GEOGRAPHIC VARIATION OF GROWTH AND WOOD PROPERTIES IN EASTERN WHITE PINE -- 15-YEAR RESULTS

Chen Hui Lee[1]

Eastern white pine (*Pinus strobus* L.) is the largest of eastern conifers and has been an important tree marketed for much of the nation's history. It attains a height of over 100 feet with straight and clear bole. Its wood is straight grained, relatively soft and suitable for a variety of uses. Aesthetically, it is a desirable shade tree as well as a member of the wild community. Numerous plantations have been established outside its natural range such as in Romania, Germany, England, Italy, Japan, and New Zealand.

The United States Forest Service initiated a range-wide provenance study to provide genetic information in summer 1955. Seeds were collected from 31 natural stands throughout the species range in fall 1956. Each of the five participating experiment stations (four U.S. and one Canadian) received some of the seedlots to establish study plantations within their district. The Northeastern Forest Experiment Station received 15 seedlots and grew them for two seasons in the Maryland State nursery near Baltimore, Maryland. In the spring of 1959, planting stock was shipped by air to Michigan State University, where it was grown for an additional year.

That 2-1 stock was used to establish the W. K. Kellogg plantation near Kalamazoo, southwestern Lower Michigan in April 1960. The plantation follows a randomized complete block design with 10 replications, each of which contains 15 four-tree plots. An 8 X 8 foot spacing was used. Altogether 600(= 15 X 4 X 10) trees were split-planted in a fertile, slightly rolling loamy soil. Immediately after planting, the plantation was sprayed with Simazine at the rate of 4 pounds per treated acre. The entire area was treated with Amitrol-T (1 pint per 4 gallons) and Simazine (2 pounds per treated acre) during the third year. DDT emulsion (2 gallons to 100-gal water) was also sprayed on the leaders for white pine weevil control. The 6-year and 10-year results were reported elsewhere (Wright et al. 1963; Wright, 1970).

The present paper was intended to report up-to-date growth data, to furnish new genetic information on the geographic variation pattern of the selected wood properties and to analyze growth-wood properties relationships.

MATERIAL AND METHODS

I measured total height to the nearest 1/4 foot and diameter 1 foot from the ground to the nearest 0.1 inch on two tallest trees per plot in August 1971. Sampling of the study material for wood properties was conducted at the same time. An increment core specimen was extracted from the north side of the largest tree (by diameter) per plot at stump height with a 0.5-cm caliber borer.

[1] Associate Professor of Forestry, College of Natural Resources, University of Wisconsin, Stevens Point, Wisconsin 54481. This project was financed by the 1971-72 State Universities Research Fund.

After debarking, I removed the 1969 growth increment from the core sample and split each core radially into two halves: one for specific gravity and the other for tracheid length study.

Alcohol-benzene extractives were removed from the study material because their presence tends to overestimate specific gravity. Specific gravity was determined at the Division of Timber Utilization Research, Forest Products Laboratory, Madison, Wisconsin, following Smith's recommendation (1954). The saturated weight (Mm) and oven dry weight (Mo) were obtained to the nearest 0.1 mg in a constant temperature and constant humidity room and specific gravity (G), defined as the ratio of oven dry weight to the green volume, was computed from the following formula:

$$G = \frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{1.53}}$$

I macerated wood fibers in an equal mixture of glacial acetic acid and 30 percent hydrogen peroxide at 50-55 °C for 48 hours. After several changes with distilled water, the macerated fibers were stained with 1 percent Bismarck Brown Y aqueous solution overnight and then mounted on slide glasses without dehydration (Echols, 1969), measured to the nearest millimeter under the Bausch and Lomb No. 2700 projector with 80x magnification at the Stevens Point University Laboratory. Mean length of 20 tracheids was used as items for statistical analysis.

GROWTH DIFFERENCES

Eastern white pine is a genetically variable species. Wright et al., (1963) summarized the 6-year results and reported significant between-seedlot differences in a number of growth characters based on 15 provenances outplanted in two Lower Michigan test sites.

Growth Rate - Between-seedlot differences were significant at the 1 percent level (table 1). At age 15 from seed, the Tennessee seedlot continued to demonstrate its superior growth rate over others. In general, southern Appalachian provenances grew fast and showed no sign of winter injury at the Kellogg study plantation.

A considerable change in the growth pattern has occurred to Tennessee trees (seedlot 3). In 1961 (5 years old from seed) they were 90 percent taller than the shortest seedlot. This figure has declined to 81, 31, and 23 percent, respectively, when height growth was remeasured in 1962, 1966, and 1971. The steady decline in superior height growth of southern origins was also reported by Funk (1971). In the northeastern Iowa plantation, Georgia white pine still was tallest at plantation age 10, but only 39 percent taller than the shortest origin. It was 81 percent taller at age 6, however. Continued observation on the growth pattern may be necessary since the studies suggest that changes in relative height can occur in the future.

Table 1.--Growth and wood characteristics of the 15 *Pinus strobus* provenances.

Seed Origin	Height at age 15	Dia- meter	Ht/dia ratio	Specific gravity	Tracheid length
	cm	cm	cm/cm	number	mm
1-GEO	780	15.2	51	.259	2.20
3-TENN	802	16.0	50	.276	2.18
6-PENN	776	16.0	49	.270	2.17
9-PENN	757	15.4	49	.265	2.17
10-N Y	801	15.3	52	.280	2.18
12-N Y	712	13.2	54	.249	2.19
13-MASS	744	16.2	46	.253	2.23
14-MAINE	693	12.7	55	.261	2.20
19-MINN	652	13.0	50	.258	2.20
20-N S	700	13.9	50	.261	2.21
21-N B	688	13.5	51	.255	2.18
24-ONT	777	15.3	51	.271	2.17
25-ONT	747	15.2	49	.256	2.21
28-MINN	696	13.3	52	.262	2.14
29-MICH	657	13.0	51	.257	2.18
Mean	732	14.5	51	.262	2.19
F*	7.79	8.52	2.41	2.33	0.40

* F values must exceed 2.30 for significance at 1% level with 14 and 121 degrees of freedom for seedlot and error respectively.

My study, as well as a number of earlier findings (Wright, 1970; Funk, 1965), supported the fact that southern Appalachian origins grow faster than others. In a 2-year, replicated Maryland nursery study for 99 origins, Genys (1968) concluded that the fastest growing white pine trees were from regions with a long frost-free period such as South Carolina. He also obtained significant internursery correlations (at the 1 percent level) for 1 year in Pennsylvania, Germany, and Australia. His results imply that there is a strong tendency for certain origins to grow fast at all test sites.

It is important to mention that all of the above test sites are characterized by relatively mild winters. How do those southern Appalachian white pine trees perform under severe winters? King and Nienstaedt (1969) presented an important story. Based on 5 years of observation at the four Lake States test sites, trees from southern Wisconsin and Michigan grew well but those from Georgia and Tennessee (seedlot° 1 and 3) grew poorly. The four test plantations range from 44 to 47 N in latitude and from 2 to 20° F in mean January temperature.

The rank correlation coefficients were weak (smaller than 0.50) between Lower Michigan and any of the other three test sites (Minnesota, northern Wisconsin and Upper Peninsula), however, the correlation was strong between Lower Michigan and Central States and between Lower Michigan and North Carolina plantations. Mean January temperature was suggested as an important guide in selecting seed sources for planting purpose in the northern Lake States area.

The adverse condition of the northern climate was similarly illustrated by Fowler and Heimburger (1969). They provenance tested 12 white pine seedlots at the two Ontario sites. At age 7 from seed, the superior growth rate of the southern provenances was observed at one site while it was lacking at the other. Trees from Pennsylvania rather that from southern Appalachian were recommended for planting in southern Ontario.

Height-to-diameter-Ratio - In August 1971, the diameter 1 foot from ground was measured by myself for the 15 seedlots at the Kellogg study plantation. Then the height-to-diameter ratios (cm/cm) were calculated. There were significant between-seedlot differences at the 1 percent level (table 1).

No geographic pattern was observed. The correlation co-efficients were never higher than 0.175 when the h/d ratios were correlated with any of origin data.

The h/d ratios were correlated with the height and the diameter. I obtained a weak (r = -0.243) and a strong (r = -0.668) relationship respectively. This finding was in agreement with the Wright's (1970) and Funk's (1971) results, however, a strong positive height-diameter correlation (r = 0.879) suggested that the two growth characters may be inherited together (La Farge, 1971).

There were eight common provenances (seedlots 1, 3, 6, 12, 14, 19, 20, 25) between Funk's and my studies. No correlations were established between Michigan and any of the three Central States plantations (Illinois, Indiana and Iowa).

DIFFERENCES IN WOOD PROPERTIES

Specific gravity and tracheid length are among the most important wood properties. Very little work has been done and none of the earlier studies has used the range-wide specimens.

Specific gravity - There were significant differences among seedlots in specific gravity (table 1). The differences were not large and followed no clear geographic pattern. There was, however, a slight but statistically significant height-specific gravity correlation (r = 0.66 at the 1% level). The five fastest growing seedlots had an average specific gravity of 0.271 and the five slowest growing seedlots had an average specific gravity of 0.258. Selection of the faster growing individuals may be associated with desirable structural strength.

Both non-significant and significant differences in specific gravity associated with geographic origins were reported. Lack of close association was found for European black pine (*Pinus nigra* Arnold) by Lee and Wright (in press) and for Norway spruce (*Picea abies* (L.) Karst.) by Knudson (1956). On the other hand, a strong correlation was reported for loblolly pine (*Pinus taeda* L.) by Zobel et al., (1960). The discrepancies may be due to differences in sampling technique and due to confounding of tree age with other factors such as soil moisture.

Overall mean for the trunkwood specific gravity was 0.262, considerably lower than the earlier studies. Eastern white pine may be an excellent lumber species for general construction purposes but may not be recommended for pulping purposes owing to a low specific gravity. Besides, it does not pulp well. The range in seedlot means varied from 0.249 to 0.280, a difference of 13 percent. The between-tree range was from 0.228 to 0.338, a difference of 48 percent. The greater between-tree variation was expected because it was also the case with European black pine (Lee and Wright, in press).

Tracheid Length - There were no between-seedlot differences (table 1). Nor was there any geographic trend.

Overall mean tracheid length was 2.19 millimeters, about 67 and 75 percent shorter than the young and old wood respectively of the Tennessee white pine (Thor, 1965). The range in seedlot means varied from 2.14 to 2.23 millimeters, a difference of only 4 percent. The between-tree range was from 1.94 to 2.51 millimeters, a 29-percent difference. Both ranges were narrower than those of specific gravity.

The tracheid length-1971 height relationship was nil. Less than 1 percent of the total variation was accounted for height growth. Nor the tracheid length-specific gravity correlation was strong (r = 0.44). This was also the case with loblolly pine (Jackson, et al., 1962) and black pine (Lee and Wright, in press). Lack of correlation suggests that the two wood properties may be inherited separately.

ACKNOWLEDGMENT

I am grateful to the staff of the Division of Timber Utilization Research, Forest Products Laboratory, U.S. Forest Service, Madison, Wisconsin, for their assistance in the removal of alcohol-benzene extractives and in the determination of wood specific gravity. My many thanks are also due Dr. Jonathan W. Wright of Michigan State University for his permission to use his Kellogg plantation material and for his critical review of this 'article.

LITERATURE CITED

Echols, R. M. 1969. Permanent slides of stained wood fibers without dehydration or cover glasses. Forest Sci. 15:411.

Fowler, D. P. and C. Heimburger. 1969. Geographic variation in eastern white pine, 7-year results in Ontario. Silvae Genet. 18:123-129.

Funk, D. T. 1965. Southern Appalachian white pine off to a good start in the Midwest. Central States For. Tree Impr. Conf. Proc. 4:26-28.

Funk, D. T. 1971. Eastern white pine seed source trials: Ten-year results from three Midwestern plantations. U.S. Forest Serv. Res. Note NC-113, 4 p.

Genys, J. B. 1968. Geographic variation in eastern white pine. Ten-year results of testing range-wide collections in Maryland. Silvae Genet. 17:6-12.

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

Knudson, M. V. 1956. A comparative study of some technological properties of Norway spruce in a provenance test (Docum.) 12th Congr. Int. Union For. Res. Organ. Oxford Na. IUFRO 56/41/2, 7 p.

La Farge, Timothy. 1971. Inheritance and evolution of stem form in three northern species. Ph. D. thesis Michigan State Univ., East Lansing, Michigan.

Lee, C. H. and J. W. Wright. 1973. Geographic variation of growth traits and wood properties in European black pine. Mich. Agri. Exp. Sta. Res. Pap. (in press).

Smith, D. M. 1954. Maximum moisture content method for determining specific gravity of small wood specimens. USFS, Forest Prod. Lab. Rep. No. 2014, 8 p.

Thor, E. 1965. Variation in some wood properties of eastern white pine. Forest Sci. 11:451-455.

Wright, J. W. 1970. Genetics of eastern white pine. USDA Forest Service Res. Pap. WO-9, 16 p.

Wright, J. W., W. L. Lemmien and J. N. Bright. 1963. Geographic variation in eastern white pine--six-year results. Mich. Agr. Exp. Sta. Quart. Bul. 45(4):691-697. Michigan State University, E. Lansing, Mich.

Zobel, B. J., E. Thorbjornsen and F. Hensen. 1960. Geographic, site and individual tree variation in wood properties of loblolly pine. Silvae Genet. 9:149-158.

ABSTRACT

The eastern white pine provenance testing plantation is located at the Kellogg Forest, Augusta, Michigan. It contains 15 four-tree plots with 10 replications and follows a randomized complete block design. I measured total height in August 1971. Collected at the same time was a 0.5 centimeter caliber increment core specimen from the north side of the largest tree per plot at stump height to provide specific gravity and tracheid length study material. All data were subjected to an analysis of variance.

Overall mean for the 1971 height (at age 15 from seed) was 732 centimeters. The range in seedlot means was from 652 to 802 centimeters, a difference of 23 percent. Overall mean for the specific gravity was 0.262. The range in seedlot means varied from 0.249 to 0.280, a difference of 13 percent. Overall mean for the tracheid length was 2.19 millimeters. The range in seedlot means varied from 2.14 to 2.23 millimeters, a difference of only 4 percent. The specific gravity seems warranted as well as growth rate for consideration of improvement of this pine species through selection breeding.

Faster growing seedlots had slightly higher specific gravity than slower growing ones. Differences among seedlots in specific gravity were small but statistically significant. The Tennessee seedlot continued to demonstrate its superior growth rate and winter hardiness in southwestern Lower Michigan; however, the steady decline in the superior growth with time suggested that changes in relative height could occur in the future.