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Geographic variation in eastern white pine, 7-year results in Ontario[1]

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Eastern white pine, Pinus strobus L., is one of the most valuable timber species of eastern North America. Until the last decade little was published concerning the genetic variability of this species.

In 1955, the U. S. Forest Service organized a range-wide provenance study of white pine to examine some aspects of its genetic variability. Four U. S. Forest Experiment Stations, namely the Northeastern, Lake States, Central States, and Southeastern, and the Research Branch of the Ontario Department of Lands and Forests, co-operated in seed collection and seedling production for this study. Much of the information now available on genetic variation in white pines of different geographic origin has been derived from this co-operative effort.

Seed germination: MERCEN (1963) and FOWLER and DWIGHT (1964) reported that white pine seeds of southern origins require longer stratification periods than seeds of northern origins.

Taxonomy: MERGEN (1963) found that seedlings of three southern origins had longer needles and fewer stomata per unit length of needle than seedlings of five northern origins, when both kinds were raised in a controlled environment at New Haven, Conn. WRIGHT, LEMMIEN and BRICHT (1963) reported that, with the exception of one origin from central Maine, eastern provenances had blue-green foliage in the fall, in comparison with the yellow-green fall foliage of northwestern provenances.

Phenology: SANTAMOUR (1960), working with seedlings of 21 origins reported that bud swelling and elongation started at about the same time, but that seedlings of southern origins (Georgia and North Carolina) continued shoot elongation for a longer period than the others. MERGEN (1963) found that seedlings from northern areas with a short growing period required less cold treatment to break winter dormancy than seedlings from southern areas.

SANTAMOUR (1960) reported slightly greater lammas shoot growth in seedlings of southern origin. Contrary to this,

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Wright *et al.* (1963) found that southern provenances tended to produce fewer lammas shoots than northern ones.

Growth rate: Most studies have indicated that seedlings of southern origins grow faster than those of northern origins (Wright *et al.* 1963, Santamour 1960, Sluder 1963, and Funk 1965). However, Pauley, Spurr and Whitmore (1955), working with other materials, found that local (Mass.) white pine outgrew all other provenances, including two from Virginia.

Frost sensitivity: Although Mergen (1963) reported that needles of seedlings of southern origin were more sensitive to artificial freezing than those of northern origins, none of the provenance studies have as yet revealed evidence of natural frost damage.

Individual tree variation: Genetic differences between individual trees of white pine of the same geographic origin have been found in respect to blister-rust *(Cronartium ribicola* Fischer) resistance (Riker, Kouba, Brener and Patton 1953, Heimburger 1956), to weevil *(Pissodes strobi* Peck) resistance (Wright and Gabriel 1959, Heimburger and Sullivan 1969) and to several morphological characteristics (Johnson 1945, Fowler 1965).

In general, white pine appears to be a moderately variable species, both at the individual tree and at the provenance levels in respect to most of the attributes examined.

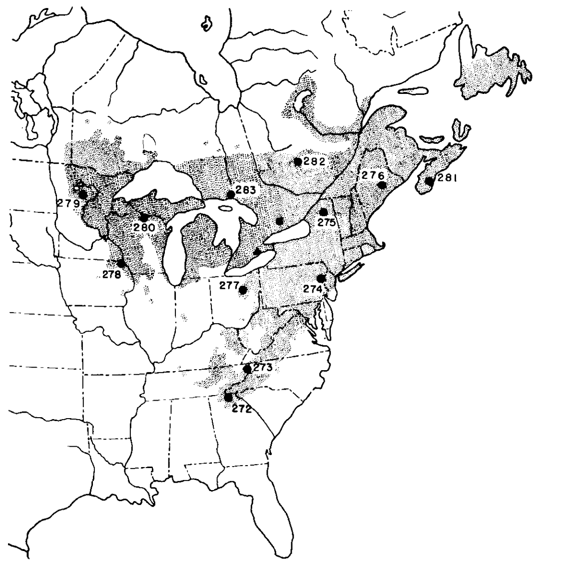


Figure 1. — Map of eastern North America showing the location of the twelve seed sources and two planting sites: Turkey Point (triangle) and Ganaraska Forest (square). The shaded area on the map represents the botanical range of eastern white pine.

Materials and Methods

In the fall of 1958, white pine seeds from 12 sources, were available for provenance studies in Ontario. The location of these 12 sources and climatic data pertaining to the origins are presented in *Figure 1* and *Table 1* respectively. In January, 1959 three lots of 1000 seeds from each of the 12 sources were stratified in moist sand and stored outside in a cold frame. In April, 1959 these seeds were broadcast sown in the Ontario Department of Lands and Forests nursery at St. Williams, Ontario. Three replications of the sowing were made. The seedlings were raised as 2—2 stock. In 1961, at the time of transplanting, top length and root length were measured of 50 2—0 seedlings from each of the three replications of each seed source.

In the spring of 1963, the 2—2 seedlings were set out in two plantations, one at Turkey Point and the other at Ganaraska Forest. The location of the two planting areas is shown in *Figure 1.* Both plantations were laid out as completely randomized blocks, replicated four times. At Turkey Point each block consisted of 11 × 11 (121) seedlings; at Ganaraska Forest 9 × 9 (81) seedlings were used. The seedlings were planted at a 6' × 6' spacing. In August, 1965, after terminal height growth had ceased, total height was recorded for all surviving plants and observations on weeviling, other top damage, forking, blister-rust and lammas shoots were recorded. The summarized data are presented in *Table 2.*

During the period 1963—1966, the plantations were visited at least once each year and casual observations were made to determine winter damage.

In March, 1966, one three-year-old branch was cut from each of five trees in each of the four replications at the Ganaraska Forest and Turkey Point plantations. Trees from only four of the 12 provenances were sampled. They were Georgia, Pennsylvania, Ohio and Ontario. A one-inch branch section containing three growth rings was fixed in F. A. A. Twenty-micron sections were cut from each sample

Table 1. — Description of white pine seed sources*).

Population Number	State or Province	County or District	Latitude °North	Longitude °West	Elevation Feet	Mean January Temperature °F	Mean Annual Frost Free Period Days **)	Mean Seed Weight mg.
272	Georgia	Union	34.8	84.1	2450	40	190	18.7
273	Tennesse	Greene	36.0	82.8	2250	36	172	20.3
274	Pennsylvania	Monroe	41.1	75.4	1800	24	129	20.0
275	New York	Franklin	44.4	74.3	1600	16	110	19.3
276	Maine	Penobscot	44.9	68.6	150	18	142	16.9
277	Ohio	Ashland	40.8	82.3	1000	28	156	18.8
278	Iowa	Allamakee	43.3	91.5	1000	16	152	22.8
279	Minnesota	Cass	47.4	94.4	1300	6	126	15.3
280	Wisconsin	Forest	45.8	88.9	1500	10	90	18.6
281	Nova Scotia	Lunenburg	44.4	64.6	150	20	137	14.4
282	Quebec	Pontiac	47.5	77.0	1000	3	80	13.8
283	Ontario	Algoma	46.4	82.6	650	10	120	17.6

*) Climatic data from: U. S. Dept. Agric. 1941 and Canada Dept. Mines and Tech. Surveys 1957.

**) Mean annual frost free periods were interpolated from climatic maps. They are not identical to length of growing season given by Santamour 1960.

Table 2. — Characteristics of white pine grown at Turkey Point and Ganaraska Forest

2-years old				7-years old												
Population Number	Origin	2—0 Top length	2—0 Root length	Survival		Mean total height normal trees only		Mean total height normal, forked and with lammas shoots		Trees with lammas shoots		Trees with tip moth *(Eucosma)* damage		Trees with weevil damage	
		cm.	cm.	Per cent		cm.		cm.		Per cent		Per cent		Per cent	
				T. P. *	G. F. **	T. P.	G. F.	T. P.	G. F.	T. P.	G. F.	T. P.	G.F.	T. P.	G.F.
272	Georgia	7.0	20.5	98.6	97.8	166	138	166	134	10.9	8.8	2.8	5.4	0	2.6
273	Tennessee	8.4	19.3	97.3	99.7	143	120	142	119	13.5	3.4	3.0	5.6	2.1	3.8
274	Pennsylvania	6.6	20.2	98.8	99.7	144	139	143	137	15.0	8.7	2.5	3.1	0	1.2
275	New York	6.0	21.7	98.6	99.1	134	125	132	122	31.7	12.8	4.8	2.8	0	3.7
276	Maine	5.5	21.2	99.2	98.8	121	114	119	112	31.6	17.6	2.5	4.7	0	3.8
277	Ohio	5.8	21.7	99.0	99.7	147	99	146	99	11.7	1.8	2.9	2.2	0	0
278	Iowa	5.6	22.7	96.5	95.1	101	104	101	102	13.9	7.1	3.4	2.3	.2	2.5
279	Minnesota	5.0	20.2	99.2	99.7	116	105	115	103	71.7	24.1	2.7	1.6	.2	0
280	Wisconsin	5.8	20.7	96.7	99.4	121	110	120	108	29.8	10.9	1.5	3.1	0	1.2
281	Nova Scotia	4.7	22.0	98.2	100.0	140	137	139	133	58.4	14.8	3.6	5.9	.6	0
282	Quebec	4.7	22.8	96.9	99.7	100	110	100	108	19.2	6.8	2.2	2.2	0	5.0
283	Ontario	5.6	22.2	99.4	99.7	124	105	123	100	25.0	14.9	3.6	2.2	.2	0

*) Turkey Point.
**) Ganaraska Forest.

and stained in safranin and fast green. The sections were examined in respect to presence and severity of frost damage. This is essentially the method used by GLERUM and FARRAR (1966). Where frost rings were observed, the numbers of tracheids laid down before the frost ring were recorded. The average number of tracheids laid down was obtained by counting the tracheids along four radii. Frost damage was rated as follows:

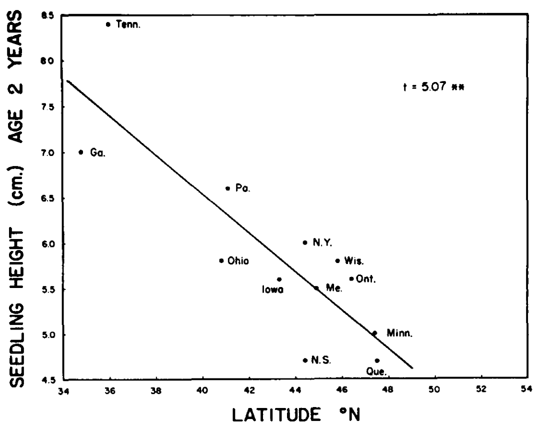
0. no frost damage evident.
1. radial rows of tracheids distorted, no or very few damaged cells.
2. incomplete frost ring present, some damaged cells.
3. frost ring complete, damage mostly confined to one layer of tracheids.
4. frost ring complete, mostly more than one tracheid layer in thickness.

Results

The summarized results of this study are presented in *Table 2* and *Figs. 2 and 3.* At two years of age, highly significant differences in height are evident between the seedlings of the different provenances. The regression of 2-year height on seed weight is significant ($t = 2.55$) but accounts for only part of the difference between provenances. The pattern of 2-year height appears to be clinal and is inversely related to latitude. The regression of 2-year height on latitude is highly significant ($t = 5.07$; *Fig. 2)* and the relationship remains significant when seedling height is adjusted for differences in seed weight ($t = 2.82$). Root length of 2-year seedlings is inversely related ($t = 3.5$) to top length, but the regression of root length on latitude is not significant ($t = 2.00$).

Survival of all provenances in both plantings was over 95 percent. The Iowa provenance had the poorest survival, i. e. 96.5% and 95.1% at Turkey Point and Ganaraska Forest respectively. Damage caused by the white pine weevil, a tip moth *(Eucosma* sp.) and blister rust was light in both plantings and does not appear to be related to provenance.

Highly significant differences in the proportion of trees with lammas shoots are found between provenances as well as between the two plantings. Lammas shoots are more common in all provenances at Turkey Point (28% of trees)



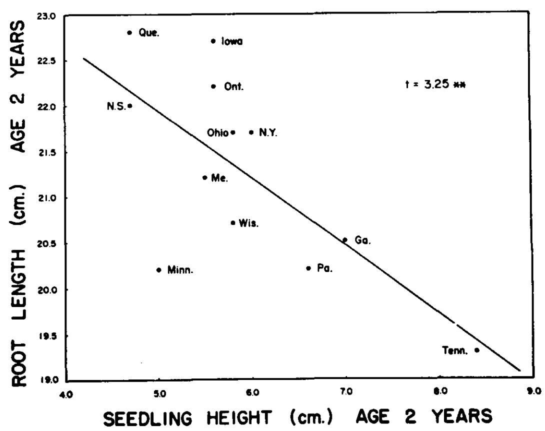


Figure 2. — Regression of 2-year seedling height on latitude (above) and 2-year seedling root length on 2-year seedling height (below).

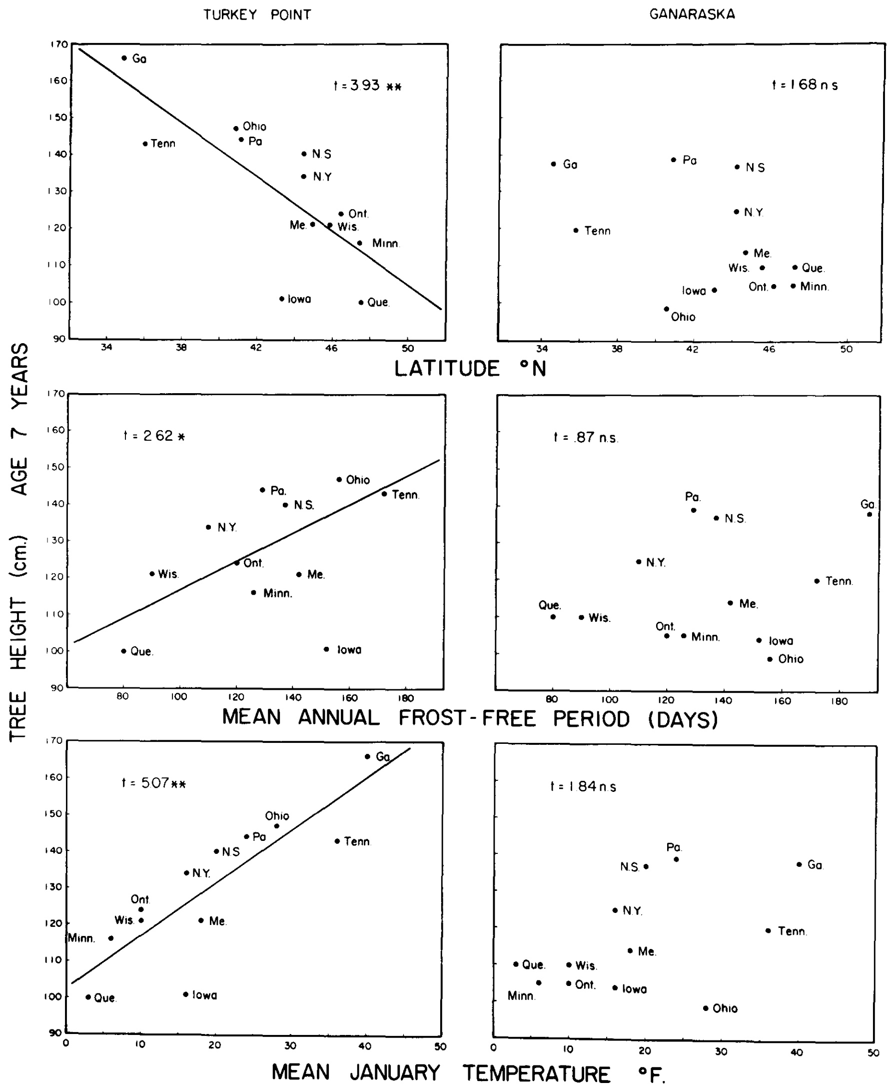


Figure 3. — Regression of 7-year height on latitude (top), frost free period (centre) and mean January temperature (bottom) in the Turkey Point (left) and Ganaraska Forest (right) plantations.

than in Ganaraska Forest (11% of trees). The interaction between provenance and planting area is low. The correlation coefficient of lammas shoot production for the 12 provenances at the two planting areas is r = .85. There is a tendency (not significant) of the southern provenances to produce fewer lammas shoots than of the northern ones. An exception to this general trend are trees from the most northern source (Quebec, Lat. 47.5⁰) which produced relatively few lammas shoots.

Total height at 7 years of trees growing in the Turkey Point plantation is significantly correlated with the following seed-source related variables: latitude (t = 3.93++), mean January temperature (t = 5.07++) and length of frost free period (t = 2.62+). None of these relationships are significant in the trees of the Ganaraska Forest plantation. The regressions are presented in *Figure 3.*

An analysis of variance for average total height at 7 years of trees in the two test plantations is given in *Table 3.* The following results can be obtained from this analysis:

1. The two southernmost provenances (Georgia and Tennessee) differ from the other provenances (1% level) and also differ from each other (5% level).

Table 3. — Analysis of Variance of Average Total Heights.

Comparison among provenances	Provenance test location			
	Turkey Point		*Ganaraska Forest*	
	N	NFL	N	NFL
272, 273 : 274—283	++	++	++	++
272 : 273	+	+	+	nqs
274, 277 : 275, 276, 278—283	++	++	ns	ns
274 : 277	ns	ns	++	++
276, 281 : 275, 278—280, 282, 283	+	+	++	++
276 : 281	ns	+	+	++
278, 279, 280 : 275, 282, 283	ns	ns	ns	ns
278 : 279, 280	+	ns	ns	ns
279 : 280	ns	ns	ns	ns
275 : 282, 283	+	+	+	+
282 : 283	+	+	ns	ns

N = normal trees only
NFL = normal plus forked plus with lammas shoots
++ = significant at 1% level
+ = significant at 5% level
nqs = not quite significant at 5% level
ns = not significant at 5% level

2. The Pennsylvania and Ohio provenances differ (1% level) from the other provenances at Turkey Point, but the difference is not significant in Ganaraska Forest. However, they differ from each other (1% level) in Ganaraska Forest, but not at Turkey Point.

3. The two maritime provenances (Maine and Nova Scotia) differ significantly (5% level at Turkey Point and 1% level in Ganaraska Forest) from the other provenances and (1% level to n. s.) from each other.

4. There is little significant difference among the three westernmost provenances (Iowa, Minnesota and Wisconsin) and between them as a group and the Ontario-Quebec-New York group.

5. The New York provenance differs (5% level) from the two Canadian provenances which differ (5% level) from each other at Turkey Point, but not in Ganaraska Forest.

Casual observations of the white pine plantations in Ganaraska Forest and at Turkey Point during the period 1963—1966 did not reveal any evidence of external damage caused by low temperatures. The foliage of the trees of all provenances retained its normal coloration throughout the year. Despite the lack of external evidence of frost damage, microscopic examination of branch sections revealed damage by low temperatures in many of the trees of the four provenances examined. The injury which expressed itself as a frost ring apparently resulted from late spring frosts that killed or damaged the cambial initials (GLERUM and FARRAR 1966). Such an injury is shown in *Figure 4*. Frost rings were found within the 1965 annual ring of the trees growing in the Ganaraska Forest while those growing at Turkey Point had frost rings in both the 1964 and 1965 annual rings.

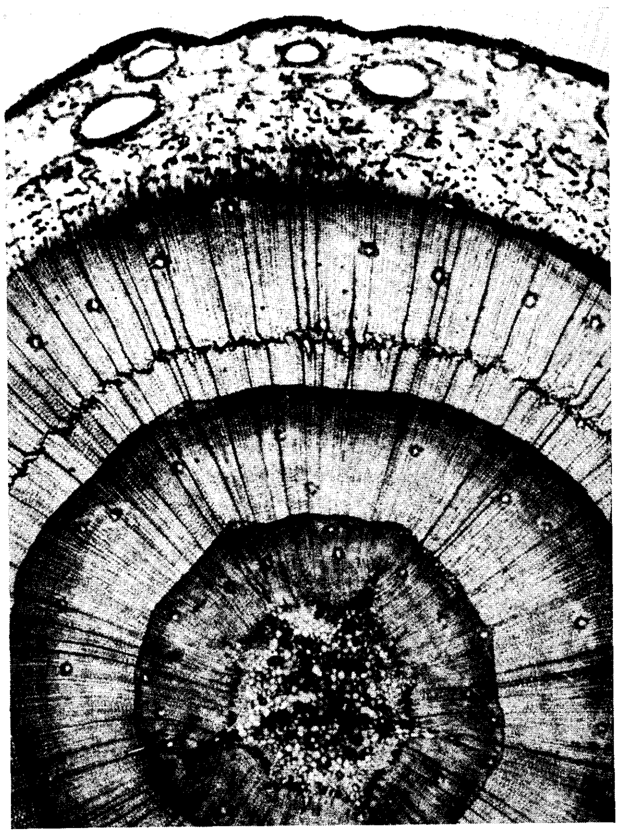


Figure 4. — Branch cross-section from a tree of Ohio origin grown at Ganaraska Forest showing a frost ring. The frost ring damage rating is four.

The degree of frost damage and numbers of tracheids produced before frost ring formation in the trees of the four provenances examined are given in *Table 4*. With the possible exception of the trees of the Ohio provenance there was little difference between provenances in the degree of frost damage. The southern (Georgia) and northern trees (Ontario) were similar in their response to late spring frosts. The trees of the Ohio provenance were more severely damaged in Ganaraska Forest than the others while little or no difference between provenances in this respect was found in the Turkey Point planting.

Table 4. — Cambial frost damage and numbers of tracheids produced before frost ring formation in white pine trees of four provenances growing at Turkey Point and in Ganaraska Forest.

Population Number	Origin	Degree of frost damage to cambium			
		Ganaraska Forest		*Turkey Point*	
		1964	1965	1964	1965
272	Georgia	0	2.5	1.0	.8
274	Pennsylvania	0	2.4	1.2	.6
277	Ohio	0	3.3	1.3	.1
283	Ontario	0	2.5	1.1	.7
		Average number of tracheids before frost ring			
		Ganaraska Forest		*Turkey Point*	
		1964	1965	1964	1965
272	Georgia	0	13	14	15
274	Pennsylvania	0	15	13	17
277	Ohio	0	12	15	16
283	Ontario	0	14	16	16

Although considerable variation (range: 9—25 tracheids) was found among the trees of each provenance in the number of tracheids produced before the frost ring, little or no difference was found between provenances. In none of the 160 trees examined for internal frost damage was it considered serious. In all cases it was evident that some cambial initials had survived or were regenerated fairly rapidly and that the effect of the frost damage on radial growth had been of short duration. The regression of 7-year height on 2-year nursery height (adjusted for seed weight) was significant for the trees growing at Turkey Point ($t = 2.42$) and not significant for those at Ganaraska Forest ($t = 1.49$). *Table 5* shows the ranking of the provenances in order of decreasing height in the nursery and the two plantations.

Table 5. — Ranking of provenances in order of decreasing height.

2-Year Height	2-Year Height adjusted for seed weight	7-Year Height: Turkey Point	7-Year Height: Ganaraska Forest
Tenn.	Tenn.	Ga.	Pa.
Ga.	Ga.	Ohio	Ga.
Pa.	Pa.	Pa.	N. S
N. Y.	{Me.	Tenn.	N. Y.
Ohio	P. Q.}	N. S	Tenn.
Wisc.	{N. Y.	N. Y.	Me.
Iowa	Minn.	Ont.	{Wisc.
Ont.	Ont.}	{Me.	P. Q.}
Me.	{Ohio	Wisc.}	{Ont.
Minn.	N. S	Minn.	Minn.}
N. S.	Wisc.}	Iowa	Iowa
P. Q.	Iowa	P. Q.	Ohio

Discussion

As was to be expected, the 2—0 height of white pine seedlings was inversely related to latitude of origin. Seedlings of southern provenances were taller than those of northern provenances, even after adjustments had been made to compensate for differences in seed weight. The results obtained from the measurement of root lengths of 2—0 seedlings are unexpected. The regression of 2—0 root length on 2—0 top length is negative and highly significant ($t = 3.25$). Seedlings with the longest tops had the shortest roots.

Under normal growing conditions and when seeds of a local source are used, a relatively high proportion of root development takes place toward the end of the growing season. It is possible that seedlings of southern provenances, when grown in a northern area, are unable to produce their normal amount of roots before the weather becomes unfavourable for this. This could explain the relatively, but not the absolutely, shorter root system of the seedlings of southern provenances. It would be of interest to know if this low root/top ratio of southern provenances is maintained in older seedlings and trees. If this pattern of growth continues, it could result in reduced top growth and lack of wind firmness. No evidence of this has been observed in the test plantations thus far.

Sluder (1963) and Wright *et al.* (1963) observed significant differences in seedling survival between provenances. These differences did not appear to be related to latitude of origin. Wright, *et al.* (1963) found highest mortality to be associated with the two slowest growing (northern) and the two fastest growing (southern) origins. The poor survival was attributed to the poorly developed root system of the slow-growing materials and to the very deep root system (which had been damaged in lifting) of the fast-growing materials. In our studies, there were no adverse effects of provenance on survival, in spite of what appeared to be a rather inferior root/top ratio of seedlings of southern provenances. Mortality of seedlings of all provenances was less than five per cent. Seedlings of the Iowa source, with an above average root/top ratio had the poorest survival. Seedlings from this source had an above average survival when planted in North Carolina (Sluder 1963).

It is evident from the results of these and other provenance tests with the same or similar white pine materials, that variation in height growth follows a climate-dependent cline. Height growth of the provenances studied is inversely related to latitude and directly related to mean January temperature and length of growing season of the place of origin. This pattern of development apparently holds true for planting areas where climatic or other factors do not have adverse effects on survival and growth.

Of the several provenance tests that have been reported as part of the range-wide study (Wright *et al.* 1963, Sluder 1963, Funk 1965) the Ganaraska Forest test is thus far the only one showing adverse effects of what seems to be a northern climate on trees of relatively southern origin.

It is of interest that the trees examined there did not exhibit any external evidence of frost damage. There was no needle browning nor bud damage such as often occurs in other pine species when raised in a too severe environment. Internal frost damage, as expressed by frost rings, did occur in many of the trees examined. However, it was about as frequent and of the same severity in both the most southern and northern provenances. Frost rings were found in trees of both the Ganaraska Forest and Turkey Point plantations. Only the trees of the Ohio provenance, growing in the Ganaraska Forest, appeared to have been more severely damaged by frost than trees of the other provenances examined. The nature of the frost rings and the rapid regeneration of the cambial initial make it improbable that freezing temperatures in late spring had any measurable effect on tree growth. It is doubtful if this could account for the considerably reduced height growth of the trees of Georgia, Tennessee and Ohio provenances in the Ganaraska Forest.

The conditions causing formation of frost rings likely were effective on all the trees of all provenances at the same date within each planting area. Any difference in the number of tracheids produced before the frost ring should indicate differences in time of radial growth initiation or rate of subsequent cambial activity. Although considerable variation in the number of tracheids produced before the frost ring was evident among the trees of every provenance, there was little if any difference between provenances in this respect. This may be in agreement with Santamour (1960) who reported bud swelling and elongation to have started on or about the same date for seedlings of all the 21 provenances he studied.

The interaction between the Ohio provenances and the two planting areas is of interest. At Turkey Point trees of this source were second only to those from Georgia in height growth while in Ganaraska Forest they were the shortest. As mentioned above, the Ohio provenances appeared to have received more severe internal frost damage, in the Ganaraska Forest than the other provenances. It is not probable, however, that such a relatively small difference in internal frost damage (see *Table 4)* could have a casual connection with the poor height growth of this provenance in Ganaraska Forest.

The seedlings and trees of the Iowa provenance also should have performed better at both test areas, based on the climate of their origin. Trees of this source were mediocre in provenance tests established in Illinois, Indiana, Iowa, Kentucky and Ohio (Funk 1965) and showed only mediocre growth performance in North Carolina (Sluder 1963). White pine in Iowa is at the southwestern limit of the present species range. In this area the species is generally found as scattered single trees or in small groups. It is conceivable that under such circumstances white pine has experienced gene depauperation during postglacial migration and establishment and that present populations also exhibit inbreeding depression. This may, in part, account for the poor showing of this provenance in most tests.

It has been suggested (Fowler and Dwight 1964) that a distinct maritime ecotype of white pine may exist. This suggestion is based on the similarity of the New Brunswick provenance of Mergen's (1963) study and the Nova Scotia provenance of the study of Fowler and Dwight (1964) in response to seed stratification. The two maritime provenances (Nova Scotia and Maine) of this study differ significantly from other provenances and from each other in respect to height growth. (See *Table 3)*. There is no great similarity of these two provenances in response to seed stratification (Fowler and Dwight 1964). If there is a distinct maritime ecotype of white pine, it apparently is not found in central Maine.

The relationship between provenance and lammas shoot production remains obscure. There is a weak tendency of trees of southern provenances to produce fewer lammas shoots than those of northern provenances. This is in general agreement with Wright *et al.* (1963) for provenance tests in the Lake States and contrary to Santamour's (1960) observations in New Jersey. The relationship of provenance and lammas shoot production is not strong and is possibly influenced by planting area, site and local weather conditions.

On the basis of 7-year height, it appears that the selection of rapid growing provenances based on nursery performance would have been satisfactory for both the Turkey Point and the Ganaraska Forest planting sites. The three provenances which grew most rapidly in the nursery are among the four and five fastest growing provenances at Turkey Point and Ganaraska Forest respectively. The apparent success of such a nursery selection is probably an illusion as the average and slow growing provenances did not maintain their relative rankings from the nursery to the planting site. The change in ranking was such that the regression of 2-year on 7-year height was not significant for the Ganaraska Forest material. It is doubtful if selection of provenances based solely on nursery performance is reliable enough to warrant the risk of plantation failure. Continued plantation examination will be required to obtain a reliable evaluation of the various provenances as a source of seeds for reforestation.

Recommendations

Results from white pine provenance tests carried out in the Central States (Funk 1965) and in Lake States (Wright *et al.* 1963) indicate that southern Appalachian white pine can be safely planted considerably to the north of its natural range. We would hesitate to recommend the use of southern Appalachian white pine in Ontario for the following reasons:

1. The provenance tests have been under way for a period of only seven years. The plantations will very likely be subjected to considerably more variation in climate before they reach rotation age. We do not known as yet how the trees will respond to these conditions.

2. It is evident, from our data, that several southern provenances. including the Appalachian, when grown in the Ganaraska Forest, are being adversely affected by some environmental factor or factors. This is most likely a response to the more severe climatic conditions found in Ganaraska than at Turkey Point.

3. Although this study did not indicate any relationship between weeviling and provenance, we strongly suspect that trees of the more southern provenances will prove to be more seriously damaged by weevil than of the northern ones.

Rather than recommend that white pine seed from the southern Appalachian area be used for reforestation in southern Ontario, we would recommend the use of seed of Pennsylvania origin. This provenance has shown the best height growth in Ganaraska Forest and is one of the best at Turkey Point. However, future observations on weevil damage may change this conclusion to a considerable degree.

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Summary

The U. S. Forest Service in co-operation with the Northeastern, Lake States, Central States and Southeastern Forest Experiment Stations, and the Research Branch of the Ontario Department of Lands and Forests, initiated a series of range-wide provenances of white pine (*Pinus strobus* L.) in 1955. The 7-year results of such tests in Ontario are presented. Seeds from 9 sources in the U. S. and 3 in Canada were sown in 1959. Two-year seedlings from southern sources were larger than those from northern sources, with root length being inversely related to top length. Two test plantations were established in 1963, one at Turkey Point, in southern Ontario, and one in Ganaraska Forest, in south-central Ontario, and examined in the fall of 1965. Lammas shoots were more frequent at Turkey Point, with significant differences between provenances, the southern generally producing fewer than the northern. Total height at age 7 was significantly correlated with latitude, mean January temperature, and length of frost free period of place of origin in the Turkey Point plantation while these relationships were not significant in Ganaraska Forest. The lack of significant superiority in height growth of the southern provenances in Ganaraska Forest is thus far the only example in this range-wide study of seemingly adverse effects of a northern climate on trees of relatively southern origin. No external frost damage was observed in either plantation during 1963—66. Internal frost damage, in the form of frost rings, was found in branches collected early in 1966, in both plantations, with little difference between provenances. The regression of 7-year height on 2-year nursery height, adjusted for seed weight, was significant for the trees at Turkey Point, but not significant in Ganaraska Forest. Because of their performance in Ganaraska Forest the most southern provenance of white pine used in this study are not recommended for planting in Ontario.

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