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Geographic Variation of EASTERN WHITE PINE in the Northeast

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174.7 *Pinus strobus* L. : 165.52

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ABSTRACT

Eastern white pine is the most valuable conifer in the Northeast, and its large botanical range has provided ample opportunity for the development of ecotypes. Provenance plantings in nine states provided information on variability within the species and recommendations for moving seed from one region to another. Good growth was obtained on southern Appalachian sources moved as far north as central Pennsylvania. Needle length, branching habit, cone production, and other characters are discussed.

INTRODUCTION

THE NORTHEASTERN Forest Experiment Station held a "White Pine Research Program Conference" at New Haven, Connecticut, in February 1955 to set up priorities for the Station's research with this species. The growth potential of eastern white pine (*Pinus strobus L.*) was well known; but in much of the Northeast, timber quality was a major problem. The primary cause of degrade could be attributed to forest pests, particularly to the white pine weevil (*Pissodes strobi* Peck), which had been responsible for annual losses exceeding 7 million dollars in New England forests alone (*Marty and Mott 1964*). But quality is also affected by the growth rate (distance between nodes), stem form, number and diameter of branches, branch angle, and other factors that may be genetically controlled.

For the Genetics Project, it was concluded that information was urgently needed on racial variation. There was evidence for the existence of racial differences in eastern white pine, but no experiments to provide adequate information about the extent or nature of such genetic variation or the best provenances for use in different parts of the region.

As a follow-up to the Connecticut meeting, representatives of the USDA Forest Service's Southeastern, Lake States, Central States, and Northeastern Forest Experiment Stations, and Dr. Heimburger of the Southern Research Station, Maple, Ontario, conferred on white pine racial tests in Washington, D.C., on Au-

Table 1.—Location and design of plantations

Plantation No.	Location	Field design	Lat.	Long.	Elev. (feet)
Established by Northeastern Station:					
1	Orono, Maine	III	44°53′N	68°39′W	100
2	Alfred, Maine	I, II, III	43°32′N	70°40′W	300
3	Essex Junction, Vermont	III	44°28′N	73°09′W	327
4	Paul Smiths, New York	I	44°26′N	74°13′W	1,815
5	Williamstown, Massachusetts	I	42°44′N	73°14′W	1,050
6	Warren, Pennsylvania	I	41°50′N	79°15′W	1,180
7	Standing Stone, Pennsylvania	III	40°37′N	78°55′W	960
8	Kennett Square, Pennsylvania	I	39°52′N	75°41′W	400
9	Savage River State Forest, Maryland	III	39°40′N	79°15′W	2,740
10	Horseshoe Run, West Virginia	I	39°11′N	79°35′W	1,720
11	Rison, Maryland	II	38°30′N	77°20′W	100
Established by Central States Station:					
12	Nelsonville, Ohio	IV	39°28′N	82°12′W	700
13	London, Kentucky	III C.S.	36°59′N	84°17′W	1,100

gust 4, 1955. This group recommended that the same 14 provenances in a standard field design (with 81-tree plots) would be included in at least one outplanting in each region, and that any number of additional provenances could be included in other field designs.

Eleven of the 13 provenance plantations evaluated in this report were established by the Northeastern Station; 2 plantations were established by the former Central States Forest Experiment Station (table 1).

MATERIAL AND METHODS

Seed Collection

Seed for the Northeastern Station's tests was supplied by cooperators from 32 provenances (fig. 1, table 2). Instructions for seed collection were as follows:

> All seed must be from trees in naturally regenerated stands; they may be either pure stands of white pine or white pine in mixture with other species.
>
> Approximately 25 cones should be collected from each of 10 trees chosen at random over an area of 5-10 acres, or approximately 1/4 mile of forest road in a good stand. Trees in openings or border trees may be chosen for ease of cone collection *provided they are definitely of natural origin.* Squirrel-cut cones may be collected from the ground if they can be assigned with reasonable certainty to a single tree.
>
> *The cones from each tree should be packed in separate bags* for extraction at the Northeastern Station.

Nursery Stock

The Northeastern Station's outplantings in 1959 (plantations 7 to 11) were established with 2-0 stock grown in the Maryland State Forest Nursery. The 1960 plantations (1 to 6) were established with 3-0 stock grown in the New Jersey and New York State Forest Nurseries.

Seedlots were kept separate by individual seed trees through the nursery phase of this study for two reasons: (1) to allot (for outplanting) approximately the same number of seedlings from each of the seed trees represented in a provenance; (2) for information on juvenile variation between one-parent progenies from the same provenance (*Santamour 1960*).

The seed for the Central States plantations was extracted, bulked by provenance, and grown at the Ralph Edwards Nursery in North Carolina.

FIELD TEST LOCALITIES

The Northeastern Station established plantations in 12 localities to sample the environmental conditions under which eastern white pine might be planted in the region: 3 in Pennsylvania; 2 each in New York, Maine, and Maryland; and 1 each in Massachusetts, Vermont, and West Virginia (fig. 2). (One of

Figure 1.—Map of seed sources used in the provenance tests. Shaded areas show the natural range of eastern white pine. Numbers indicate seed-collection points (table 2).

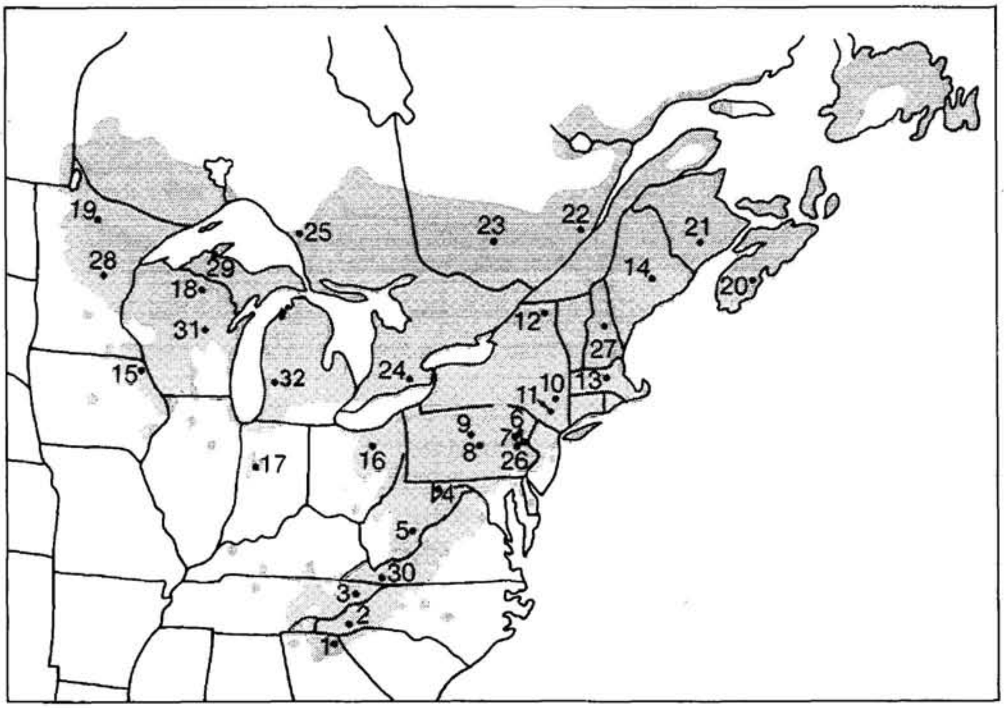
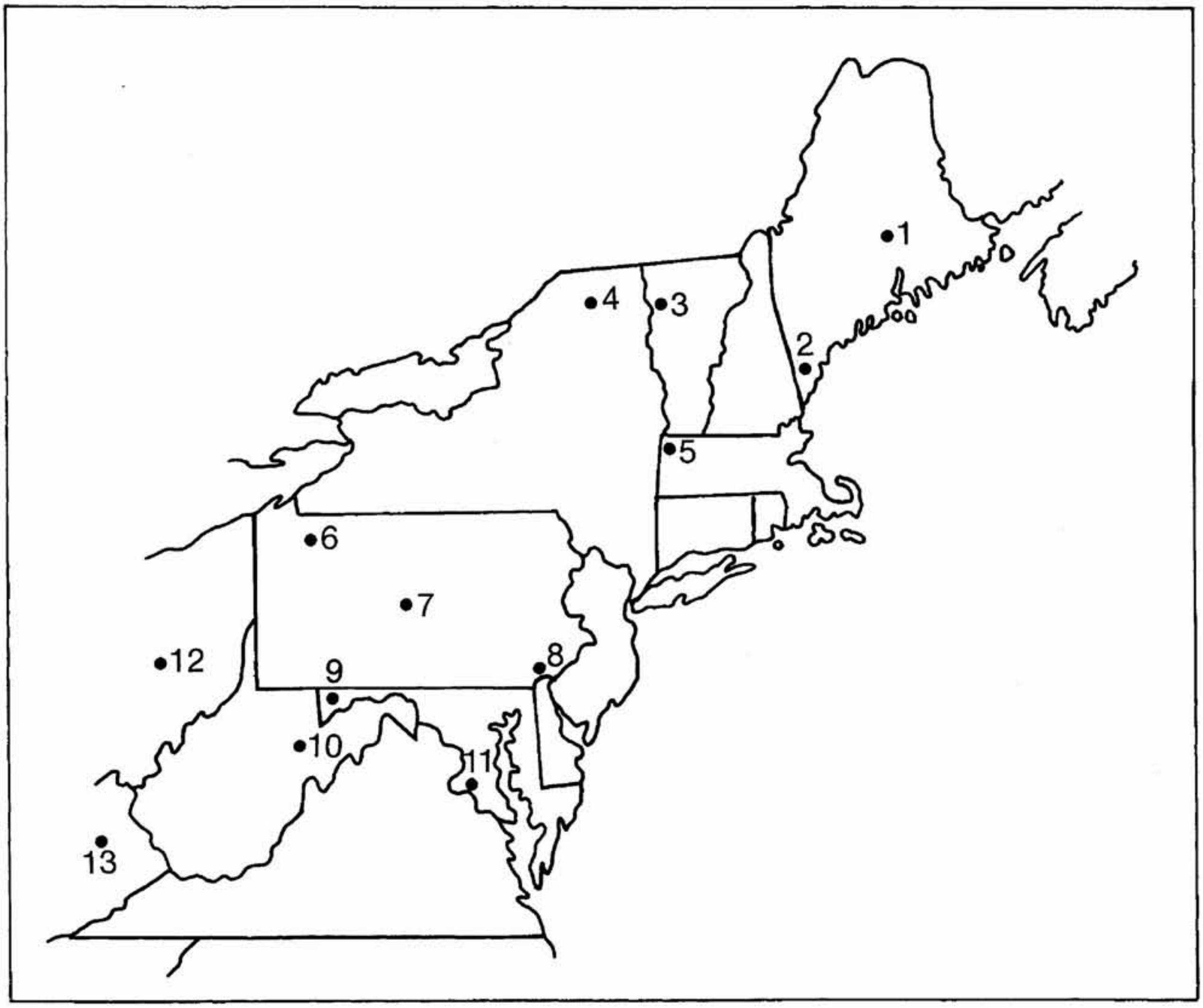


Table 2—Seed source locations for white pine provenance study

Seedlot No.	Location	Lat.	Long.	Elev. (feet)
1	Union County, Georgia	34°46′N	84°03′W	2,450
2	Transylvania County, North Carolina	35°14′N	82°38′W	2,120
3	Greene County, Tennessee	36°00′N	82°48′W	2,250
4	Garrett County, Maryland	39°39′N	78°45′W	2,460
5	Greenbrier County, West Virginia	38°00′N	80°30′W	2,600
6	Monroe County, Pennsylvania	41°05′N	75°25′W	1,800
7	Monroe County, Pennsylvania	41°05′N	75°25′W	740
8	Clearfield County, Pennsylvania	41°00′N	78°30′W	—
9	Clearfield County, Pennsylvania	41°00′N	78°30′W	—
10	Ulster County, New York	41°45′N	74°15′W	—
11	Ulster County, New York	41°45′N	74°15′W	—
12	Franklin County, New York	44°25′N	74°15′W	1,600
13	Worcester County, Massachusetts	42°30′N	72°15′W	1,275
14	Penobscot County, Maine	44°51′N	68°38′W	150
15	Allamakee County, Iowa	43°15′N	91°30′W	1,000
16	Ashland County, Ohio	40°45′N	82°15′W	1,000
18	Forest County, Wisconsin	45°30′N	88°30′W	1,500
19	Cass County, Minnesota	47°30′N	94°30′W	1,300
20	Lunenburg County, Nova Scotia	44°25′N	64°35′W	150
21	Sunbury County, New Brunswick	46°00′N	66°15′W	200
22	Quebec County, Quebec	47°30′N	72°00′W	550
23	Pontiac County, Quebec	47°30′N	77°00′W	1,000
24	Norfolk County, Ontario	42°40′N	80°27′W	750
25	Algoma District, Ontario	46°10′N	82°37′W	650
27	Carroll County, New Hampshire	43°45′N	71°25′W	610
28	Lake County, Minnesota	48°00′N	91°45′W	1,300
29	Houghton County, Michigan	47°00′N	88°30′W	625
30	Pulaski County, Virginia	37°00′N	80°50′W	2,400
31	Sauk County, Wisconsin	43°30′N	89°30′W	1,000
32	Newaygo County, Michigan	43°30′N	85°40′W	600

Figure 2.—Location of white pine provenance planting sites (table 1).



the New York plantings, near Antwerp, was destroyed when the same location was machine-planted by the State and reference stakes were lost.)

Two additional plantings near New Haven, Connecticut, were established by Northeastern Station entomologists for evaluation of weevil damage; the results of their research are not included in this report.

The Central States established the plantations in Nelsonville, Ohio, and London, Kentucky (table 1).

The number of seeds in some collections was not sufficient to permit planting all 32 provenances at each test location, and the actual number of sources varied from 17 to 29.

FIELD DESIGNS

Design I.—Two trees of each provenance were planted 6 to 10 inches apart at a spacing of 10 x 10 feet in 24 randomized blocks (replicates). The purpose in planting two closely spaced trees was to reduce the need for replanting failed one-tree plots. At the end of the second year, when the trees were well established, one tree was removed from each planting spot.

Design II.—Two-tree row-plots of each provenance were planted in 24 randomized blocks. Provenance trees were spaced 7 feet in rows 14 feet apart. The intervening (alternate) rows were planted with filler trees to obtain a spacing of 7 x 7 feet. There were two rows of border trees around the plantations.

Design III.—Four-tree row-plots of each provenance, spaced 7 feet in rows 14 feet apart, were planted in 12 randomized blocks. As in Design II, filler trees were used to obtain a spacing of 7 x 7 feet, and two rows of border trees were used.

Design III C.S.—This Central States design was a complete randomization of twelve 4-tree row-plots in a single block, with spacing, fillers, and border trees as in Design III.

Design IV.—The decision of the conferees at the Washington meeting called for a "large-plot" design, with 14 provenances, in each region; 81-tree plots of each provenance, in 4 randomized blocks, planted at 7 x 7 feet spacing with 2 border rows around each block. This design would require 3.64 acres *per block without the border trees.*

The Nelsonville, Ohio, plantation, established by the Central States Station, is the only design IV plantation included in this report.

A design IV was included in the Northeastern Station working plan, but in 1960 there was no suitable area of cleared land available to the Station for such a large design. Four blocks of 81-tree plots with different numbers of provenances were established at Alfred, Maine, on heavily revegetated pasture land. The blocks were extremely irregular, both in topography and natural vegetation (brush and 5- and 6-inch d.b.h. tree growth, mostly aspen). There was no labor available to clear this land either before or after planting; so this plantation has not been included in this report.

PLANTATION SITES, SITE PREPARATION, AND AFTER-CARE

There has been no systematic or detailed analysis of climates or soils for any of the plantation sites, but there are obvious and contrasting local differences that may affect growth and development. With one exception (Paul Smiths, N. Y.) all plantations were established on old fields. The Northeastern Station plantations were sprayed, where necessary, for control of the white pine weevil; they will be sprayed as necessary until the leaders are beyond reach of the back-pack sprayer.

1. *Orono, Maine:* This planting is on the Penobscot Experimental Forest. The site is flat with a fairly heavy textured soil, permitting only moderate drainage. Spring site preparation (scalped furrows) was planned, but was not possible because the ground was too wet. Severe frost-heaving occurs in the area, but it did not contribute significantly to mortality in this planting. The site is considered a fair to moderate pine site in ths area.
2. *Alfred, Maine:* These plantations are on gently sloping abandoned farmland leased to the Forest Service by P. Chadbourn. They are adjacent to the Massabesic Experimental Forest. Design I (plantation GP-4-60) is located on the upper portion, design II (GP-5-60) is in the midsection of the slope, and design III (GP-6-60) is at the lower end. The soil on the upper portion of the slope appears to be rather shallow, possibly indicating topsoil erosion in the past; but generally the site is good, and growth reflects this condition. The trees were bar-planted in scalped furrows made with a planting machine.
3. *Essex Junction, Vermont:* This is an exposed, gently sloping old pasture site. The soil is heavy, but drainage appears fair to good. Two replicates had to be planted on an area scalped for topsoil; the remaining replicates were planted in sod.
4. *Paul Smiths, New York:* The plantation slopes down into an artificial pocket formed by highway construction. Most of the mortality and climate-induced damage occurred in the lower end of this "cold" pocket. A general improvement in height and vigor was apparent on the higher portions of the slope.

   This was an old clearcut forest site with sparse brush cover. Site preparation consisted of plowed furrows spaced 10 feet apart; the trees were planted in 3-foot circular scalps at 10-foot intervals along the furrows.

5. *Williamstown, Massachusetts:* This was an old hay field with very little woody vegetation. The soil is only moderately fertile and has a tendency to become droughty during most of the growing season. Two-foot-wide strips were mowed at 10-foot intervals to facilitate planting.

6. *Warren, Pennsylvania:* This plantation is on an old-field flood plain ideally suited for growth of this species. There was no site preparation. Approximately one-half of the replicates were lost to new highway construction since the 10th-year remeasurements.

7. *Standing Stone, Pennsylvania:* This is an exposed hilltop in gently rolling terrain. Soil fertility is probably fair to good, but the exposed nature of the site may contribute to less than optimum growth when compared to the general area. Inadequate soil moisture in spots during several very dry summers probably contributed to mortality. The plantation site was plowed and disked before planting.

8. *Kennett Square, Pennsylvania:* This plantation is on fertile, gently sloping farm land on the grounds of Longwood Gardens, maintained by Longwood Foundation, Inc. The plantation included contour strips of sod land, fallow land (corn in 1957), and corn land (corn in 1958). The area is kept mowed and most of the early mortality was due to this practice.

9. *Savage River State Forest, Maryland:* The plantation is on an exposed, somewhat eroded slope facing the prevailing winds. The field was in corn in 1957; it was seeded in 1958 and carried a light sod at the time of planting. There was no site preparation.

10. *Horseshoe Run Recreation Area, West Virginia:* This is an excellent site; bottomland subject to overflow at the base of a steeply wooded slope, with an accumulation of topsoil from the slope and flood deposits from the small stream. The water table is optimum for plant growth, and the narrow valley affords protection from adverse weather conditions. The field was plowed and harrowed before planting.

11. *Rison, Maryland:* This planting, on the General Smallwood State Park grounds, is level and probably has adequate moisture and nutrients for good white pine growth. Weeds and sweetgum, sassafras, and ash reproduction were mowed at the end of the first, second, and third growing seasons. The field was in corn in 1958; there was no site preparation before planting.

12. *Nelsonville, Ohio:* This plantation was established by the Central States Station on the Wayne National Forest. The field had been limed and fertilized for pasture by permittees and therefore was more fertile than typical old pastures. The soil is a silt loam, and the site has a slight west-facing slope. Early maintenance included mowing and chemical weed control.

13. *London, Kentucky:* This plantation was established by the Central States Station on the Baldrock Experimental Forest. The site is level, and the soil is a silt loam. The field was disked before planting, and herbicides were used to eliminate brush competition the first season.

MEASUREMENTS AND OBSERVATIONS

At the end of 10 growing seasons from seed (nursery-planted in 1957), the following measurements and observations were recorded for all trees in the Northeastern Station plantations: (1) survival; (2) 10-year height; (3) the following measurements from the third whorl from the top—number of branches, branch angle, and needle length (average of 5 fascicles taken from center of current season's growth); (4) frost and snow damage; (5) disease, weevil damage, and injury due to insects other than weevils; (6) secondary flushing; (7) presence of cones; and (8) forks and offsets.

Data supplied by cooperators on the Central States Station's Ohio and Kentucky plantings included: survival, heights at several ages, branch measurements, and occurrence of proleptic growth.

RESULTS AND DISCUSSION

Survival

Wright, *et al.* (*1963*) reported significant differences in survival in two lower Michigan plantings, but most of the mortality occurred in the first year following planting and was probably due to seedling handling at the time of planting and not differences in site adaptability.

Sluder (*1963*) found significant differences in provenance survival in Georgia, North Carolina, and Virginia plantings; but the differences were not correlated with latitude of seed sources. Fowler and Heimburger (*1969*) reported over 95 percent survival for all sources in two plantings in southern Ontario (lat. 42°30'N and 44°05'N), and survival of seed source was not correlated with seed source latitude.

Survival (10th year) was generally good (84 to 99 percent) in our 15 plantings located in a number of climatic zones—from Rison, Maryland, (lat. 38°30'N) to Orono, Maine (lat. 44°50'N). Provenance survival was significantly correlated with provenance latitude only in Massachusetts (5) and New York (4). Both were positively correlated at the 0.01 level.

There were slight non-significant trends in our data to suggest that local sources may survive better in the North and South, but source becomes less important in mid-range latitudes. However, these slight differences in survival are probably far less important than either growth rate or pest resistance within the geographic range of our outplantings.

Height at Age 10

Results from white pine provenance plantings in the Central States Region indicate that southern sources, with the possible exception of Virginia (30) outperform northern source trees (*Wright 1970*). Funk (*1970*) reported similar results in Indiana and Illinois, but not in Iowa, suggesting that Iowa may be near the northern or western limit for superiority of southern Appalachian provenances.

Based on growth data collected in the Lake States, King and Nienstaedt (*1968*) reported that northern Michigan, Minnesota, and Wisconsin all appear to be north of the line where southern sources outperform local sources (the southern Ontario source—24—does well in these areas). The southern portion of Michigan's lower peninsular is probably below the line, because southern Appalachian sources do well in that area.

Sluder (*1963*) established plantings of southern Appalachian provenances in three southeastern states and found that height growth was correlated with latitude of seed source. Faster growth occurred on southern source trees and slower growth on northern source trees. Genys (*1968*) reported similar results in Maryland.

Several plot sizes (1-, 2-, 4-, and 81-tree plots) were included in our study. The mean and variance were calculated for each plot containing two or more living trees. No relationship was found between mean and variance, and no difference in variance due to plot size was found. Variances were subsequently pooled over all plots, blocks, and locations, except for location 2-59 (central Pennsylvania) where the variances were too high.

Because all provenances were not represented at all locations, Scheffe's S-method was used to test hypotheses of interest (table 3). The results indicated significant differences

Table 3.—Selected comparisons, using Scheffe's S-method

[Location vs. all provenances]

Plantation No.	Location	Significance
1-59	Southeastern Pennsylvania	n.s.
2-59	Central Pennsylvania	*
3-59	Southern Maryland	*
4-59	Western Maryland	n.s.
5-59	West Virginia	*
1-60	Massachusetts	n.s.
2-60	New York	n.s.
3-60	Northwestern Pennsylvania	*
4-60	Southern Maine (I)	*
5-60	Southern Maine (II)	n.s.
6-60	Southern Maine (III)	*
7-60	Central Maine	n.s.
12-60	Vermont	n.s.

Figure 3.—Correlation of provenance height with provenance latitude at all planting sites.

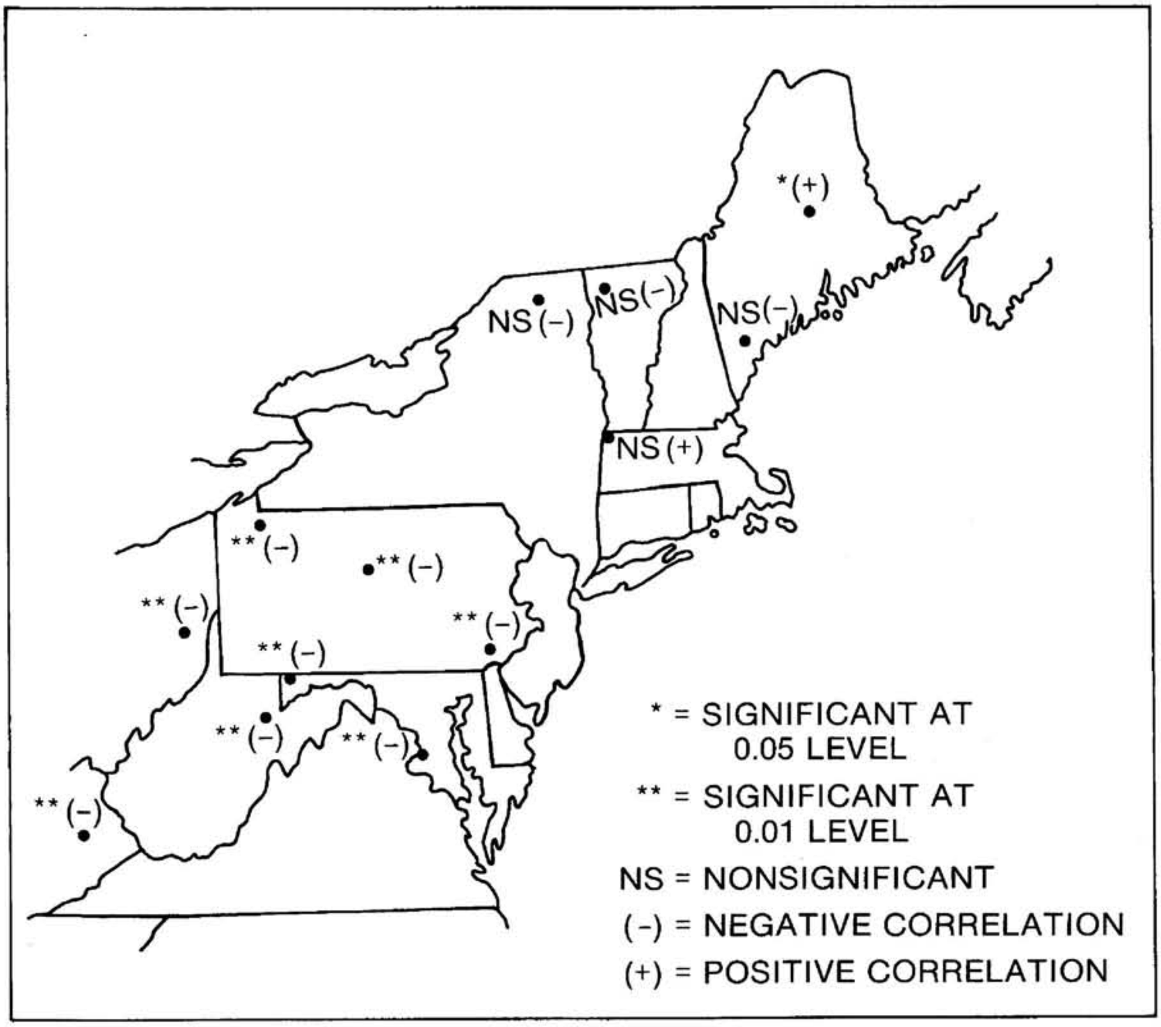


Table 4.—Correlations between several parameters at age 10: White pine provenance study

Plantation	No.	Source latitude / Tree height	Number branches / Source latitude	Tree height / Needle length	Source latitude / Needle length
Kentucky	6-59	−.8670**	—	—	—
Southern Maryland	3-59	−.8145**	+.2882ns	+.8931**	−.4806*
Central Pennsylvania	2-59	−.7292**	−.4622*	+.8269**	—
Ohio	7-59	−.6890**	—	—	−.6429*
West Virginia	5-59	−.6788**	+.4745*	+.8597**	−.7917**
Western Maryland	4-59	−.6659**	+.4882*	+.7720**	−.8533**
Northwestern Pennsylvania	3-60	−.6307**	+.1594ns	+.6315**	−.7095**
Southeastern Pennsylvania	1-59	−.5230**	−.0156ns	+.8100**	−.3118ns
Vermont	12-60	−.3161ns	+.5426**	+.6240**	−.6320**
Southern Maine	6-60	−.1787ns	+.4477*	+.6799**	−.7214**
Southern Maine	4-60	−.1379ns	+.4905**	+.0565ns	−.5798**
Southern Maine	5-60	−.0652ns	+.7598**	+.3210ns	−.7656**
New York	2-60	−.0253ns	+.4530*	+.7973**	−.3439ns
Massachusetts	1-60	+.0789ns	+.6112**	+.1560ns	−.3493ns
Central Maine	7-60	+.3964*	+.6822**	+.8519**	+.3452ns

between provenances in 6 of 13 locations. Four of these were among the five fastest growing plantations based on average height of all sources. Plantation height generally reflected the existing site conditions, and a strict geographic pattern did not occur.

Height was correlated with provenance latitude in both the upper and lower latitude plantations but not in the mid-range plantations (fig. 3, table 4). In the West Virginia, Maryland, Pennsylvania, Ohio, and Kentucky plantings, trees from southern sources (other than Virginia) were tallest, while northern source trees were tallest when planted in central Maine. Seed-source latitude was not a factor in height growth in New York, Vermont, or southern Maine.

Results from our 15 plantations (13 locations) in the Northeast indicate that southern sources should do very well in all but the northernmost locations (table 5). On the basis of 10-year growth, we would recommend that southern Appalachian (Georgia, Tennessee, North Carolina), southeastern New York, eastern Pennsylvania, and Ontario sources be planted as far north as central Pennsylvania; that southern provenances and provenances from Pennsylvania and southeastern New York be considered in the zone between latitudes 40° and 45°N; and that only provenances from above latitude 40°N be used in central and northern Maine. The poor growth of the Quebec provenances in all the plantings, and the relatively poor performance of the Virginia source, suggest that seedlings from those sources should not be included in future planting programs.

Santamour (*1960*) and Sluder (*1968*) have suggested that seedlings of southern sources, when moved north, either grow at a faster rate or utilize a greater portion of the growing season than northern sources. If this movement does not exceed certain limits (approximately latitude 43°N) the trees are able to harden off in time to escape damage by early fall frost. If moved too far north, however, spring frost damage keeps net growth below that of northern sources. This may be a factor in some areas, but we did not observe frost damage in our northern most plantation, where latitudes and heights or provenances were positively correlated.

Number of Branches

We were interested in the possible relationship between seed source and number of branches. Number of branches on the third whorl from the top was chosen as an indicator of branchiness. The correlation of latitude of planting and number of branches (all sources combined) was not significant ($r = -.4617$). The correlation between average height and number of branches in a plantation, however, indicates that plantations with the tallest trees also have the most branches ($r = +.914$).

The correlation of number of branches with provenance latitude, computed separately for each plantation, was positive in all cases except the plantations in central and southeastern Pennsylvania (table 4).

The southern seed sources definitely had fewer branches in our northern plantations, but differences between sources tend to diminish and finally disappear entirely in the southern plantations. Funk *(1970)* also reported greater growth and fewer branches on southernsource trees grown in Indiana and Illinois.

Needle Length

Needle lengths were not measured in the Ohio and Kentucky plantations.

Average height of trees in the other plantations was correlated with average needle length of all provenance trees in the plantation ($r = +.644$). When individual provenances within plantations were analyzed, the correlations were always positive indicating that the tallest sources have the longest needles. In 10 of 13 plantations it was significant at the .01 level of probability, and in the other 3 it was positive but nonsignificant (table 4) (Massachusetts, two at Alfred, Maine).

As we speculated with number of branches, this may be a function of tree size at this young age and could very well disappear as the trees grow.

There was also a strong correlation with length of needles and latitude of planting (table 4). With the exception of the northern most plantations, the southern sources produced the tallest trees and had the longest needles. Genys *(1968)* reported similar results for 2-year-old white pine in Maryland.

Table 5.—Relative height of white pine seed source plantations

[Seed-source mean as percentage of plantation mean]

Seed source No.	Location	SE. Pa. 8	Cent. Pa. 7	S. Md. 11	W. Md. 9	W. Va. 10	Ky. 13	Ohio 12	NE. Pa. 6	Mass. 5	N.Y. 4	2[1]	S. Maine 2[2]	2[3]	Cent. Maine 1	Vt. 3
1	Georgia	132	130	128	112	119	126	150	129	87	91	98	91	97	80	111
2	North Carolina	102	120	119	100	110	138	120	98	99	78	93	97	102	79	103
3	Tennessee	134	124	131	117	115	126	136	120	91	100	102	97	109	82	100
4	Maryland	102	106	101	112	101	—	—	119	97	99	103	96	90	82	92
5	West Virginia	100	89	103	98	106	114	97	98	89	96	86	95	96	91	94
6	Pennsylvania	106	108	103	108	112	117	119	118	103	105	102	109	115	119	112
7	Pennsylvania	—	—	—	—	—	—	—	—	115	102	108	102	105	114	—
8	Pennsylvania	86	103	102	94	105	—	—	—	104	114	97	99	97	91	106
9	Pennsylvania	116	113	113	113	122	—	—	119	116	113	105	109	118	114	108
10	New York	110	112	103	101	105	82	78	110	117	118	109	112	114	109	103
11	New York	133	114	109	111	113	—	—	106	103	126	109	113	109	109	110
12	New York	108	103	108	108	99	—	—	114	93	107	107	102	109	107	105
13	Massachusetts	116	103	97	106	116	—	—	111	101	97	107	110	113	116	106
14	Maine	90	94	86	93	93	73	70	94	90	112	106	96	103	111	109
15	Iowa	91	97	95	—	95	74	68	98	95	107	94	97	89	102	98
16	Ohio	92	98	101	102	99	113	117	108	105	102	107	106	117	99	110
18	Wisconsin	87	76	85	—	—	108	116	99	102	114	94	98	96	102	94
19	Minnesota	99	84	89	92	91	72	82	98	97	100	102	101	110	98	93
20	Nova Scotia	87	86	94	91	89	89	95	92	109	84	109	103	98	102	106
21	New Brunswick	79	95	94	89	81	—	—	94	99	80	97	93	88	102	93
22	Quebec	80	82	86	73	71	74	66	69	92	83	96	81	73	84	83
23	Quebec	78	72	76	91	78	—	—	31	—	—	72	—	86	89	86
24	Ontario	105	123	113	111	120	88	99	94	95	86	105	108	109	101	110
25	Ontario	93	97	90	92	95	—	—	90	—	—	94	—	101	106	88
27	New Hampshire	112	110	—	—	—	—	—	—	—	—	96	94	109	100	101
28	Minnesota	92	94	90	94	89	—	—	—	—	—	—	—	101	112	94
29	Michigan	94	81	85	91	88	—	—	—	—	87	99	93	85	—	—
30	Virginia	81	92	93	—	90	103	88	—	—	—	103	—	71	—	86
31	Wisconsin	98	94	107	102	100	—	—	—	—	—	—	—	—	—	—
32	Michigan	—	—	—	—	—	105	107	—	—	—	—	—	—	—	—
Plantation mean (ft.)		7.1	5.8	9.0	4.8	13.1	10.1	6.0	8.4	6.1	5.3	6.8	6.8	7.4	4.1	6.5

[1]Design I [2]Design II [3]Design III

Branch Angle

The angle of branch growth from the main stem was measured at the third whorl from the top, and our data indicated that most eastern white pine, regardless of seed source, are similar in this particular characteristic. No significant differences were found between latitude of provenance and branch angle in any of our plantings. Branches tended to be fairly flat (60 to 70 degrees from the main stem) in this study.

A few individual trees had a very pronounced fastigiate branching habit, but this was not related to provenance. Because half-sibs were not identified in the final outplantings, it is not known if the fastigiate types within a provenance came from the same parent trees.

Frost Damage

The only planting with a measurable amount of external frost damage was at Paul Smiths, New York, and the difference among seed sources were not significant. On the basis of our observations, we would agree with Wright *(1963)* that winter injury is unimportant, at least as far north as latitude 45°N.

No attempt was made to record internal frost injury, and perhaps this should be considered in future measurements. Fowler and Heimburger *(1969)* found that late spring frosts cause some injury to the cambial initials of eastern white pine branches, but no provenance differences were noted in their southern Ontario plantings.

Snow Damage

Snow damage was observed only in areas where heavy showfalls occur and in slower growing plantations within these areas. The principal damage was separation of lateral branches from the main stem. As the snow encasing the foliage of lower branches settles in the spring, it pulls the branches downward. Damage is usually limited to lower whorls of branches, and permanent external damage rarely occurs on the main stem.

Only in one of the Alfred, Maine, plantings (2-I) were more than a few trees damaged by snow, and provenance was not a contributing factor. Trees from below latitude 40°N had about 12 percent damage, trees from above latitude 45°N had about 10 percent, and provenances between 40° and 45°N sustained about 7.5 percent.

Insects and Diseases

The major disease of eastern white pine is blister rust (*Cronartium ribicola* Fischer), and programs to eradicate the alternate host in the Northeast have been successful in controlling the disease up to the present time. No rust was observed in any of our plantings at the time of remeasurements, but several infected trees were found at Alfred, Maine, in 1970.

No recognized symptoms of other diseases occurred on any of the trees. There were occasional trees with noticeable yellowing or stunted foliage that we attributed to site conditions, air pollutants, and causes other than diseases.

The only serious insect pest on white pine is the white pine weevil (*Pissodes strobi* Peck). Annual spraying of terminal shoots with Lindane in those plantations growing within the natural range of the weevil (Maine, Vermont, New York, north and central Pennsylvania) was highly successful in controlling weevil damage. Only a few trees that did not receive the complete leader drench necessary for weevil control were damaged.

Populations of this insect have been so high in recent years in the Northeast that most of the trees would have sustained major leader damage, and height comparisons would have been virtually impossible without chemical controls. Plantation 2-I at Alfred, Maine, was not sprayed after the tenth year, and all 27 sources had more than 70 percent leader kill within 2 years. No significant correlations were found between provenance and weeviling under these high weevil population pressures *(Garrett 1972)*.

A stem borer, *Eucosma gloriola* Henrich, attacked lateral branches on a number of trees, but caused no dámage to main stems. There were a very few light attacks by aphids and what appeared to be damage by other unknown insects.

A few leaders were broken off by snow or perching birds, and a few buds were removed by birds or squirrels.

Secondary Flushing

Lammas growth has been defined by Rudolph *(1964)* as: "... terminal shoot elongation characterized by one or more periods of growth following the first elongation of the terminal shoot earlier in the season." The condition in which one or more lateral buds at the base of the terminal bud break dormancy and add another flush of growth at the end of the normal seasonal growth is referred to as prolepsis.

Secondary flushing in many species has been observed on trees of southern origin grown in northern latitudes. Genys *(1963)* reported a negative correlation of lammas growth for both latitude and height for 2-year-old white pine in Maryland. In southern Michigan *(Wright et al. 1963)* and in southern Ontario (*Fowler and Heimburger 1969*), the southern provenances produced the fewest lammas shoots. Significant differences were also found between their two plantings in Ontario (28 and 11 percent), suggesting that environmental changes over a short distance can also be important.

We had expected to find considerable late-season flushing in our New York, Vermont, and Maine plantings; but only the southern Maine location has more than a few trees with this type of growth. Lammas growth occurred more frequently than did prolepsis, but there were many trees with both types of secondary flushing.The number of trees in a provenance with late-season growth varied from fewer than 4 to more than 30, but no correlation was found between provenance latitude and lammas growth. The Lake County, Minnesota, source (lat. 48°00′N) had about 9 percent of trees with secondary flushes; the Cass County source (lat. 47°30′N) had almost 31 percent; and Pontiac County, Quebec (lat. 47°30′N), was lowest with slightly more than 3 percent. Tennessee (lat. 36°00′N) ranked second with over 23 percent, while Virginia (lat. 37°00′N) was ranked near the bottom with 5 percent.

Secondary flushing was not recorded for the Kentucky plantation; it was recorded at age 7, but not for age 10 for the Ohio test. In the Ohio plantation, secondary flushing was positively correlated with height ($r = +.662^*$) and negatively correlated with provenance latitude ($r = -.602^*$).

Cone Production

Very few cones were found in any plantation at the end of the tenth growing season, although some female, flowers were reported at Standing Stone, Pennsylvania, by age 7. In 1966 cones were present on more than 30 percent of four northern sources, and two southern sources had no cones. Male strobili did not occur until 5 years after the first female flowers (*Gerhold, H. D., personal communication*).

Results similar to those in Pennsylvania were found in our plantations as far south as West Virginia, where not a single tree in the six sources from below latitude 40°N had produced a mature cone at age 10.

While we have not had a lot of flowering in our plantations yet, there is good evidence of a positive correlation between latitude of provenance and cone production. The number of cones was definitely higher on northern seed sources than on southern sources.

Forks and Offsets

Among the suspected causes of stem deformities recorded under this heading were snow damage, terminal-bud feeding by squirrels and birds, shoot damage by weevils, and possibly frost damage. We found it extremely difficult to assign a cause to stem deformity that occurred in past seasons.

Forks and offsets on main stems occurred on a few trees in all plantations, but such deformities were not related to provenance.

SUMMARY

The results obtained from these plantings and the conclusions reached from them may be summarized as follows:

1. Trees from southern Appalachian sources (Georgia, Tennessee, North Carolina), southeastern New York, eastern Pennsylvania, and southern Ontario should be favored in planting programs at least as far

north as central Pennsylvania (lat. 41°00′N). From central Pennsylvania to southern Maine (lat. 44°00′N), growth of local and southern sources is about equal. Above latitude 45°00′N, the southern Appalachian sources are no longer superior, and Pennsylvania, New York, and local sources should be selected.

2. Needle length is greatest in the southern sources. Because these trees have fewer branches, it may be that total photosynthetic surface does not vary greatly by provenance; however, if photosynthetic surface is greater in southern sources, it could partially explain the superior growth of these sources.
3. Most individual trees have the typical flat branching habit, but fastigiate types not related to provenance do occur.
4. Frost and snow damage is unimportant as far north as latitude 45°00′N. More work needs to be done on the effects of internal frost damage, but it does not appear that this will be correlated with provenance.
5. Diseases were not an important factor in these northeastern tests, and there does not appear to be any relationship between weevil damage and provenance.
6. The relationship of secondary flushing to provenance is not clear; it was more frequent on southern sources in Maryland, but less in Michigan and Ontario. Our results are inconclusive.
7. Cone production was correlated with provenance. Central and northern provenances produced more cones at an earlier age than southern provenances, even in southern plantings.

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