GENETIC VARIATION IN EASTERN WHITE PINE FROM THE SOUTHERN APPALACHIAN MOUNTAINS

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ABSTRACT

GENETIC VARIATION IN EASTERN WHITE PINE
FROM THE SOUTHERN APPALACHIAN MOUNTAINS

By

Ray Jerome Amiel

Provenance test in eastern white pine (*Pinus strobus*) from the southern Appalachian Mountains representing 177 half-sib families from 49 stands. Four test plantations were established in southern Michigan: W.K. Kellogg Forest (161 seedlots), Fred Russ Forest (80 seedlots), Hidden Lake Garden (85 seedlots) and Roscommon County (94 seedlots).

Mortality in all plantations was low to moderate, ranging from 8-33%. Greatest mortality occurred in the first year after planting, due to planting shock.

Growth rate differences were large between stand progenies. Trees from the Tennessee-North Carolina border southward to northern Georgia grew the fastest in both height and diameter. Trees from these stands grew 4-14% faster than the plantation average. The slowest growing stand progenies were trees from Virginia and West Virginia. Trees from these stands grew 6-14% slower than the plantation

averages. A 30% growth rate difference was recorded between the fastest and slowest growing stand progenies when planted in Michigan.

Diameter growth recorded similar results to that of height. Trees from along the Tennessee-North Carolina border grew 8-16% faster than the plantation average. Absent from among the 20% largest in diameter were trees from northern Georgia. These trees were among the tallest 20% in height, but were near or below the plantation average in diameter. Trees from Virginia and West Virginia recorded the smallest diameters.

Insects were a minor problem in all test plantations. White pine weevil (Pissodes strobi) attacks ranged from 0.0 at Hidden Lake Garden and Fred Russ Forest to 14 trees at Kellogg Forest (0.5% of the live trees). White-pine shoot borer (Eucosma gloriola) recorded 180 attacks in the Kellogg Forest plantation. Most white-pine shoot borer attacks occurred on the lateral branches. Stem form is excellent in all plantations.

Needle growth was scored in the spring of 1977 at the Kellogg Forest plantation. Trees from Virginia and West Virginia began needle growth first. Trees from North Carolina were the last to begin needle growth.

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INTRODUCTION

Eastern white pine (*Pinus strobus*) is a favorite tree in the eastern United States. In the latter half of the 19th and early part of the 20th century, eastern white pine was the main staple of the lumber industry. The species grew in pure or mixed stands, with red pine (*Pinus resinosa*) and eastern hemlock (*Tsuga canadinsis*) being its main associates. Tall, straight, clear-bole trees were found in many virgin stands, some trees towering over 200 ft tall and 4 to 5 ft in diameter (maximum 220 ft by 6 ft). Unfortunately, most of these stands are gone.

Today, the species plays a minor role in the lumber and pulp industries. Planting has been limited for several reasons. White pine is not a good pulp species and early thinnings are difficult to sell. Fear of damage from two forest pests has been the main reason for the low volume planted in the past. The pests are white pine weevil (*Pissodes strobi*), a native forest insect and white pine blister rust (*Cronartium ribicola*), an introduced fungus from Asia. White pine weevil causes serious stem deformation in many areas, attacking and killing the leader. Foresters were concerned that white pine blister rust would

cause serious mortality in young trees.

Eastern white pine is very intolerant to salt spray. In areas where road salting is common, trees near the road have brown mottled foliage in the spring. This salt spray affects both young and old trees. Growth can be greatly reduced.

However, eastern white pine has many valuable characteristics. The species is very adaptable. Although it prefers a sandy loam, it will successfully grow on soils ranging from sand to lowland swamps and bogs. On good sites, eastern white pine will grow 3 ft per year in height and 1/2 in per year in diameter. In areas of low weevil population, tree bole are tall and straight. The wood quality is excellent. The species has soft, strong durable wood ideal for windows and doors. White pine blister rust is common in only a few areas of Michigan. The tree has found great value as an ornamantal in our cities and parks. The blue-green foliage and rapid growth gives the species an advantage over many other conifers. Also, it is an impressive exotic in many European and Asian countries.

MATERIAL AND METHODS

Seed was collected from natural stands in the autumns of 1964 to 1966 in the extreme southern part of the native range of the species, Maryland to Georgia. The seeds were sown at the Michigan State University Tree Research Center nursery in the fall of 1966 and germinated in the spring of 1967. Four test plantations were established in Michigan, two in 1969 with 2-0 seedling stock and two in 1970 with 3-0 seedling stock. In all, there were a total of 177 half-sib families stands (Figure 1).

Of the four test plantations, three were established in the southern third of the lower pennisula and the fourth, Roscommon, is found in the northern half of the lower pennisula. All plantations, with the exception of that at Hidden Lake Garden, are in the natural range of eastern white pine. Site and soil conditions vary greatly between plantations, below is a brief description of each plantation:

1.) W.K. Kellogg Forest, Augusta, Kalamazoo County, Michigan. Site rolling with a sandy loam soil, grass 2-5 ft tall, gentle south aspect.

2.) Fred Russ Forest, Volinia, Cass County, Michigan. Site rolling with steep north and south aspects, slopes up to 25%; sandy loam soil with sparse

Figure 1. Location of eastern white pine parental stands whose offspring were tested in the present experiment (numbered dots) and previous experiments (triangles). (from Wright, 1976).

grass ground cover and natural regeneration of black walnut, yellow poplar, white ash and sugar maple.

3.) Hidden Lake Garden, Tipton, Hillsdale County, Michigan. Site nearly level with a dense cover of grass 3-5 ft tall; soil a loam to clay loam.

4.) Roscommon, Crawford County, Michigan. Level site, a sandy to loamy sand; sparse grass and sweet-fern ground cover; eastern white pine was originally supported on the site; site both the coldest and driest.

Each plantation was treated with amino-triazole (2 gal/treated acre), sprayed in two-foot wide strips the fall before planting and with simazine (4 lbs/treated acre) immediately after planting. The Kellogg plantation was re-sprayed with simazine 3 years after planting.

Plantations were established in the springs of 1969 (Kellogg and Roscommon) and 1970 (Hidden Lake and Russ). Three plantations were established with an 8 X 8 ft spacing, randomized complete block design, with 4 tree line plots, and surrounded by a single border row. The other plantation at Hidden Lake Garden has no border row and was planted with 15 X 15 ft spacing. Not all seedlots were planted in all plantations, due to the unavailability of planting stock. The Kellogg Forest plantation is the largest having 161 half-sib families from 44 stands. That at Russ Forest is the smallest, having 80 half-sib families from 26 stands.

Measurements were made periodically, with each plantation having been measured 3-4 times since planting and once in the nursery. Height measurements were recorded as the average of the tallest 50% of the trees in the plot, measured to the nearest quarter of a foot.

In the winter and spring of 1977, I measured the height and weevil damage at Kellogg Forest and Hidden Lake Garden. Diameter, phenology, and number of branches were measured at Kellogg Forest. In previous years, white-pine shoot borer attacks were measured at Kellogg Forest. At Russ Forest, height and weevil attacks were measured by J.W. Wright and Don DeHayes in the summer of 1975.

The Kellogg plantation has been measured for diameter at heights of 1 ft and 4 1/2 ft. Diameters were recorded as the average of the tallest 50% trees in the plot to the nearest tenth inch. Needle growth was scored in the spring of 1977 on a scale of 0 (no needle growth) to 5 (needles 3/4 in long or greater).

Most plantations have been scored for the amount of infestation of the two major pests of eastern white pine, white-pine shoot borer (Eucosma gloriola) and white pine weevil (Pissodes strobi). In each case the data was recorded as the number of trees attacked. There was no damage or mortality recorded due to white pine blister rust.

An analysis of variance was performed on each of the 8 sets of data using the plot means as items for height, diameters, number of branches and phenology and plot totals

for insect attacks. For missing plots, I substituted the seedlot means, and subtracted the appropriate number of degrees of freedom from the error term.

The total variation was separated into variances due to blocks, error and half-sib families. The half-sib family variances were separated into between stand variance and within stand variance. To determine the levels of significance, the between stand and within stand variance terms were tested against error of variance.

RESULTS

MORTALITY

Mortality in the four plantations is summarized in Table 1. Survival was moderate to high in all plantations. The greater mortality recorded in Roscommon County was due to the heavy cover of sweet fern (Comptonia peregrina) which resisted the weed control chemicals. In the other plantations, most mortality was in the first year after planting and was probably due to transplanting shock.

The greatest field mortality recorded was in the West Virginia seedlots that arrived to late to be sown in the nursery in the fall of 1966 . These seedlots accounted for 48% of all West Virginia seedlots. At the time of field planting, these seedlots were smaller than the other planting stock. Plantation mortality would likely have been much smaller if these West Virginia seedlots would have been larger at the time of planting.

Table 1.--Establishment details and morality in eastern white pine plantations in southern Michigan.

Plantation Number and Location	Planting	Last Measurement	Number of trees Planted	Mortality
			no.	%
W.K. Kellogg Forest (8-69)	1969	1977	3312	14
Fred Russ Forest (1-70)	1970	1975	1416	20
Hidden Lake Garden (10-70)	1970	1977	1874	8
Roscommon County (5-69)	1969	1975	1816	33

FRUITING

Cone production has begun on a limited number of trees. In 1977, Kellogg Forest has 39 trees bearing cones. No single seed source is producing a large number of cones, but the greatest concentration of fruiting is in the West Virginia and Virginia provenances. Unfortunately, these provenances are among the slowest growing in all plantations. At Kellogg Forest, the Virginia and West Virginia trees contain 73% of the total trees producing cones.

Only the Kellogg Forest plantation has many trees bearing cones. It will be a number of years before this or the other plantation may be used as an improved seed orchard.

COLOR

Foliage color was scored at Kellogg Forest by J.W. Wright and Donald DeHayes in the summer of 1975. Color ranged from green to blue-green. The differences among seedlots were not significant.

NUMBER OF BRANCHES

I counted the number of lateral branches formed in 1977 at Kellogg Forest. The average of the two tallest trees was recorded for each plot. Trees from Amherst County, Virginia had the least number of branches, averaging 7 branches per whorl. Trees from Garrett County, Maryland had the most branches, averaging 11 branches per whorl. I found no evidence of a north-south cline. Differences between stand progeny from the same state were as large as those recorded between states. Table 2 ranks the results of the 10 stands with the least branches and 10 stands with the most branches.

Funk (1970) found that northern stand progenies tend to produce more branches that stand progenies further south. Garrett (1973), working with many plantations throughout the northeast, found similar results, the northern provenances having more branches. In this study, no relationship was found between number of branches and region of origin.

No relationship was found between number of branches and height. Correlation analysis between height and number of branches showed no significance at the 5% level, with 160 degrees of freedom.

Table 2.--Number of branches in the 1977 whorl, the 10 stand progenies with the least and the 10 stand progenies with the most branches.

Rank	Map Number	State	County	Number of Branches
1	24	VA	Amherst	7.2
2	26	VA	Craig	7.2
3	33	WV	Greenbrier	7.3
4	21	TN	Anderson	7.4
5	45	WV	Braxton	7.6
6	30	TN	Monroe	7.7
7	43	WV	Pocahontas	7.8
8	1	GA	Fannin	7.8
9	18	NC	Burke	7.8
10	37	WV	Greenbrier	7.8
40	30	VA	Rockingham	8.5
41	27	VA	Botetourt	8.6
42	46	WV	Pleasants	8.7
43	12	NC	Buncombe	8.7
44	25	VA	Montgomery	8.8
45	6	GA	Rabun	9.0
46	10	NC	Graham	9.3
47	32	WV	Greenbrier	9.3
48	29	VA	Augusta	10.7
49	48	MD	Garrett	11.0
Plantation Mean				8.2

NEEDLE GROWTH

On May 22, 1977, the amount of new growth was scored at the Kellogg Forest plantation. In most plots, the candles were fully extended. A scale of 0-5 was used. The grades are defined below:

0--fasicle sheath not expanded,

1--fasicle sheath slightly expanded, needles not yet visible,

2--needles less than 1/4 in long,

3--needles 1/4 to 1/2 in long,

4--needles 1/2 to 3/4 in long and

5--needles greater than 3/4 in long.

The Virginia and West Virginia trees began growth earlier than trees from farther south. Trees from Virginia had needles 3/4 in long, whereas trees in North Carolina had needles less than 1/4 in long.

Steiner (1975), working with the rangewide provenance trial at Kellogg Forest, recorded a trend similar to that found in the southern Appalachian study. On June 6, 1973, he scored the trees on a scale of 0 (fasicle sheath not expanded) to 10 (needle greater than 1 in long). He reported that the Minnesota progeny began needle growth first and the Virginia progeny started needle growth last. Differences recorded between first and last trees to begin needle growth were as large as those recorded in the southern Appalachian study. However, there was a difference

between the two studies. The Virginia trees which began needle growth among the earliest in the southern Appalachian study, were the last to begin growth in the earlier range-wide study. Also, needle growth began two weeks earlier in 1977 than in 1973.

WINTER INJURY

Branch breakage due to snow caused some damage in the Kellogg Forest plantation. Deep snow drifts covered the lower 2-3 whorls of branches on trees along the western edge of the plantation. In the spring, the heavy compacted snow caused some branch breakage. In the more protected areas of the plantation, snow drifts were smaller and less limb breakage was recorded.

Salt spray injury is apparent in the Hidden Lake Garden plantation. Trees planted along state highway-50 have brown mottled foliage. The first 2-3 rows have heavy damage. Trees away from the highway had little foliage discoloration.

INSECT DAMAGE

Eastern white pine has three major pests. Two insects, white pine weevil (Pissodes strobi) and white-pine shoot borer (Eucosma gloriola) caused the greatest damage. The third pest, white pine blister rust (Cronartium ribicola), is a fungus causing problems only in the northwestern portion of the natural range. The four test plantations have recorded no tree losses due to the fungus.

At Kellogg Forest, white pine weevil attacks were spread randomly throughout the plantation, attacking 0.5% of the live trees in 1976. Stem form in all plantations remains excellent. The range of weevil attacks in the plantations is 0.0 at Hidden Lake Garden and Fred Russ Forest to 14 trees at W.K. Kellogg Forest.

White-pine shoot borer had the greatest frequency of attack of the insects studied at Kellogg Forest. A total of 180 attacks were recorded. The insect attacks the lateral branches or the leader, feeding on the cambium in the new growth. Branch dieback is unsightly and causes stem deformation when the leader is attacked. Fortunately, most of the attacks were on lateral branches.

Analyses of the attacks were done two ways. First analysis of variance was done, calculating variances due to block, seedlot within stand, and seedlot between stands. There were significant differences at the 1% level among stand progenies and blocks. There were also significant

differences recorded within stands.

Also, Chi-square analysis was used to test significance of differences among stand progenies and blocks. In both cases, significant differences were recorded between stand progenies and between blocks at the 1% level.

The block differneces are due to the large number of insect attacks in the southern half of the plantations. Blocks 2, 4, and 5 are adjacent to each other in the southern portion of the plantation. These blocks contain 78% of white-pine shoot borer attacks in the plantation. The insect, commonly attacks in a pocket pattern (Baker, 1972., Drooz, 1960). In all liklihood, this accounts for the high block effect found in the plantation.

Stand progenies from the Tennessee-North Carolina border, south to northern Georgia, had the greatest frequency of attacks. When considering the 3 blocks with the highest number of attacks, 66% (93 attacks) of all white-pine shoot borer attacks were in the tallest 20% (10 stands) stand-progenies.

Correlation analysis was done on the height and number of attacks in blocks 2, 4, and 5 were compared with the sum of the plot mean heights for the same blocks. The results showed a relationship between the two characteristics, significant at the 1% level ($r=.66$), with 160 degrees of freedom. Height accounted for 44% of the variation of the frequency of attacks in those blocks.

Analysis was done on the relationship between the number of branches and frequency of attacks. The results

were significant at the 1% level ($r=.22$), with 160 degrees of freedom. The number of branches may account for only 5% of the variation in the frequency of attack.

The greatest frequency of white-pine shoot borer attacks were in the stand progenies from Tennessee-North Carolina border south to north Georgia. These trees are among the tallest, are in the process of crown closure with their neighbors and are the dominate trees in the plantation. These factors may influence the adult female in her selection of the trees for depositing her eggs.

HEIGHT

Plantations have been measured periodically since planting in the springs of 1969 and 1970. After 1973, the plantations began maximum height production. Many trees have an annual increase in height of 3 ft or more. In 1977, some individual trees were taller than 20 ft. The southern Appalachian eastern white pine plantations at Kellogg and Russ Forests are among the fastest growing pine plantations relative to age.

Growth rate differences between stands were large in all plantations. Trees from along the Tennessee-North Carolina border southward into northern Georgia had relative height 4-14% above the plantation means. Trees from Virginia, West Virginia and Maryland grew 6-16% slower than the plantation means (Table 3). The growth differences were 84% to 114% of the mean of the mean.

Plantation averages varied greatly. The Kellogg Forest plantation was the tallest, 12.2 ft after 10 seasons growth. The shortest plantation was that at Roscommon, 2.6 ft tall after 8 seasons growth. The Roscommon plantation, in earlier studies by Fowler (1969) and King (1969), is considered to far north for vigorous growth of the southern Appalachian eastern white pine. The three most southern plantations are growing well. In the past 3 years, heights of some trees in these plantations have more than doubled.

Analysis of variance of the Kellogg Forest and Hidden

Table 3.--Height of the 10 fastest and 10 slowest growing stand progenies at age 10 when measured at W. K. Kellogg Forest and Hidden Lake Garden.

Rank	Map Number	State	County	Kellogg Forest	Hidden Lake Garden	Combined Average
1	19	TN	Polk	117	110	114
2	21	TN	Anderson	112	113	112
3	3	GA	Union	112	-	112
4	10	NC	Graham	110	-	110
5	20	TN	Monroe	106	114	110
6	22	TN	Carter	110	110	110
7	11	NC	Buncombe	108	-	108
8	2	GA	Fannin	112	93	107
9	13	NC	Yancey	108	93	104
10	4	GA	Rabun	104	104	104
40	28	VA	Augusta	94	-	94
41	46	WV	Pleasants	92	102	94
42	42	WV	Podahontas	92	96	93
43	16	NC	Burke	90	99	93
44	36	WV	Greenbrier	92	-	92
45	28	VA	Alleghany	-	90	90
46	47	WV	Wetzel	84	98	90
47	45	WV	Braxton	78	100	88
48	37	WV	Greenbrier	80	98	88
49	26	VA	Craig	84	-	84
Actual mean, cm.				373	269	337

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2	21	TN	Anderson	112	113	112
3	3	GA	Union	112	-	112
4	10	NC	Graham	110	-	110
5	20	TN	Monroe	106	114	110
6	22	TN	Carter	110	110	110
7	11	NC	Buncombe	108	-	108
8	2	GA	Fannin	112	93	107
9	13	NC	Yancey	108	93	104
10	4	GA	Rabun	104	104	104
40	28	VA	Augusta	94	-	94
41	46	WV	Pleasants	92	102	94
42	42	WV	Podahontas	92	96	93
43	16	NC	Burke	90	99	93
44	36	WV	Greenbrier	92	-	92
45	28	VA	Alleghany	-	90	90
46	47	WV	Wetzel	84	98	90
47	45	WV	Braxton	78	100	88
48	37	WV	Greenbrier	80	98	88
49	26	VA	Craig	84	-	84
Actual mean, cm.				373	269	337

Lake Garden plantations resulted in significant differences among stands of origin at the 1% level. No differences were recorded among parents within stands. The best stand progenies in one plantation were likely to be among the best in the other plantations in southern Michigan.

Correlation analysis on the mean seedlot height at Kellogg Forest were calculated, comparing the first three plantation measurements to the results recorded in 1977 (Table 4). The results indicate that the seedlots and stands that were the fastest growing at age 4 are likely to be the fastest growing at age 10, statistically significant at the 1% level with 160 degrees of freedom. The results closely resemble the age X age correlations reported by Genys (1967, 1977) and Sluder (1971) for the rangewide eastern white pine studies. In this study and others, the provenances from Tennessee, North Carolina and Georgia remain the tallest after 10 seasons of growth.

Table 4.--Correlation analysis between half-sib family heights at age 10 and half-sib family heights at ages 4, 7 and 9 when measured at W.K. Kellogg Forest.

Year Measured	Number of Seasons Growth	r	Degrees of Freedom	Plantation Means (in feet)
1970	4	.82**	160	1.83
1974	7	.97**	160	4.87
1975	9	.98**	160	10.20
1977	10	--	160	12.24

**--significant at 1% level

DIAMETER GROWTH

Differences in diameter growth, both at 1 foot and 4 1/2 feet, were as large as those recorded in height. Significant differences were recorded at the 1% level between stands, at both diameter locations and difference within stands (5% level) in diameter at breast height.

At Kellogg Forest, the plantation average at d.b.h. was 2.2 in (5.6 cm). Average diameter at 1 foot was 3.1 in (7.9 cm). The range of stand means were 1.5 in (3.8 cm) to 2.9 in (7.4 cm) at d.b.h. and 2.1 in (5.3 cm) to 4.0 in (10.2 cm) for diameter at 1 foot. Stands with the largest diameter were from Burke County, North Carolina. Trees with the smallest diameters were from Braxton County, West Virginia. Correlation analysis on seedlot means recorded an $r=.86$, significant at the 1% level. The best stands at one diameter would likely be the best at the other diameter.

The correlation between height and diameter was calculated. Correlation was significant ($r=.72$) at the 1% level, with 160 degrees of freedom. Even though the coefficient of correlation was significant, the height X diameter relationship can only account for 52% ($r=.52$) of the variation between these two characteristics.

Due to the low coefficient of determination (r^2), analysis of variance was performed on the height/diameter (diameter at 1 ft) ratio. The results show significant differences between stands and replications. Stand progeny

with the lowest height/diameter ratio were trees from North Carolina. Generally, these trees were in the top 20% in both height and diameter growth. Trees with the highest/ diameter ratio were from Virginia, West Virginia and central North Carolina (Table 5). Trees from Georgia were among the top 20% in height, but in diameter these same stand progenies were near or below the plantation mean.

When selecting southern Appalachian eastern white pine for planting, trees from along the Tennessee-North Carolina border would likely have maximum height and diameter growth. These stand progenies were in the top 20% in height and were above the plantation average in diameter when measured at Kellogg Forest.

Table 5.--Ranking of the 10 lowest and 10 highest height/diameter ratios at W.K. Kellogg Forest.

Rank	Map No.	State	County	Relative Height-Diameter Ratio
1	10	NC	Graham	85
2	7	NC	Macon	85
3	33	WV	Greenbrier	85
4	23	VA	Carroll	85
5	18	NC	Burke	89
6	17	NC	Caldwell	91
7	11	NC	Buncombe	91
8	9	NC	Henderson	92
9	39	WV	Pocahontas	93
10	48	MD	Garrett	93
40	35	WV	Greenbrier	103
41	25	VA	Montgomery	104
42	16	NC	Burke	108
43	11	NC	Buncombe	108
44	34	WV	Greenbrier	110
45	43	WV	Pocahontas	110
46	3	GA	Union	112
47	6	GA	Rabun	116
48	47	WV	Wetzel	116
49	29	VA	Augusta	122
Mean				16.4

RESULTS OF PLANTATIONS IN AUSTRALIA, INDIANA, WEST VIRGINIA, NEBRASKA AND TENNESSEE

Seeds or planting stock was distributed to Australia, Indiana, West Virginia, Nebraska and Tennessee. These plantations were established in a method similar to those in Michigan. The Australian plantation was planted intermixed with seed from the rangewide provenance trial of the University of Maryland (Genys, 1967). The other plantations were the same stand progenies as those found in Michigan.

Survival at all plantations was high. The Indiana plantation had the highest survival, with 89%. The Victoria, Australian plantation recorded the lowest survival, 73%.

Similar to the results recorded in Michigan test plantations, the stand progenies from Tennessee and North Carolina were the tallest. Trees from Virginia and West Virginia were the shortest. Sprackling and Read (1976) in Nebraska found that the Tennessee trees from Polk County were the tallest and trees from Cherokee County, North Carolina were the shortest. Both counties' trees were in the top 20% in height when planted in Michigan. In the other plantations, it was the more northern trees that had the slowest height growth (Thor, 1975).

In Nebraska, 20 trees were producing cones in 1974. Fifteen of these trees (75%) were from West Virgina (Sprackling, et al. 1976). Similar results were recorded in this

study, where 39 trees were bearing cones and 73% of these trees were from Virginia and West Virginia.

Limitations to the planting of southern Appalachian eastern white pine have been discussed by Garrett (1977) and King (1969). In many plantations throughout the northeast, the southern Appalachian trees from Tennessee, North Carolina and Georgia grew the fastest when planted south of southern New York. In areas north of southern New York, north central Michigan and central Wisconsin, trees from central and lower midwestern trees grew the fastest when planted in this area. Fowler (1969) found in southern Ontario that trees from Pennsylvania and southern Michigan and Ontario had the best results north of a line from New York to central Wisconsin.

Results from plantations throughout the United States and Australia were similar to those in southern Michigan. Trees from Tennessee and North Carolina had the best overall height. These plantations were where southern Appalachian eastern white pine has recorded excellent height growth. Planting of the southern Appalachian trees is undesirable north of central Michigan and central Wisconsin. Cone production had similar results as those recorded in Michigan. Virginia and West Virginia trees are producing the most cones.

PRACTICAL APPLICATION

Eastern white pine from the southern Appalachian Mountains has the potential for excellent growth when planted in southern Michigan. In this area of extensive farming and numerous small woodlots, eastern white pine is an impressive timber species, capable of short rotations of 40 years, producing excellent, knot-free, high value logs with careful thinning and pruning. Annual growth of 3 ft or more in height and 1/2 - 3/4 in in diameter can be achieved.

When planting the southern Appalachian sources, careful consideration should be taken in the selection of planting site. Planting in the northern half of Michigan may be undesirable. As discussed earlier in the paper, the Roscommon plantation has had very poor height development. Early studies by Wright (1970, 1976) and King et al. (1969) found the southern Appalachian sources did poorly when planted north of a line from Muskegon to Bay City, Michigan. North of this region, the plantations have shown slow growth, some needle damage, loss of vigor and some additional mortality.

Stem deformation due to white pine weevil or white-pine shoot borer has been a minor problem in the Michigan test

plantations. In some areas of the United States, white pine weevil has caused serious stem deformation. In these areas, serious consideration should be taken before planting eastern white pine. Other pine species may be more desirable than eastern white pine in the areas with large weevil populations.

The procurement of southern Appalachian planting stock and seed is the largest problem facing foresters in the near future. Forest nurseries in Tennessee and North Carolina use seed collected from native white pine stands and for the next few years this will be the only reliable source of planting stock available. Collection of seed from dominate trees in natural stands on the Tennessee-North Carolina border is likely to be of the same genetic quality as trees planted in the test plantations throughout Michigan. A seed dealer in Oklahoma has shown interest in the procurement of eastern white pine seed from Tennessee. This dealer and others in Tennessee and North Carolina are likely to be the only reliable source of southern Appalachian eastern white pine seed at the present time. Seed orders through these dealers are likely to have a 1-2 yr delay before fulfillment. This is due to the low stock pile of suitable seed.

In the future, test plantations will be thinned in order to make seed orchards. Seedlots from the best stands are well represented in the test plantations and seed collected for these plantations in the future should

be of the same genetic quality as seed collected from natural stands. Within the next two years, crown closure will be complete and the thinning process will begin for rapid change of the plantations into seed orchards.

The NC-99 rangewide provenance trials for eastern white pine has begun producing a large number of cones 18 yrs after planting. Unfortunately, the slower growing Minnesota trees are producing the greatest number of cones. Trees from Tennessee and North Carolina are producing few cones. Moderate quantities of southern Appalachian seed should become available in the next 10 years from these two studies. Trees will have obtained the height of 40-50 ft.

SUMMARY

Seed of eastern white pine was collected in the autumn from 177 natural trees located in 49 stands scattered from Maryland to northern Georgia. The resulting seedlings were replicated in four plantations in southern Michigan. Plantations were last measured at age 10 from seed.

Growth and survival were high in the three southern Michigan plantations. Trees grown from seed collected along the Tennessee-North Carolina border grew the fastest in height and diameter, averaging 3 ft or more per year in height and 1/2 - 3/4 in per year in diameter growth. Trees from these stands grew 15-25% faster than most trees from Maryland, West Virginia and Virginia.

White pine weevil (Pissodes strobi) and white-pine shoot borer (Eucosma gloriola) has caused minor stem deformation in the test plantations. Weevil damage ranged from 0 trees attacked at Hidden Lake Garden to 14 trees attacked at Kellogg Forest. White-pine shoot borer averaged .06 attacks per tree at Kellogg Forest.

Start of needle growth showed a cline from north to south, with Virginia and West Virginia trees starting growth earliest. North Carolina trees were the last to begin needle growth. Trees from Virginia produced the

least number of branches and trees from Maryland had the most branches. No evidence of a north-south cline was evident.

Cone production has been light in all plantations. Thirty-nine trees are presently producing cones. Trees from Virginia and West Virginia are producing 73% of the cones at Kellogg Forest. Trees will likely be 20 yr old and 40-50 ft tall before large quantities of seed are produced.

LIST OF REFERENCES

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Baker, W. L. 1972. Eastern forest insects. U.S.D.A. Forest Serv. Mis. Pub. No. 1175.

Drooz, A. T. 1960. White-pine shoot borer (Eucosma gloriola Heinrick). Econ. Entomol. 53:248-251.

Garrett, P. W., E. J. Schreiner and J. Kettlewood. 1973. Geographic variation of eastern white pine in the Northeast. U.S.D.A., Forest Serv. Res. Pap. NE-274. 14pp.

Genys, J. B. 1968. Geographic variation in eastern white pine. Two-year results of testing rangewide collections in Maryland. Silvae Genet. 18:83-86.

Genys, J. B., D. Canavera, J. D. Gerhold, J. J. Jokela, B. R. Stephan, I. J. Thalin, R. Westfall and J. W. Wright. 1977. Intraspecific variation of eastern white in seven states of the J.S.A. and in Germany, Australia and New Zealand. (in press).

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

Funk, D. T. 1971. Eastern white pine seed sources trials: ten-year results from three midwestern plantations. U.S.D.A. For. Serv. Res. Note NC-113. 4pp.

King, J. P. and H. Neinstaedt. 1969. Variation in eastern sources planted in the Lake States. Silva Genet. 18:83-86.

Sluder, E. R., K. W. Dorman. 1971. Performances in the southern Appalachians of eastern white pine seedlings from different provenances. U.S.D.A. For. Ser. Res. Pap. SE-90, 11pp.

Sprackling, J. A. and R. A. Read. 1976. Eastern white pine in eastern Nebraska: a provenance study of southern Appalachian origins. U.S.D.A. For. Ser. Res. Pap. RM-179.

Steiner, K. C. 1975. Patterns of genetic variation within fifteen tree species in time of bud burst and flowering. Michigan State University, Ph. D. thesis.

Thor, E. 1975. White pines from the southern Appalachians. Central States For. Tree Improv. Conf. Prov. 9:145-152.

Wright, J. W. 1970. Genetics of eastern white pine. U.S.D.A. For. Serv. Res. Pap. WO-9, 16pp.

Wright, J. W., W. A. Lemmien, J. N. Bright and G. Kowalewski. 1976. Rapid growth of southern Appalachian white pine in southern Michigan Mich. Ag. Expt. Sta. Res. Pap. 307.

APPENDIX

Table A1.--Analysis of Variance table of height, diameter, needle growth, number of branches, height/diameter ratio and Eucosma.

Characteristic and Plantation	Degrees of Freedom				Sum of Squares				F-Value		
	BS	WS	R	ER	BS	WS	R	ER	BS	WS	R
Height (Kellogg Forest)	32	128	4	619	20788	3913	8066	35362	11.37**	17.15**	1.10
Height (Hidden Lake)	12	73	4	301	2214	741	2643	10995	5.05**	5.07**	.99
Diameter at 4 1/2 feet (Kellogg Forest)	32	128	4	619	7162	1740	6378	19705	7.03**	13.67**	1.57
Diameter at 1.0 feet (Kellogg Forest)	32	128	4	619	12556	1920	4178	24852	9.77**	11.96**	.81
Phenology (Kellogg Forest)	32	128	2	320	87.98	13.20	269.63	575.00	1.53*	3.67**	1.17
Number of Branches (Kellogg Forest)	32	128	2	320	189	523	1595	1431	1.32	.59**	2.78**
Height-Diameter Ratio (Kellogg Forest)	32	128	4	619	726	132	1681	7228	1.94**	2.83**	1.13
Eucosma (Kellogg Forest)	28	132	4	619	27.32	8.21	59.28	184.36	2.93**	7.09**	1.58

BS--Between stands
WS--Within stands
R--Replication
*--significant 5% level
**--significant at 1% level
ER--Error

Table A2.--Height data on stand progenies at W.K. Kellogg Forest and Hidden Lake Garden.

Stand Map Number	State and County	Relative Height		
		Kellogg Forest	Hidden Lake Garden	Weighted Total
		(% of mean)		
1	GA Fannin	106	94	102
2	GA Fannin	112	93	107
3	GA Union	112	--	112
4	GA Rabun	104	104	104
5	GA Rabun	--	--	--
6	GA Rabun	95	--	95
7	NC Macon	117	90	103
8	NC Cherokee	100	102	101
9	NC Henderson	106	--	106
10	NC Graham	110	--	110
11	NC Buncombe	108	--	108
12	NC Buncombe	106	98	103
13	NC Yancey	108	93	103
14	NC Madison	102	96	99
15	NC Burke	--	--	--
16	NC Burke	90	99	95
17	NC Caldwell	102	--	102
18	NC Burke	98	103	100
19	TN Polk	119	110	114
20	TN Monroe	106	114	110
21	TN Anderson	112	113	112
22	TN Carter	110	110	110
23	VA Carroll	104	--	104
24	VA Amherst	104	--	104
25	VA Montgomery	104	96	100
26	VA Craig	84	--	84
27	VA Botetourt	94	--	94
28	VA Alleghany	--	90	90
29	VA Augusta	94	--	94
30	VA Rockingham	94	101	96
31	KY Whitley	104	--	104
32	WV Greenbrier	104	96	100
33	WV Greenbrier	96	--	96
34	WV Greenbrier	90	93	92
35	WV Greenbrier	92	97	95
36	WV Greenbrier	92	--	92
37	WV Greenbrier	80	98	88
38	WV Mercer	100	--	100
39	WV Pocahontas	98	--	98
40	WV Pocahontas	104	--	104

Table A2 (cont'd.)

41	WV Pocahontas	100	85	93
42	WV Pocahontas	92	96	93
43	WV Pocahontas	90	--	90
44	WV Tucker	--	--	--
45	WV Braxton	78	100	88
46	WV Pleasants	92	102	94
47	WV Wetzel	84	98	90
48	MD Garrett	104	--	104
49	OH Monroe	--	82	82
Actual mean, cm.		373	269	337

Table A3.--Diameter data on stand proginies at W.K. Kellogg Forest.

Stand Map Number	State	County	Diameter at D.B.H.	Diameter at Base
			(% of mean)	
1	GA	Fannin	101	100
2	GA	Fannin	113	113
3	GA	Union	91	93
4	GA	Rabun	--	--
5	GA	Rabun	--	--
6	GA	Rabun	114	106
7	NC	Macon	110	116
8	NC	Cherokee	101	100
9	NC	Henderson	114	109
10	NC	Graham	132	129
11	NC	Buncombe	105	103
12	NC	Buncombe	110	109
13	NC	Yancey	114	113
14	NC	Madison	105	103
15	NC	Burke	--	--
16	NC	Burke	78	80
17	NC	Caldwell	114	106
18	NC	Burke	105	106
19	TN	Polk	119	116
20	TN	Monroe	110	106
21	TN	Anderson	114	109
22	TN	Carter	114	106
23	VA	Carroll	119	113
24	VA	Amherst	110	103
25	VA	Montgomery	96	100
26	VA	Craig	82	87
27	VA	Botetourt	96	93
28	VA	Alleghany	--	--
29	VA	Augusta	96	96
30	VA	Rockingham	84	88
31	KY	Whitley	105	103
32	WV	Greenbrier	105	103
33	WV	Greenbrier	101	109
34	WV	Greenbrier	82	87
35	WV	Greenbrier	87	90
36	WV	Greenbrier	110	103
37	WV	Greenbrier	68	80
38	WV	Mercer	105	100
39	WV	Pocahontas	110	103
40	WV	Pocahontas	110	109

Table A3 (cont'd)

41	WV	Pocahontas	110	100
42	WV	Pocahontas	87	93
43	WV	Pocahontas	82	84
44	WV	Tucker	--	--
45	WV	Braxton	68	77
46	WV	Pleasants	87	87
47	WV	Wetzel	78	80
48	MD	Garrett	109	106
49	OH	Monroe	--	--
Actual Plantation Mean (1/10 inches)			21.9	31.1

Table A5 (cont'd)

41	WV	Pocahontas	1.0
42	WV	Pocahontas	1.4
43	WV	Pocahontas	2.5
44	WV	Tucker	--
45	WV	Braxton	2.3
46	WV	Pleasants	1.7
47	WV	Wetzel	1.5
48	MD	Garrett	1.8
49	OH	Monroe	--
Plantation Mean			1.0

Table A6.--Number of lateral branches in the 1977 whorl for stand progenies at W.K. Kellogg Forest.

Stand Map Number	State	County	Number of Branches
1	GA	Fannin	7.8
2	GA	Fannin	9.0
3	GA	Union	7.3
4	GA	Rabun	---
5	GA	Rabun	---
6	GA	Rabun	9.0
7	NC	Macon	8.0
8	NC	Cherokee	8.3
9	NC	Henderson	8.3
10	NC	Graham	9.3
11	NC	Buncombe	8.0
12	NC	Buncombe	8.7
13	NC	Yancey	8.3
14	NC	Madison	8.0
15	NC	Burke	---
16	NC	Burke	8.3
17	NC	Caldwell	9.3
18	NC	Burke	7.7
19	TN	Polk	8.0
20	TN	Monroe	7.7
21	TN	Anderson	7.3
22	TN	Carter	8.0
23	VA	Carroll	8.7
24	VA	Amherst	7.3
25	VA	Montgomery	8.7
26	VA	Craig	7.0
27	VA	Botetourt	8.7
28	VA	Alleghany	---
29	VA	Augusta	10.7
30	VA	Rockingham	8.5
31	KY	Whitley	8.3
32	WV	Greenbrier	9.3
33	WV	Greenbrier	7.3
34	WV	Greenbrier	7.0
35	WV	Greenbrier	8.0
36	WV	Greenbrier	8.0
37	WV	Greenbrier	7.7
38	WV	Mercer	8.3
39	WV	Pocahontas	7.7
40	WV	Pocahontas	8.3

Table A6 (cont'd)

41	WV	Pocahontas	8.3
42	WV	Pocahontas	8.3
43	WV	Pocahontas	7.7
44	WV	Tucker	---
45	WV	Braxton	7.7
46	WV	Pleasants	8.7
47	WV	Wetzel	8.3
48	MD	Garrett	11.0
49	OH	Monroe	---
Plantation Mean			8.2