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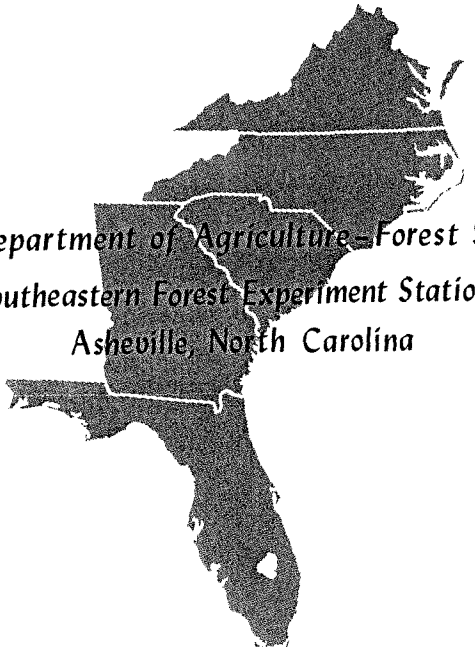

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Intensive forest management demands high rates of return, and these are affected by such things as growth rate per acre and quality of wood produced. It is necessary therefore to use trees that grow rapidly and produce wood of the best possible quality in the specific characteristics desired. Such trees can be developed through genetic improvement of commercially important species.

Provenance studies such as the one reported in this paper are important sources of basic information for tree improvement programs. This study is being conducted on three Southern Appalachian sites using provenances of white pine (Pinus strobus L.) from throughout the range.[1/] Height and survival data taken from the plantations after three growing seasons indicate significant differences among provenances and a strong correlation between height growth and latitude of the seed source. The study will be continued for a number of years to observe the effect of time on these and other relationships.

Tree improvement programs are often based on variability within a species. Forest geneticists therefore must determine the nature and extent of variation, both local and geographic, within forest tree species for which they wish to develop improved strains. A number of studies have been established to determine the nature and extent of geographic variation in several species. Perry (1961), commenting on results from these studies, made the generalization that "when and where a variation in an environmental factor exists within the range of a species, there also exists a corresponding and appropriate variation in physiological-genetic makeup of the species. " He also added that "species occupying the same geographic range frequently display a parallel pattern of physiological-genetic adaptation."

1/ Schreiner, E. J., and Wright, J. W. Working plan for a provenance study of Pinus strobus. U. S. Forest Serv. Northeast. Forest Expt. Sta. 1955.

Very little information is available on geographic variation of eastern white pine (Pinus strobus L.). This species, as a result of increasing supplies and better management practices, is expected to regain much of the importance it once had as a timber species in the Northeast and Lake States (U. S. Forest Service, 1959). One study has been made in New Jersey on seasonal height growth of white pine seedlings from various locations over its range. Results showed a significant clinal pattern of variation in duration and amount of height growth (Santamour, 1960). Seedlings of southern origin grew longer into the season and thus more in height during the third year from seed than did seedlings of northern origin.

Geographic variation has been studied rather intensively in several other coniferous species, Results of some of the studies should give some indication of the variation that one might expect to find in white pine.

Average 5-year heights of loblolly pine (Pinus taeda L.) seedlings from nine locations planted in Dooly County, Georgia, were correlated with temperature zone of seed source. Seedlings from warmer temperature zones averaged taller than seedlings from cooler zones (Bethune and Roth, 1960). Seedlings of loblolly pine from four seed sources were planted near Buckingham, Virginia. The more northern seedlings were best in height, diameter, and volume after 15 years (Kormanik et al. , 1961). A similar test in southern Illinois indicated that loblolly seedlings from the northern portion of the species range should be used in Illinois in preference to seedlings from farther south (Minckler, 1952).

Wakeley (1961), in summarizing results of the southwide pine seed source study, stated. that 5-year-old plantations of loblolly pine and 5- and 3-year-old plantations of shortleaf pine (Pinus echinata Mill.), showed a clinal relationship between height growth of seedlings and latitude of seed source. When like sets of stocks were compared, curves of height over latitude of source had nearly significant to highly significant negative slopes in southern plantations and highly significant positive slopes in northern plantations. The slopes were variable in direction and less significant or nonsignificant in plantations at intermediate latitudes,

Eastern hemlock (Tsuga canadensis (L.) Carr.) seedlings from several geographic sources were studied in Rhinelander, Wisconsin. The seedlings exhibited a distinct clinal variation in photoperiodic response. Seedlings from areas of longer frost-free seasons grew later into the season and thus more in height than seedlings from areas of shorter frost-free seasons (Nienstaedt and Olson, 1961). More frost injury was sustained by hemlock seedlings from areas of longer growing seasons than by seedlings from areas of shorter growing seasons (Nienstaedt, 1958).

More information on geographic variation in white pine is needed. The following pages, and other reports to come from the range-wide study, will help to fill that need.

METHODS

Establishment and Maintenance

Three plantations of a range-wide provenance study of white pine were established in the Southern Appalachians in the spring of 1959. Seedlings from six geographic sources were planted in Wythe County, Virginia (elevation 2,500 feet), and in Union County, Georgia (elevation 1,850 feet). Seedlings from fifteen sources were planted in Transylvania County, North Carolina, (elevation 2,160 feet); seedlings from an additional source were added in the spring of 1960 (table 1). All seedlings were 2-O stock grown at Ralph Edwards State Forest Tree Nursery, at Morganton, North Carolina,

Table 1. --Geographic seed sources represented in three plantations of a provenance study of white pine

State or Province	county or Township	Latitude
		Degrees N
Iowa	Allamakee	43" 28'
Tennessee	Green	36" 00'
Georgia 1/	Union	34" 46'
North Carolina	Transylvania	3.5" 14'
Ohio	Ashland	40" 45'
West Virginia 1/	Greenbriar	38° 02'
Maine	Penobscot	44" 51'
New York	Franklin	44" 25'
Nova Scotia 1/	Lunenburg	44° 2.5'
Ontario 1/	Spragge	46" 10'
Quebec	Pontiac-Upper Ottowa R.	47° 30'
Pennsylvania 1/	Monroe	41° 05'
Wisconsin	Forest	45° 51'
Minnesota 1/	Cass	47" 23'
Virginia	Pulaski	37" 05'
Michigan	Newaygo	43" 30'

1/ Seed sources used in the Virginia and Georgia plantations. All 16 sources listed were used in the North Carolina plantation.

Eighty-one seedlings from each seed source were planted at a spacing of 7 x7 feet in each of four randomized-block replications at each planting site. All first-year mortality was replaced in the North Carolina plantation with heeled-in extra seedlings, but not enough seedlings were available from three sources to replace all first-year mortality in the Virginia and Georgia plantations. No dead seedlings from the West Virginia source were replaced and some dead seedlings in the two outer rows of plots from Ontario and Pennsylvania were not replaced in these two plantations.

The planting areas in Virginia and Georgia were old fields, while the North Carolina planting area was part of a large pasture. The Georgia site is on a dry, southeast slope, the Virginia site is in a poorly drained streambottom, and the North Carolina site is in a moderately well drained streambottom. The North Carolina and Virginia sites were plowed before planting. Small brush was removed by bulldozer from the site of two replications in the Georgia plantation. The planting areas are illustrated in figures 1 through 4.

Heavy weed competition made cultural operations necessary in the North Carolina plantation (fig. 5). Weeds were kept in check by plowing and hand hoeing. Seedlings in the Georgia plantation were released once during the second growing season. In Virginia all seedlings were sprayed in 1959 to control weevils boring into the seedlings at ground level.

Survival counts and height measurements were made after each growing season. All 81 seedlings in each plot were tallied for survival, and heights were measured on the 25 center seedlings. First- and second-year data for the Michigan seedlings, planted 1 year later than the other sources, were analyzed with first- and second-year data for the other seedlings in the North Carolina plantation. The third-year analysis did not include data from the Michigan seedlings, since they had been planted for only 2 years.

Root-collar diameters and root-shoot weight ratios were measured in the spring of 1959 on 50 randomly selected plantable seedlings from each of 14 of the seed sources.

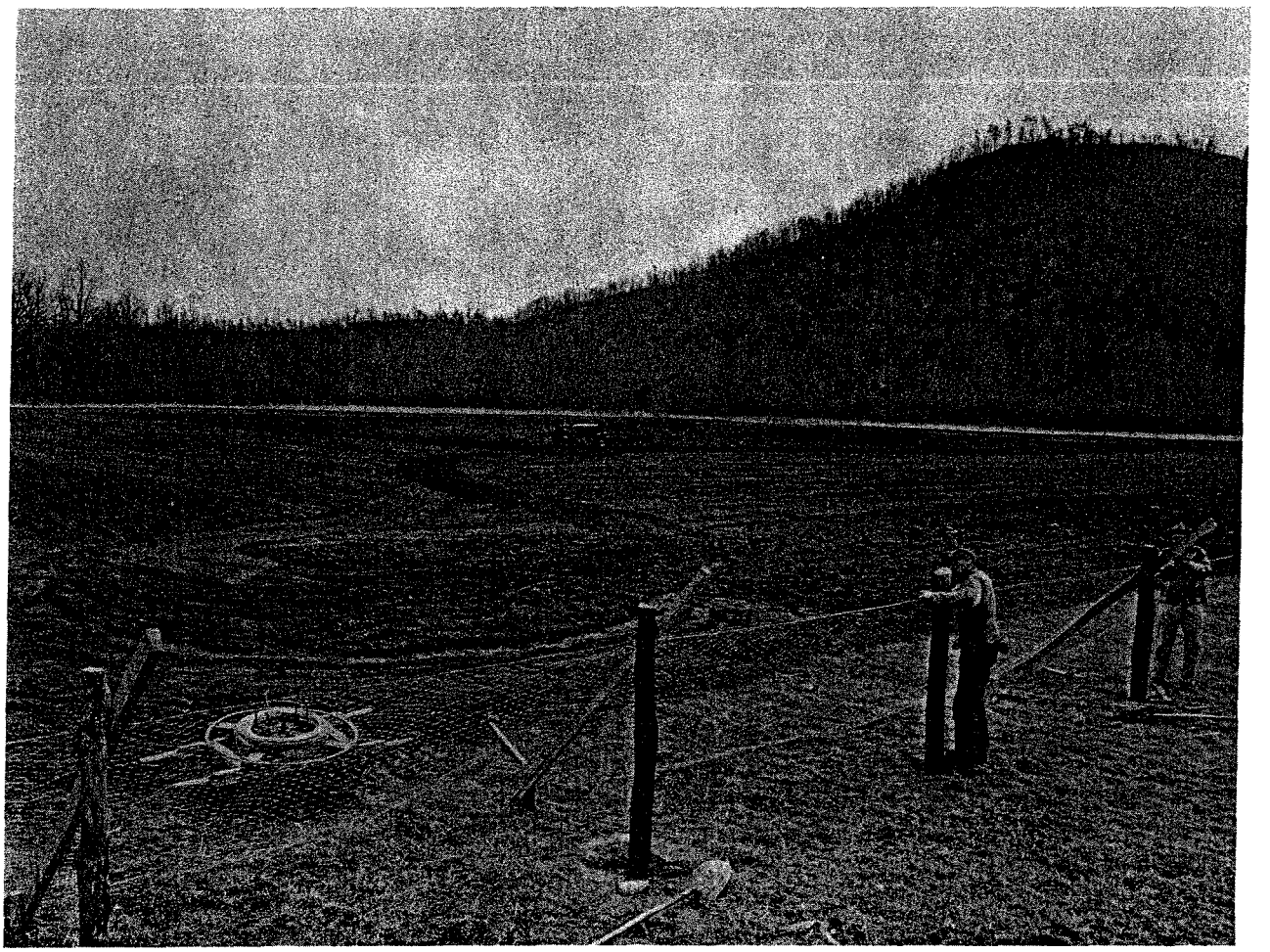

Figure 1.--Prepared planting site in North Carolina. The fence is designed to keep out deer. Barbed wire was added above the net wire.

Figure 2. --A portion of the Virginia planting site. Drainage is relatively poor on most of the area.

Figure 3. --Blocks C and D of the Georgia plantation. This area was lightly bulldozed to remove brush.

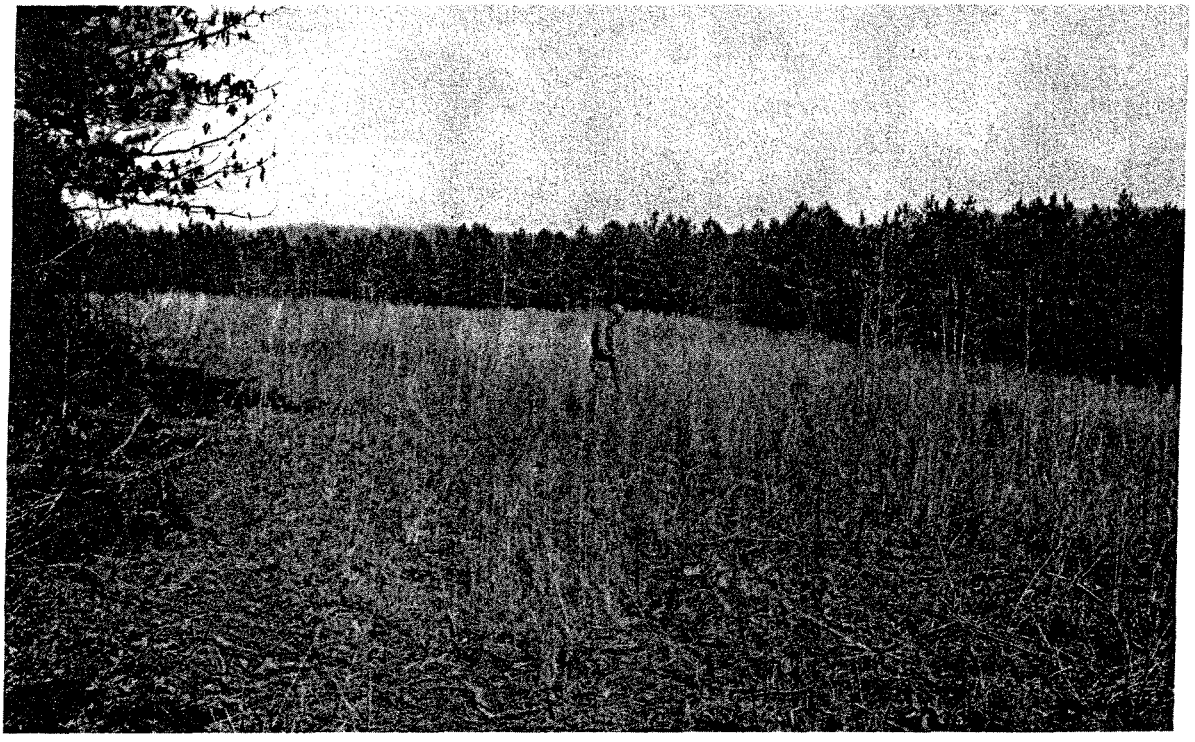

Figure 4. --Blocks A and B of the Georgia plantation. No site preparation was needed here except removal of a few small pines and hardwoods.

Figure 5. --Dead ragweed in the North Carolina plantation. This heavy weed cover developed during the first growing season despite two cultivations.

RESULTS

survival

North Carolina plantation. --First-year survival in the North Carolina plantation averaged 90 percent, ranging from 81.7 percent for Michigan seedlings to 98.2 percent for Iowa seedlings (table 2). The North Carolina seedlings averaged 92.9 percent survival. Mean survival of the original seedlings after the second and third growing seasons was 35.1 percent. Differences among the survival means were significant after each of the three growing seasons (table 2).

Average survival of all seedlings, including replants, was 95.6 percent after 2 years and 94.9 percent after 3 years (table 3). Differences among the survival means of the various lots of seedlings, including replants, was significant at the l-percent level of testing after 2 years, and at the 5-percent level of testing after 3 years.

Table 2. --Average survival [1] after the first, second, and third years, North Carolina plantation

First year		Second year		Third year	
Source	Average survival	Source	Average survival	Source	Average survival
	Percent [2]		Percent [2]		Percent [2]
Iowa	98.2	Georgia	94.9	Georgia	94.9
Georgia	96.8	Iowa	93.5	Iowa	93.1
Pennsylvania	93.71	Pennsylvania	91.41	Pennsylvania	91.4
North-Carolina	92.9	North Carolina	91.0	North Carolina	90.5
Maine	89.7	Virginia	86.4	Virginia	86.3
Ontario	89.7 1	Ontario	86.1	Ontario	87.8
Virginia	89.7 1	Ohio	82.9	Ohio	82.6
Tennessee	88.6	Minnesota	82.8	Maine	82.6
Quebec	87.8	Maine	82.6	Minnesota	82.5
Wisconsin	87.3	West Virginia	82.5	West Virginia	81.7
Ohio	87.1	Tennessee	82.4	Wisconsin	81.3
Minnesota	87.1	Quebec	81.8	Tennessee	81.2
New York	87.0	Wisconsin	81.3	Quebec	80.9
West Virginia	86.6	Michigan	80.5	New York	77.6
Nova Scotia	84.5	New York	77.9	Nova Scotia	74.4
Michigan [3]	81.7	Nova Scotia	74.4		
Average	90.0		85.1		85.1

1/ Original seedlings only. Does not include replants.

2/ Means not under the same bracket are different at the 5-percent level. The brackets are used as a method of comparing the average survivals. Differences between numbers included under a common bracket are not large enough to be significant; that is, they may have occurred by chance. Numbers not under a common bracket are significantly different; that is, they are different because of the effect of seed source.

3/ The Michigan source was planted 1 year later than the other sources and is not shown under third-year results.

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Table 3. --Average survival [1] after the second and third years, North Carolina plantation

Second year		Third year	
Source	Average survival	Source	Average survival
	Percent [2]		Percent [2]
Michigan	99.4	North Carolina	98.3
North Carolina	98.7	Georgia	98.2
Pennsylvania	98.2	Pennsylvania	97.2
Virginia	97.5	Virginia	96.7
Minnesota	97.1	Minnesota	95.4
Iowa	96.3	Ohio	95.3
Ohio	95.7	Ontario	95.2
Ontario	95.6	Iowa	93.6
West Virginia	94.7	West Virginia	93.2
Quebec	94.2	Quebec	92.3
Tennessee	92.5	Wisconsin	92.0
Wisconsin	92.3	Maine	91.5
Maine	92.0	Tennessee	90.7
Nova Scotia	90.7	Nova Scotia	89.1
New York	89.4	New York	
Average	95.6		94.9

[1] Includes replants.
[2] Means not under the same bracket are different at the 5-percent level.

Georgia plantation. --Survival of the original seedlings (excluding replants) in the plantation near Blairsville, Georgia, averaged 59.7, 56.1, and 55.5 percent, respectively, after one, two, and three growing seasons (table 4). Differences among the survival means of the different seedling lots were significant after one growing season, and highly significant after the second and third growing seasons. Third-year survival varied from 34.4 percent for the West Virginia seedlings (significantly lower than all other seedling lots) to 69.3 percent for the Nova Scotia seedlings (significantly higher than all other seedling lots). The local Georgia seedlings averaged 56.9 percent survival three growing seasons after planting.

Virginia plantation. --Average survival of the original seedlings after one, two, and three growing seasons, respectively, was 82.8, 80.7, and 79.6 percent (table 5); differences among source averages were highly significant after each growing season. Third-year survival (excluding replants) ranged from 59.1 percent for the West Virginia seedlings to 87.2 percent for the Ontario seedlings. The West Virginia seedlings had significantly lower survival than all the other seedling lots.

All plantations. --Average third-year survival of original seedlings in each of the plantations was plotted over latitude of seed source, seedling root-shoot weight ratio, and seedling root-collar diameter. No correlation between survival and any of these variables was evident.

Table 4. --Average survival [1] after the first, second, and third years, Georgia plantation

First year		Second year		Third year	
Source	Average survival	Source	Average survival	Source	Average survival
	Percent [2]		Percent [2]		Percent [2]
Nova Scotia	13.7	Nova Scotia	69.6	Nova Scotia	69.3
Ontario	65.2	Ontario	63.0	Ontario	62.4
Minnesota	65.2	Minnesota	58.7	Minnesota	57.3
Pennsylvania	54.5	Pennsylvania	52.9	Pennsylvania	52.6
Georgia	50.3	Georgia	37.2	Georgia	36.6
West Virginia	36.7	West Virginia	34.7	West Virginia	34.4
Average	59.7		56.1		55.5

1/ Original seedlings only, Does not include replants.
2/ Means not under the same bracket are different at the 5-percent level,

Table 5. --Average survival [1] after the first, second, and third years, Virginia plantation

First year		Second year		Third year	
Source	Average survival	Source	Average survival	Source	Average survival
	Percent [2]		Percent [2]		Percent [2]
Ontario	91.3	Ontario	89.6	Ontario	87.2
Nova Scotia	87.4	Nova Scotia	85.7	Nova Scotia	85.2
Minnesota	86.0	Minnesota	82.1	Minnesota	81.3
Georgia	80.1	Georgia	80.1	Georgia	80.1
Pennsylvania	77.7	Pennsylvania	75.7	Pennsylvania	74.8
West Virginia	59.7	West Virginia	59.4	West Virginia	59.1
Average	82.8		80.7		79.6

1/ Original seedlings only. Does not include replants.
2/ Means not under the same bracket are different at the 5-percent level.

Height

Average heights by source were calculated from data collected at the end of each growing season. These averages included heights of replanted seedlings. Average heights, excluding replants, were calculated from third-year data. Comparison of average third-year heights including replants and average third-year heights excluding replants showed only minor differences. Replanted seedling heights were therefore retained in all the calculations described in the following pages.

North Carolina plantation. --Differences among average heights of seedlings from various sources were highly significant at the end of three growing seasons (table 6). Heights of some plots after 3 years are illustrated in figures 6 and 7. Average third-year heights ranged from 1.08 feet for Minnesota seedlings to 2.44 feet for Georgia seedlings. The local North Carolina seedlings averaged 2.31 feet in height. The difference between averages of shortest and tallest seedlots was 0.34 of a foot after one growing season, and had increased to 1.36 feet after three growing seasons. Curves of average height over age indicate that differences in average height between shorter seedling lots and taller seedling lots will continue to increase with plantation age (fig. 8).

A highly significant correlation was found between average third-year seedling heights and latitude of seed source, with seedlings from southern sources making better height growth than seedlings from northern sources (fig. 9). Eighty percent of the total variation in third-year seedling height was accounted for by variation in latitude. Seed source latitudes range from 34° 46' N to 47° 30' N (table 1).

Georgia plantation. --Differences among average heights of seedling lots from the six seed sources planted in Georgia were highly significant at the end of three growing seasons (table 6). Seedlings from southern sources were tallest and those from northern sources shortest, with average height differences tending to increase with time (fig. 10). A very strong correlation exists between average 3-year heights of seedling lots and latitude of seed source (fig. 9), with variation in latitude accounting for 96 percent of the variation in third-year heights.

Table 6. --Average heights 1/ after three growing seasons, all plantations

North Carolina plantation		Georgia plantation		Virginia plantation	
Source	Average height	Source	Average height	Source	Average height
	Feet 2/		Feet 2/		Feet 2/
Georgia					
North Carolina	2.31	West Virginia	1.40	West Virginia	1.63
Tennessee	2.27	Pennsylvania	1.27	Pennsylvania	1.63
Virginia	2.04	Nova Scotia	1.21	Nova Scotia	1.51
Pennsylvania	1.89	Ontario	0.90	Ontario	1.14
West Virginia	1.80	Minnesota	0.90	Minnesota	1.02
Wisconsin	1.63				
Ohio					
Quebec	1.49				
Iowa					
Nova Scotia	1.31				
Ontario	1.29				
New York					
Maine	1.13				
Minnesota	1.08				
Average	1.65		1.18		1.45

1/ Originals and replants.
2/ Means not under the same bracket are different at the J-percent level.

Virginia plantation. --Height relationships in the Virginia plantation are similar to those in the Georgia plantation, but differences among average heights are less pronounced (table 6, fig. 11). The correlation between average 3-year heights of seedling lots and latitude of seed source was significant, with variation in latitude accounting for 80 percent of the variation in third-year seedling heights (fig. 9).

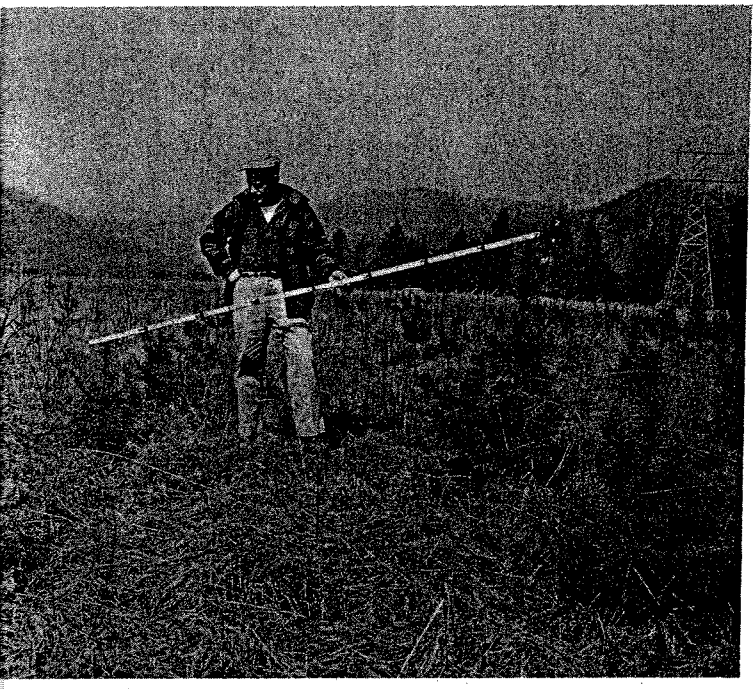

Figure 6. --Quebec seedlings (left) and North Carolina seedlings (right) after three growing seasons in the North Carolina plantation, Seedlings from the two sources averaged, respectively, 1.49 and 2.31 feet.

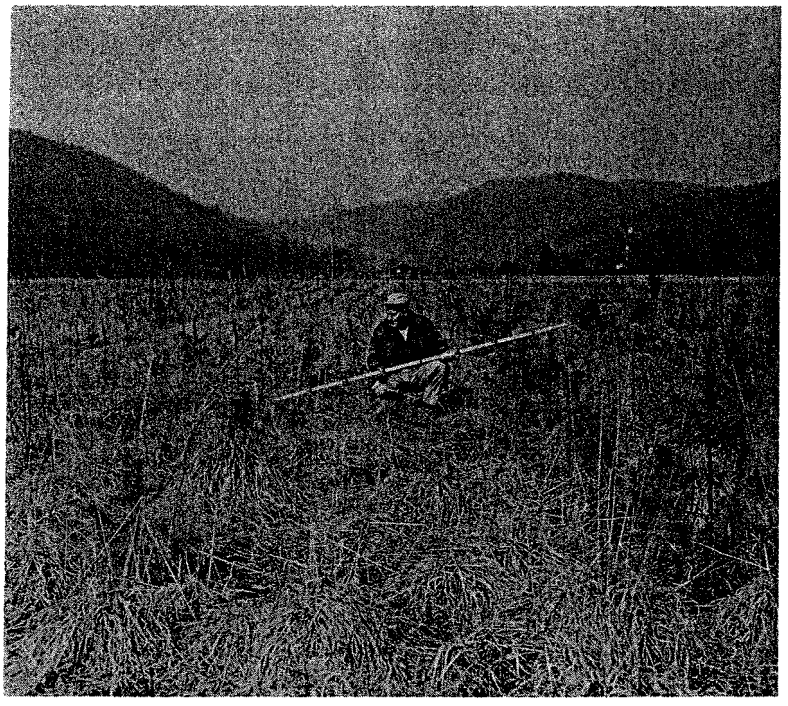

Figure 7. --Pennsylvania seedlings (left) and North Carolina seedlings (right), North Carolina plantation. Average 3-year heights were, respectively, 1.89 and 2.31 feet.

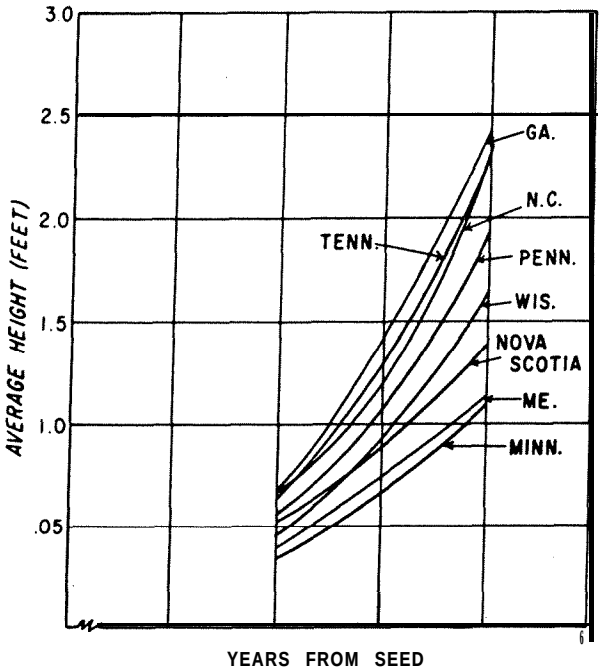

Figure 8.--Height-over-age curves for seedlings from eight selected seed sources, North Carolina plantation. Curves for seedlings from the other sources are similar to these curves.

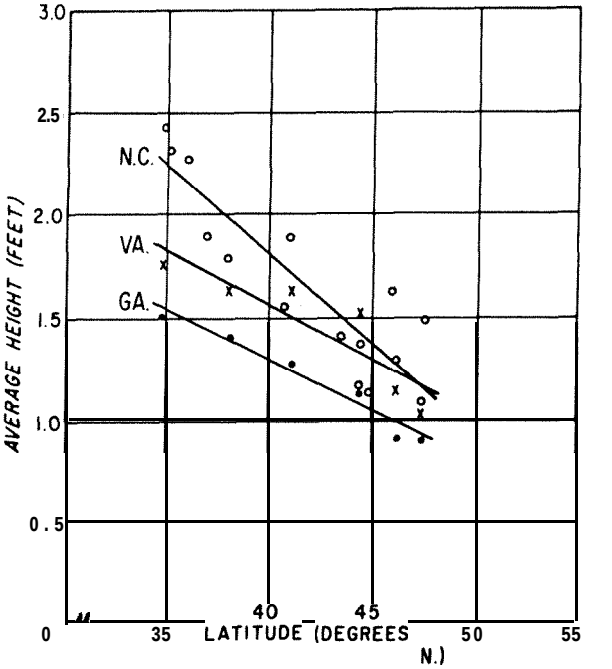

Figure 9.--Regressions of average J-year heights on latitude of seed source, North Carolina, Virginia, and Georgia plantations.

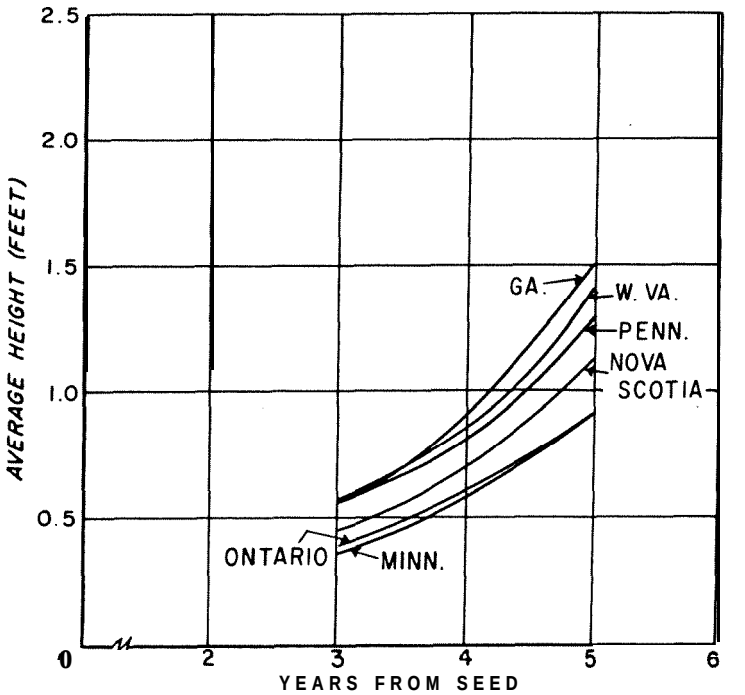

Figure 10.--Height-over-age curves for seedlings from the various seed sources, Georgia plantation.

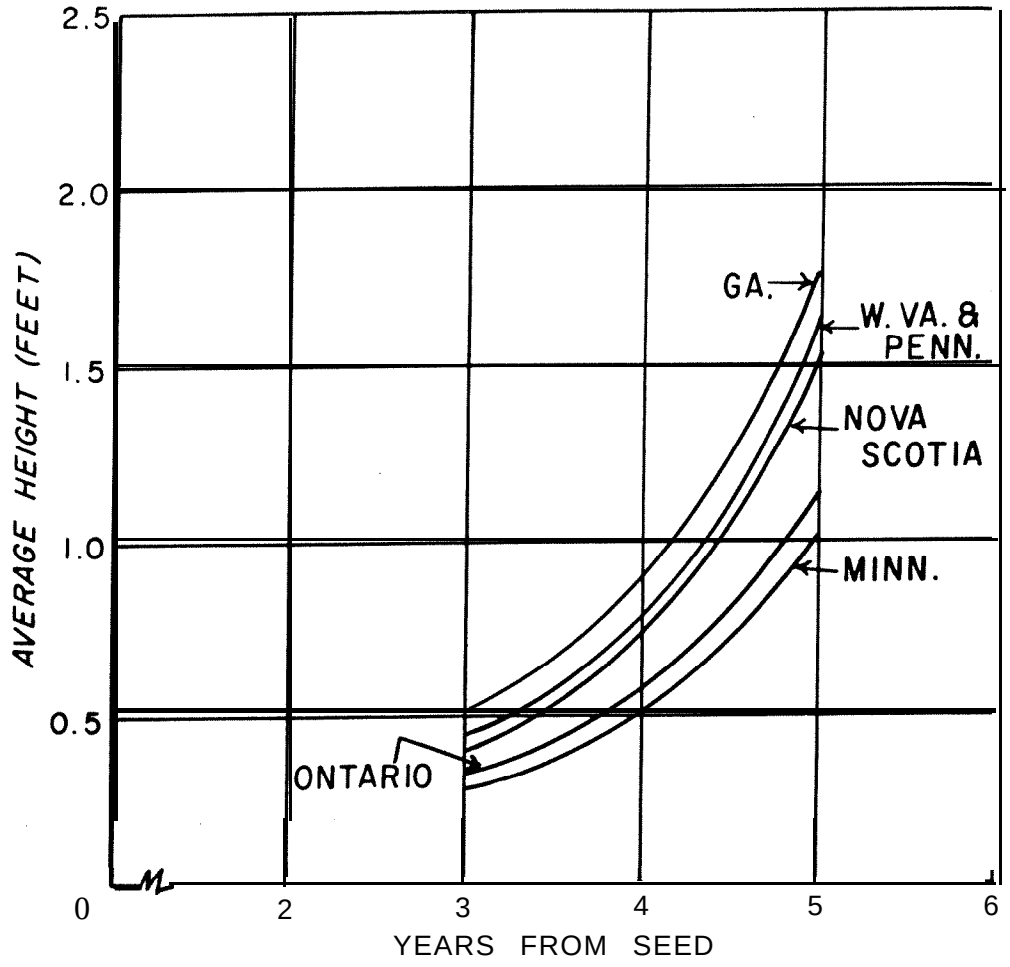

Figure 11. --Height-over-age curves for seedlings from six seed sources, Virginia plantation.

DISCUSSION

The three planting sites differ in quality. Growth is poorest in Georgia, intermediate in Virginia, and best in North Carolina (fig. 12). The Georgia plantation is on a dry, southeast-facing slope with a heavy clay subsoil, while the other two plantations are on streambottom sites. The Virginia site also has a tight clay subsoil, but the field in North Carolina is a friable loam. Elevation, latitude, and general climate also differ for the three locations.

Three-year seedling heights in the three plantations were similarly correlated with latitude of seed source despite plantation differences in latitude, altitude, soil, and climate. Tests showed no significant differences in slope among regressions of height on latitude (fig. 9). This indicates that white pine seedlings, regardless of geographic location in which they are grown, have a strong tendency toward growth rates typical of the location from which the seed was collected. Seedlings from southern sources tend to grow more during one growing season than do seedlings from northern sources, This tendency evidently is the same no matter what the latitude of the planting site.

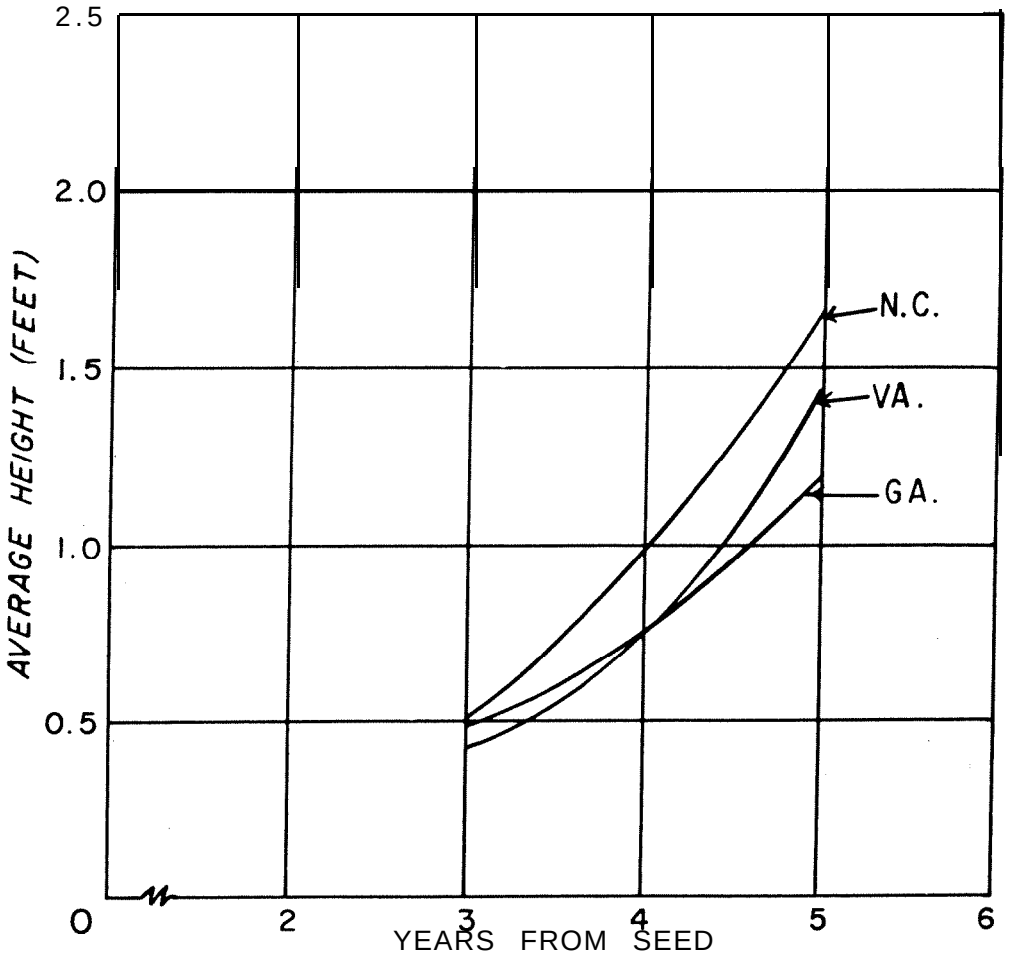

Figure 12. --Average height-over-age by plantation. The curves show the plantation average of seedlings from the six seed sources represented in all three plantations.

Plants, however, are adapted to, or are in harmony with, their native environment (Perry, 1961). Growth patterns are regulated by day length, length of growing season, temperature, and other factors typical of the environment in which plants and their preceding generations have been growing. Southern seedlings, therefore, can be taken so far north that their growth responses are seriously out of harmony with the environment. They still have the tendency to start growth earlier and grow longer into the growing season than do northern seedlings, but frost injury becomes a limiting factor. Such was the case with hemlock seedlings grown in the Lake States (Nienstaedt, 1958). In the northern part of the species range, white pine seedlings from northern sources may therefore grow faster than seedlings from southern sources. In southern plantations, loblolly and shortleaf seedlings from southern sources have done best. Similarly, in northern plantations loblolly and shortleaf from northern sources showed the most height growth (Wakeley, 1961).

White pine survival differences due to seed source were not explained by latitude, root-collar diameter, or root-shoot weight ratio. An explanation of survival results can be offered only for seedlings from the West Virginia source. These seedlings had poorly-developed root systems consisting of carrot-like tap roots with very few fibrous roots for water absorption. This is probably the reason why West Virginia seedlings had low survival rates in the heavy clays found in the Georgia and Virginia plantations.

These study results indicate that seedlings from a southern source should be used in white pine plantations in the Southern Appalachians. This recommendation is sound if the early relative growth rates observed in this study represent long-range relative growth rates. Loblolly pine seedlings from several sources growing in Virginia had the same order of relative heights at 16 years from seed as they had at 6 years from seed (Kormanik et al., 1961). In a study with Scotch pine from 25 different locations, correlation of 18-year height with l-year height was significant at the l-percent level (Schreiner et al., 1962). The white pine seedlings in this study are 5 years from seed. Long-range height relationships among seedlings from various sources may already be established. Periodic measurements over the next several years will show whether or not this is true.

SUMMARY

A range-wide provenance study is being conducted on eastern white pine. Three plantations have been established in the southern part of the white pine range, with one plantation each in northern Georgia (6 sources), western North Carolina (16 sources), and southwestern Virginia (6 sources). Survival counts and height measurements have been made after each of the first three growing seasons. Significant differences in average survival and height were found among the various seed sources after each growing season. Average 3-year heights of different lots of seedlings were closely correlated with latitude of seed source. Seedlings of southern origin were taller than seedlings of northern origin. Average survivals, however, showed no correlation with either latitude of seed source, root-shoot weight ratio, or root-collar diameter,

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White pine seedlings of southern origin were taller on the average than seedlings of northern origin after three years in plantations on three sites in the Southern Appalachians. Average survivals, however, showed no correlation with either latitude of seed source, seedling root-shoot weight ratio, or seedling root collar diameter.

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White pine seedlings of southern origin were taller on the average than seedlings of northern origin after three years in plantations on three sites in the Southern Appalachians. Average survivals, however, showed no correlation with either latitude of seed source, seedling root-shoot weight ratio, or seedling root collar diameter.