105	4
Rep X stand	40	3.53	.038	1
Family within stand	74	6.88**	.084	3
Rep X fam/stand	278	4.37***	.421	16
Within plot	2011	1.86	1.861	69
Total	2417		2.706	100

*** Significant at .1 percent level.
** Significant at 1 percent level.

CONCLUSIONS

Each of the four studies included in, this paper has made some contribution to our knowledge of variation in eastern white pine. The crude seed source tests demonstrated that a northern seed source was not well adapted to growing conditions in Tennessee and that differences in growth rate may be expected even among trees of different southern origins. The "Pilot Study" indicated a clinal pattern in juvenile height growth accounting for about 45 percent of the seed source variation. This gradual reduction in progeny growth with increasing latitude of the source does not, however, 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 (Tables 2 and 5).

Even though there is considerable variation within a seed source (stand) the heritability estimates obtained for juvenile height growth were rather modest. The low estimate ($h^2 = 0.11$) from the Pilot Study is probably the least reliable due to the small number of families (30) and many missing plots. Data from the heritability test are more reliable; when observations from the other outplantings are analyzed the additional heritability estimates, including a combined estimate for all locations, should provide sufficient information for a selection breeding program.

Such a breeding program for white pine must emphasize the identification of superior natural populations. Even though superior families may be found in several locations, fast-growing families tend to come from a few superior populations. In the Oak Ridge plantation all nine families of the local population were "superior" (upper one-third) in height while three stands did not have a single family in this select group.

LITERATURE CITED

Funk, D. T. 1965. Southern Appalachian white pine off to a good start in the Midwest. Proc. Fourth Central States Forest Tree Impr. Conf., p. 26-28.

Garrett, P. W., E. J. Schreiner, H. Kettlewood. 1973. Geographic variation of eastern white pine in the Northeast. USDA Forest Service Res. Pap. NE-274, 14 p.

King, J. P. and H. Nienstaedt. 1969. Variation in eastern white pine sources planted in the Lake States. Silvae Genetica 18:83-86.

Kriebel, H. B., G. Namkoong, and R. A. Usanis. 1972. Analysis of genetic variation in 1-, 2-, and 3-year-old eastern white pine in incomplete diallel cross experiments. Silvae Genetica 21:44-48.

Sluder, E. R. and K. W. Dorman. 1971. Performance in the Southern Appalachians of eastern white pine seedlings from different provenances. USDA Forest Service Res. Pap. SE-90, 11 p.