esters and National Science Foundation from 1961 to 1966. At the University of Minnesota this concern expressed itself by his active role in University and School of Forestry affairs. As a teacher he was superb. He possessed the intuition and patience needed to guide students and yet encourage their independence of thought. When necessary he could be severe, but his criticism was always tempered with kidness.

Always interested in the development of scientific literature, Dr. PAULEY served on the editorial board of Forest Science from 1957 to 1958 and was an associate editor of the Journal of Forestry from 1960 to 1963. He was editor of Minnesota Forestry Notes and special publications and authored numerous book reviews.

He served on the advisory committee of the Quetico-Superior Wilderness Research Center. Professor PAULEY was a member of the American Association for the Advancement of Science, American Institute of Biological Sciences, the Genetics Society of America among other professional organizations and took an active part in the Society of American Foresters.

Dr. PAULEY is survived by his widow FRITZI, his mother FLOSSA, his daughter Mrs. NAN PAULEY JOHNSTON, three grandchildren, and a brother, JACK. It was his wish that his ashes be dispersed on Loon Lake near Grand Rapids, Minnesota where he had enjoyed the beauty of nature and life at his summer residence. He was a great humanist and his students and associates deeply cherish his memory.

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Genetic Variability in Eastern White Pine from Michigan

6-Year Results

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In former days eastern white pine (Pinus strobus L.) was the principal northern timber tree. It grew to large sizes and its wood was durable, easily worked and able to retain its shape after seasoning. Partly for those reasons and partly for its delightful appearance it was chosen as Michigan's state tree. The same qualities that made it important 80 years ago make it a valuable species to plant today.

Results from two range-wide provenance tests indicate that trees from the southern Appalachians grow fastest, even as far north as Pennsylvania and southern Michigan (WRIGHT et al., 1963; FUNK, 1965; GENYS, 1968). In the northerly parts of the Lake States, however, more northerly origins are preferable (KING and NICNSTAEDT, 1968). Published American inheritance data are limited to studies of half-sib progenies of Wisconsin parents selected for resistance to white pine blister rust; parent-progeny correlations were not significant but there were differences among progenies in resistance (PATTON and RIKER, 1966).

Aims *and* Methods

Through their 11th year, eastern white pines from southern states have grown well in southern and central Michigan. Perhaps they will continue to grow well and will be recommended for commercial planting. Perhaps they will succumb to a cold winter. If that happens, northern white pines must form the basis for long-term improvement programs aimed at northern areas. This experiment was undertaken to assess the genetic variability present in Michigan's native stands. If there is sufficient variability,

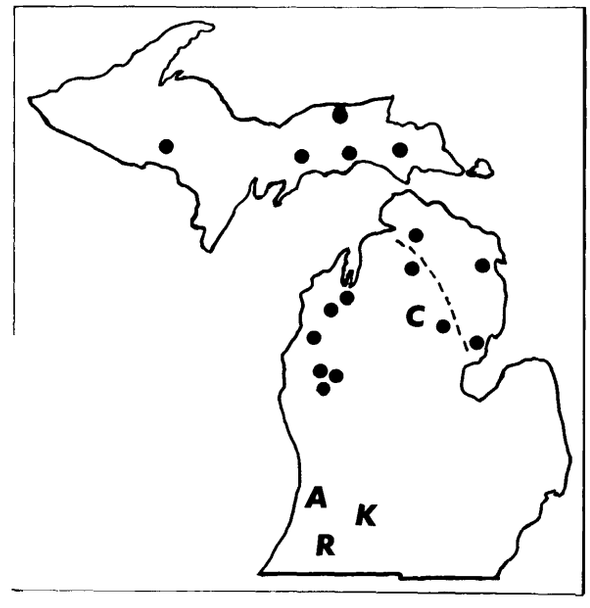

Figure 1. — Distribution of the parental stands (black circles) from which the half-sib progenies were obtained. The four measured test plantations are shown as A = Allegan, C = Crawford, K = Kellogg and R = Russ. The dashed line is an arbitrary separation of the northeastern and west-central portions of the Lower Peninsula.

the plantations are designed to serve also as seed orchards and breeding arboreta.

In the autumn of 1960 open-pollinated seed was collected from 123 native trees in 17 stands in 15 Michigan counties (Figure 1). Some collectors tried to select superior parents but could not; few native stands in the state contain enough trees growing under uniform conditions to permit meaningful phenotypic selection.

The seeds were given a 10-day cold water stratification treatment and sowed in the university's research nursery in the spring of 1962, using a 5-replicate randomized complete block design. Each plot was a 4-foot row con-

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taining about 50 seedlings; the rows were 1 foot apart. Unforeseen building needs caused the transfer of the year-old seedlings to the Southern Michigan (state) Nursery near Brighton the following spring. Again a 5-replicate randomized complete block design was used. The transplants were lined out in 24-tree rows 4 feet long and 1 foot apart. Four (three of them have been measured) experimental plantations were established in 1965 with 1—2 stock *(Figure 1)*. The remaining trees were returned to East Lansing and used as 1—2—1 stock for the establishment of four more (one measured at this time) plantations in 1966.

Each test plantation follows a randomized complete block design with 4-tree plots and 8 × 8-foot spacing. One on a light sandy soil with little weed competition received no weed control; the others were sprayed with aminotriazole and simazine to give the trees weed-free conditions their first year.

All trees for a single plantation were lifted from the same nursery replicate. Thus, in spite of replication within a plantation, some differences among single-tree progenies could be non-genetic due to persistent nursery effects. This deficiency in design makes it necessary to place a conservative interpretation on interactions between single seedlots and planting sites (such interactions were slight). It does not affect interpretation of data gathered about groups of seedlots or the average performance of a seedlot in all planations.

We attempted no correction for seed size because of recent experience with four other pine species in which the seed-weight effect was not important.

Growth Rate

The nursery experiment was a good one. Growth conditions were uniform — the standard error of a seedlot mean was an acceptably low 3 percent. The 1-1 trees averaged 12 centimeters tall, being slightly shorter than 2-0 commercial seedlings grown in the state. At age 3 they averaged 26 centimeters in height, larger than 2-1 commercial stock.

Table 1. — Average mortality, height, and reliability of seedlot means at age 6 in four test plantations.

Plantation	Year planted	Mortality	Height	Standard error of seedlot mean
		percent	*cm.*	*percent of mean*
Crawford County	1966	12	41	13
Fred Russ Forest	1965	20	46	16
Allegan County	1965	9	50	7
W. K. Kellogg Forest	1965	6	60	9

Of the four plantations which have been measured, that in Crawford County was the shortest, probably because it was planted a year later *(Table 1)*. The plantation at the Fred Russ Forest was next slowest growing, had the highest mortality and was the most variable, probably because first-year weed control was only partially effective. The effects of transplanting shock were evident in the higher standard errors for the plantations than for the nursery.

The same four seedlots were tallest at ages 2 and 6. Of the 18 tallest seedlots at age 2, 16 were above average at age 6. These examples illustrate the high correlation between nursery and plantation performance which is also evident in *Table 2*.

Most of the genetic variation was associated with region of origin *(Table 2)*. Trees from Michigan's Upper (northern) Peninsula grew slowest and trees from the west-central counties of the Lower Peninsula grew fastest. Differences among individual-tree progenies from the same

Table 2. — Relative heights of eastern white pine from 15 Michigan counties at age 2 (nursery) and age 6 (plantations).

County of origin	Relative height at					Mean for four plantations
	Nursery	Crawford County	Russ Forest	Allegan County	Kellogg Forest	
UPPER PENINSULA						
Iron	88	88	87	83	84	86
Luce	88	69	87	81	78	79
Schoolcraft	89	89	77	79	87	81
Mackinac	88	78	80	88	89	84
Chippewa	82	75	72	83	80	78
Average	88	85	80	82	84	82
NORTHEASTERN LOWER PENINSULA, BORDERING LAKE HURON						
Cheboygan	98	85	88	89	93	89
Iosco	83	69	96	92	96	88
Alpena	101	81	98	97	103	95
Average	94	81	94	94	98	92
WESTERN AND CENTRAL LOWER PENINSULA						
Otsego	105	100	111	99	125	109
Ogemaw	106	91	117	115	111	109
Lake	106	118	117	100	107	110
Lake	112	113	105	113	112	111
Manistee	103	114	112	112	100	110
Newaygo	100	115	109	107	104	109
Grand Traverse	104	101	102	108	101	103
Grand Traverse	106	101	91	104	104	100
Average	106	109	106	106	105	106
Grand average, cm.	12	41	46	50	60	49

stand were significant (1 percent level) only at the Kellogg Forest. There they accounted for 9 percent of the total variance whereas differences among stands accounted for 59 percent.

Four stands in Lake, Manistee, Newaygo- and Grand Traverse counties (west-central Lower Peninsula) had been selected for phenotypic excellence in form and growth rate by experienced area foresters. In fact, three of those stands were thinned to serve as seed production areas. Judging from the 6-year data, the selection was ineffective; some of the seed production areas produced less vigorous trees than did average stands 50 to 100 miles away.

Two stands in Grand Traverse County produced noticeably smaller trees than did some other stands from the same region *(Table 2)*. An analysis of variance was performed, using stand-progeny means within plantations as items, to determine whether such between-stand-within-region differences were significant. They were (5 percent level). However, they accounted for much less of the total variation than did differences among regions of origin. That is shown in the following tabulation.

Source of variation	percent of variance
Stand of origin within region	7*
Region of origin	68**
Stand × plantation interaction	25

*, ** = significant at 5 or 1 percent level, respectively.

Considering the absence of overlap in height, it is best to think of the populations from the three regions as separate ecotypes. The Upper Peninsula ecotype is separated from the other two by the Straits of Mackinac joining Lakes Michigan and Huron. The Straits provide a barrier more than four miles wide from forest to forest. The slower growth rate of the Upper Peninsula population is undoubtedly an adaptation to the generally colder conditions prevailing there.

Within the Lower (southern) Peninsula, there is no range discontinuity to explain the genetic differences between the northeastern and west-central populations. Those regions have the same gamut of climatic factors such as January temperature, length of growing season and distribution but their soils differ. According to DONALD P. WHITE, soils in the northeastern counties bordering Lake Huron are generally less well drained and less favorable for pine than are soils to the south and west. Natural selection in the northeastern counties may have favored types with shallow root systems rather than types with rapid growth.

PELLATI (1967) reported on a 7-year-old half-sib progeny test conducted in Italy, using seed collected from planted Italian trees. There were significant differences among progenies but those may reflect the (unknown) geographic origin of the parents.

Unpublished results supplied by HOWARD KRIEBEL of the Ohio Agricultural Research and Development Center are more nearly comparable to the present data. His data are from 3-year-old half-sib and full-sib progeny tests of native trees in a northeastern Ohio stand. The experiment was well replicated at Wooster, Ohio. There were significant differences among families derived from the one stand.

Practical recommendations may be superseded if southern Appalachian trees continue to grow well. For the present, growers in southern Michigan (possibly northern Michigan also) who want to use Michigan seed should collect it in the west-central portion of the Lower Peninsula, or be faced with a 10 to 25 percent loss in growth rate. Heritability of growth rate seems so low that attempts to select superior trees or superior stands on the basis of phenotype will be ineffective.

The plantations were established with the thought that they would be thinned to the best families and be converted into seed orchards. This will be done but genetic gain will probably be nil or small. The seed produced will be of the same quality as that obtainable from certain natural stands. The data do not indicate that clonal seed orchards or full-sib progeny tests would have resulted in greater gain.

Lammas Growth

The progenies were similar in other growth traits except for lammas shoot development. In the nursery but not in the plantations, a large percentage of trees produced new shoots in midsummer from seemingly dormant buds, particularly in replicates near water lines.

Progenies from the three regions of origin differed significantly in frequency of lammas growth, Upper Peninsula seedlings having the lowest frequency. The average (and range of stand means in parentheses) percents were:

Upper Peninsula	16.4% (14 to 20%)
Northeastern Lower Peninsula	21.0% (19 to 27%)
West-central Lower Peninsula	23.5% (19 to 28%)

The regional differences were not, however, as marked as in the case of height growth.

A breakdown of the variance components following analysis of variance of the nursery data indicated that:

Parent-within-stand accounted for 8% of total variance,
Stand of origin accounted for 41% of total variance,
Replicate accounted for 6% of total variance, and
Error accounted for 44% of total variance.

"Stand of origin" and "Replicate" were significant at the 1 percent level; "parent-within-stand" was significant at the 5 percent level.

Lammas growth is sometimes regarded as undesirable because it may suffer winter injury if it does not harden properly. This did not happen in the present experiment, nor was there an effect on total height growth.

Abstract

A half-sib progeny test of eastern white pine included offspring of 123 native trees from 15 Michigan counties and four test plantations in Michigan. There was a strong correlation between height at age 2 and height at age 6. Trees from the west-central Lower Peninsula grew 15 percent taller than trees from the northeastern Lower Peninsula; they in turn grew 12 percent taller than trees from the Upper Peninsula. Height differences among families from the same stand were not significant and progenies from selected stands were no taller than average. Lammas shoot development was greatest in trees from the west-central Lower Peninsula but the differences among ecotypes were not so marked as in the case of height growth.