PINE PROVENANCE TESTS

Thesis for the Degree of M. S.

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WARREN L. NANCE

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ABSTRACT

EARLY EVALUATION OF HEIGHT GROWTH IN SEVEN PINE PROVENANCE TESTS

by Warren L. Nance

Height growth data from seven pine provenance tests located in lower Michigan were analysed in order to determine the feasibility of early evaluation of height growth. The seven plantations ranged in age from eight to ten years old, and included one eastern white pine (*Pinus strobus* L.) plantation, one ponderosa pine (*Pinus ponderosa* Laws.) plantation, and five Scotch pine (*Pinus sylvestris* L.) plantations. Three of the Scotch pine plantations were part of a range-wide study. The other two Scotch pine tests were made up of provenances from the northern latitudes.

Three methods of analyses were used: simple correlation; multiple linear regression; and Pearce's growth analysis. The latter method is essentially a variance-covariance analysis designed to determine growth patterns in trees.

Simple correlation analysis revealed that nursery performance was a good indicator of future growth in the field for the Scotch pine range-wide study and the white pine test. However, in the ponderosa pine test and the Scotch pine northern latitude study, nursery performance was not a reliable indicator of future growth. Winter injury was considered responsible for the poor age-age correlations in height growth in the ponderosa pine test.

Multiple regression analysis revealed that in most cases height measurements spaced at three-year intervals are sufficient for height growth evaluation in field tests. In the case of ponderosa pine, multiple regression also proved useful in determining the influence of winter injury on height growth predictability.

Pearce's analysis was performed on the Scotch pine northern latitude plantations. The analysis revealed that temporary nursery effects were still detectable in the field and had declined very slowly over the eight-year test period. The analysis also showed that planting site had an affect on the pattern of growth exhibited by the trees.

The present results indicate that early selection for height growth is feasible provided that the species is adapted to the site and the test conditions are precise enough to eliminate most of the temporary variation induced in the nursery.

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by

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INTRODUCTION

Time is critical in a forest tree improvement program. The long life cycle in trees makes field-testing procedures in forestry much longer than in other agricultural crops. The result has been relatively slow progress in the genetic improvement of forest tree species. How can the tree breeder overcome this basic problem and produce improved planting stock in a fraction of the time now consumed? One promising method is early evaluation of performance; that is, early selection for a quantitative trait based on performance early in the life cycle.

If early selection methods are to be practical, they must produce reliable and lasting gain. This means that only traits which are under relatively strong genetic control are eligible for early selection. More heritability studies are needed to identify these traits and determine the strength of their genetic control. Also, the phenotypic correlations in performance throughout the life cycle must be high enough for reliable selection.

Forest genetic field tests offer a good opportunity for the study of phenotypic correlations in performance, provided they meet three basic requirements. First, they must be well designed; that is, replicated, randomized, and locally restricted (blocked). Second, they must be old enough to provide useful information. Finally, accurate records must be available for past performance in the traits under study.

The objectives of this study were two:

1. Determine the feasibility of early selection for height growth.
2. Establish methods of analysis for early evaluation studies.

Three species were selected for study: eastern white pine (*Pinus strobus* L.), Scotch pine (*Pinus sylvestris* L.), and ponderosa pine (*Pinus ponderosa* Laws.). Phenotypic correlations in height growth were investigated in seven provenance tests of these three species in lower Michigan. In addition, multiple regression and analysis of variance and covariance were examined for their utility in determining the reliability of early performance in height growth within the seven tests.

REVIEW OF LITERATURE

An extensive review of the literature related to early evaluation in forestry is included in a recent publication by Nanson (1968). Of the more than 250 papers reviewed by Nanson covering all phases of early evaluation, only 43 contained data on age-age correlations in height growth of forest trees. Obviously, early evaluation has been a popular subject, but few of the papers contained experimental data. Many early forest researchers either accepted the validity of early evaluation and terminated their studies in the nursery, or rejected it's validity and failed to measure juvenile growth.

Most of the existing knowledge on phenotypic correlations in height growth is a by-product of early provenance tests of pines. The IUFRO (International Union of Forest Research Organizations) experiments in the early 1900's are among the most valuable of the early tests. More recently established tests have included provisions for detailed study of early selection methods. The work of Callaham _et al_ (1961, 1962) is typical of efforts in this direction.

A third source of information is the nursery selection studies initiated in the United States in the past two decades. These studies were designed to test the efficiency of mass selection for height growth in commercial nursery beds. Superior seedlings were selected within nursery beds at a rate of 1/30,000 or more and outplanted with a nearby seedling of average height. Height superiority of the select trees was used as a measure of the effectiveness of mass selection.

Age-age correlations.-- Age-age correlations in height growth taken from provenance and progeny tests are summarized in Table 1. This summary points out three important facts about the status of our knowledge in this field. First, with the possible exception of four Scotch pine plantations reported by Nanson (1968), there are no replicated tests which have reached rotation age. One can conclude from this that any improved planting stock produced up to the present time is a result of an early evaluation of the results.

A second feature is the paucity of species studied. Results for Scotch pine and ponderosa pine make up the bulk of our knowledge on the subject. As more tests become older, the list of species should become more representative.

Finally, the case for early evaluation based on the limited amount of information available is undeniably strong. With few exceptions, the early height growth was a reliable indicator of future growth.

Nursery selection studies.-- The sucess of mass selection for height growth in commercial seedbeds has been inconsistent. The oldest nursery selection study in the United States was initiated by Ellertsen (1955) and later reported on by Zarger (1963). The authors selected 70 2-year old eastern white pine seedlings over a 5-year period. After 11 to 14 years in the field, the selected seedlings were significantly taller than their controls.

Table 1. Summary of phenotypic correlations between height at different ages reported in the literature. Each entry is a separate field test.

Species	Type of study	No. of sources, families or trees	Ages correlated X on Y (years)		Correlation coefficient	Researcher and date of publication
Acer saccharum Marsh.	provenance	19	2	9	0.78**	Kriebel (1962)
"	"	19	2	9	0.48*	"
Malus hybrids	early evaluation of single trees		2	9	0.09	Dorsey *et al* (1943)
"	"		2	9	0.06	"
"	"		2	9	0.39**	"
"	"		2	9	0.40**	"
"	"		2	9	0.42**	"
"	"		2	9	0.29**	"
"	"		2	9	0.20*	"

Table 1. Continued.

Species	Type of study	No. of sources, families or trees	Ages correlated X on Y (years)		Correlation coefficient	Researcher and date of publication
			X	Y		
Picea abies (L.) Karst.	provenance	22	12	22	0.88**	Vincent (1963)
Pinus ponderosa Laws.	provenance	10	5[a]	30	0.85*	Squillace *et al* (1962)
"	"	10	3	30	0.81*	"
"	"	10	4[a]	30	0.67*	"
"	"	10	11[a]	30	0.75*	"
"	"	10	3	30	0.92**	"
"	early evaluation of single trees	112	12[a]	20	0.75*	Callaham *et al* (1962)
"	half-sib progeny	80	2	15	0.30*	"

Table 1. Continued.

Species	Type of study	No. of sources, families or trees	Ages correlated X on Y (years)		Correlation coefficient	Researcher and date of publication
Pinus resinosa Ait.	half-sib progeny	20	5[a]	11	0.8*	Lester *et al* (1966)
Pinus sylvestris L.	provenance	17	3	58	0.84**	Nanson (1968)
"	"	8	7	59	0.28	"
"	"	14	10[a]	54	0.83**	"
"	"	9	10	53	0.79*	"
"	"	23	7	29	0.64**	"
"	half-sib progeny	15	2	11	0.82**	"
"	provenance	55	3	17	0.93	Wright *et al* (1957)
"	"	10	8	17	0.94**	Johnsson (1955)
"	"	43	2	[illegible]	0.[illegible][b]	Schreiner *et al* ([illegible])

Table 1. Continued.

Species	Type of study	No. of sources, families or trees	Ages correlated X on Y (years)		Correlation coefficient	Researcher and date of publication
Pinus sylvestris L.	provenance	31	12	22	0.87**	Vincent (1963)
Pinus taeda L.	provenance	4	1	35	0.8[c]	Wakeley *et al* (1963)
Populus hybrids	early evaluation of single trees	--	1	8	high	Bialobok (1963)
Pseudotsuga menziesii (Mirb.) Franco	provenance	9	4	42	0.72**	Hanson (196[illegible])

*significant at the 0.05 level
**significant at the 0.01 level

[a]correlations based on earlier years were not significant.

[b]Represents a pooled correlation coefficient for two field tests.

[c]Correlation coefficient computed by the present author from data presented in publication.

They also selected 210 loblolly (*Pinus taeda* L.) and 45 shortleaf (*Pinus echinata* Mill.) 1-year-old pine seedlings during the same period. After 11 to 14 years, the selected trees were not significantly different from the controls in either species.

In a similar study initiated by Barber and Van Haverbeke (1961), 582 slash (*Pinus elliotti* Engelm.) and 571 loblolly pine seedlings were selected. After nine years, Hunt (1967) reported that the selected trees were still taller than their controls, but the height advantage had decreased after age four.

King *et al* (1965) selected 357 superior white spruce (*Picea glauca* (Moench) Voss.) seedlings from 4-year-old transplants. The selected seedlings were significantly taller than the controls after eight years in the field. A smaller study by Bengston (1963) showed that 34 slash pine selected seedlings had outgrown their controls after eight years in the field.

Some researchers have arbitrarily graded nursery stock into height classes and compared their growth after outplanting. In all cases, the tallest class was still the tallest after 4 to 12 years in the field (Bethune *et al* (1966), Clausen (1963), Curtis (1955), Fowells (1963), Funk (1964), Hunt *et al* (1967), Schütt (1962), and Shipman (1960)).

The preceeding studies show that early height growth can be a reliable indicator of future height growth. Emphasis should be placed on obtaining more information on those important species which are not represented. Also, methods of early selection must be defined to allow the researcher to make predictions of future growth based on early performance.

MATERIAL AND METHODS

The seven plantations included in this study are among the oldest Michigan State University provenance tests located in Michigan. With one exception, they were established with stock grown in the Bogue nursery at East Lansing, Michigan. The exception was one white pine test which was transplanted for one season in the Bogue nursery. The design for all plantations is a randomized complete block with row plots. The seed source collections were all made from several trees of "average" phenotype located in a native stand.

Material.-- A summary of the details for each study follows. Additional details for each planting appear in Table 2.

The five Scotch pine plantations are all part of the North Central NC-51 regional project. The seed was requested from European researchers and seed dealers by J. W. Wright in the summer of 1958. Seeds were recieved from natural stands in 19 Eurasian countries. Each seedlot consisted of seed from ten or more average trees from one stand.

The seed were sown in two separate nursery tests. One test consisted of 108 seedlots sown in the nursery in the spring of 1959. These seedlots represented a range-wide sample of Scotch pine. The second test consisted of 59 seedlots from northern latitudes sown in the spring of 1961. Both tests were sown in five replicates. The fifth, non-randomized replicate provided most of the planting stock.

Table 2. Establishment details of seven pine provenance tests.

Plantation number	Species	Michigan location	Date planted	Soil texture	Number of Blocks	Number of Sources	Number of Tre[illegible]
1-62	ponderosa	Kellogg Forest, Kalamazoo Co.	4/13/62	sandy loam	7	53	[illegible]
2-61	Scotch	Kellogg Forest, Kalamazoo Co.	4/12/60	sandy loam	10	15	[illegible]
3-60	eastern white	Kellogg Forest, Kalamazoo Co.	4/04/61	loamy sand	10	108	[illegible]
11-61	Scotch	Allegan Forest, Allegan Co.	4/20/61	sand	10	72	[illegible]
12-61	Scotch	Rose Lake Sta., Shiawasse Co.	4/20/61	sandy loam	8	76	[illegible]
15-62	Scotch	Allegan Forest, Allegan Co.	9/21/62	sand	10	46	[illegible]
17-62	Scotch	Rose Lake Sta., Shiawasse Co.	10/12/62	loamy sand	15	51	[illegible]

The range-wide study produced excellent planting stock superior in size and uniformity to that produced locally in commercial nurseries. In contrast, the northern latitude study produced more variable stock. The stock from both studies was outplanted as 2-0 seedlings, the former in the spring of 1961 and the latter in the fall of 1962.

The white pine plantation is part of a range-wide study initiated by the U. S. Forest Service in cooperation with other Canadian and United States tree breeders. Seedlots were collected from 26 natural stands, each seedlot consisting of seed from 3 to 10 average trees in a native stand. The seed was sown in the nursery in the spring of 1957. In 1959 and 1960 more than 30 permanent test plantations were established throughout the natural range with 2-0 or 2-1 seedlings. Weed control varied from slight to intensive. There were 4 to 25 replicates within each plantation and 1 to 81 trees per plot within each replicate. Three plantations were established in lower Michigan, one of which was selected for use in this study.

The ponderosa pine plantation is part of a range-wide study initiated by the U. S. Forest Service in cooperation with Michigan State University. Seed was collected from 298 individual trees in 57 native stands in 1955 and 1956. The seed was sown in the nursery in a compact family design with 3 replications and outplanted in the spring of 1962.

Measurements.-- The bulk of the data for this study came from past records of total height measurements. The following total heights on a plot mean basis were available.

Plantation number	Total height at age (from seed)							
1-62	1	2	3	6	7	8		
3-60	3	4	5	7	8	9	10	
2-61	1	2	3	6	9	10		
11-61	1	2	3	7	10			
12-61	1	2	3	6	8	9	10	
15-62	1	2	3	4	5	6	7	8
17-62	1	2	3	5	6	7	8	

In addition, individual-tree height growth records were obtained in the fall of 1968 by measuring past internode length of approximately 100 trees in each of six plantations and every tree in the seventh plantation. The 100 trees per plantation is enough to calculate simple correlations with a 0.05 confidence limit of ± 0.20. To obtain the necessary [illegible] trees in a planting, I measured the tallest tree in every plot of one to seven replicates. By measuring only the tallest tree in a planting, most of the variation between plots due to insect damage and mortality was removed.

Analysis.-- The three classes of data (source means, plot means, and individual-tree data) were analysed with the aid of Michigan State University's CDC 3600 digital computer.

[illegible] library [illegible] entitled LSDEL (written by [illegible]. [illegible], Agricultural Experiment Station, [illegible]) [illegible] for all analyses. With this routine I did the following analyses for each class of data for each plantation:

1. All possible simple correlations for both total height and annual increment.
2. Multiple regression with total height in 1968 as the dependent variable and total heights for previous years as independent variables.
3. Multiple regression with 1968 increment as the dependent variable and previous increments as the independent variables.

<u>Pearce's analysis</u>.-- A separate type of analysis was done for the height growth data of plantations 15-62 and 17-62. This analysis, developed by S. C. Pearce (1960), is designed to answer specific questions concerning the pattern of relative growth rate in a group of developing organisms. The basic features of this analysis are outlined below.

Basically, Pearce's analysis of the manner of growth utilizes three standard errors to reveal patterns in the relative growth rate of a group of developing organisms. These standard errors are:

1. σ_T, that of logarithm of total height (= log(height)) at time t.
2. $\sigma_{T\delta}$, that of increment in log(height) between time zero and time t.
3. σ_T', that of log(height) at time t after adjustment for covariance on the corresponding values at time zero.

The first standard error is taken from the error line of the analysis of variance of log(height) at time t after adjustment for block and source effects. The second standard error is taken from the error line of the analysis of the analysis of variance for increment in log(height) between time zero and time t, after correction for block and source effects. The variable t takes on the values 1,2,...n, where n is the total age of the tree in years. Finally, the third standard error is taken from the error line of the analysis of covariance for log(height), after correction for block, source, and covariate. The covariate is log(height) at time zero.

These standard errors are obtained for each time t in which measurements were taken for total height and then plotted over time. The resulting pattern can provide answers to the following questions:

1. Is the relative growth rate of individual trees constant or dynamic?
2. Does the initial height at time of outplanting affect the future relative growth rate of the tree?
3. If the future growth rate is influenced by initial height, how does this influence change with time?

A further explanation of the method will be given in the results section along with the answers to these questions for the Scotch pine plantations analysed.

RESULTS

The results of analyses for the three classes of data were compared for each plantation. The analyses based on plot means were eliminated from consideration. They did not contribute any significant information beyond that obtained from the analysis of source means and individual-tree data.

Scotch pine.-- As noted previously, the range-wide provenance study was superior in height growth to the northern latitude study in the nursery. When the two studies were outplanted, the 2-0 stock of the former averaged 28 centimeters in height compared to an average of 15 centimeters in height for the 2-0 stock of the latter. Average height at age eight for the three range-wide plantations (Nos. 11-61, 12-61, and 2-61) was 209 centimeters compared to an average height of 145 centimeters for the two northern latitude plantations (15-62 and 17-62). Thus the early height growth differences between the two studies has persisted to the present time.

Four sources of variation between the two studies contributed in varying degrees to the observed differences in height growth. These are:

1. Differences in range of geographic origin between the two studies.
2. The studies were outplanted in different seasons: fall plantings for the northern latitude study and spring plantings for the range-wide study.

3. The studies were sown in the nursery in different years.

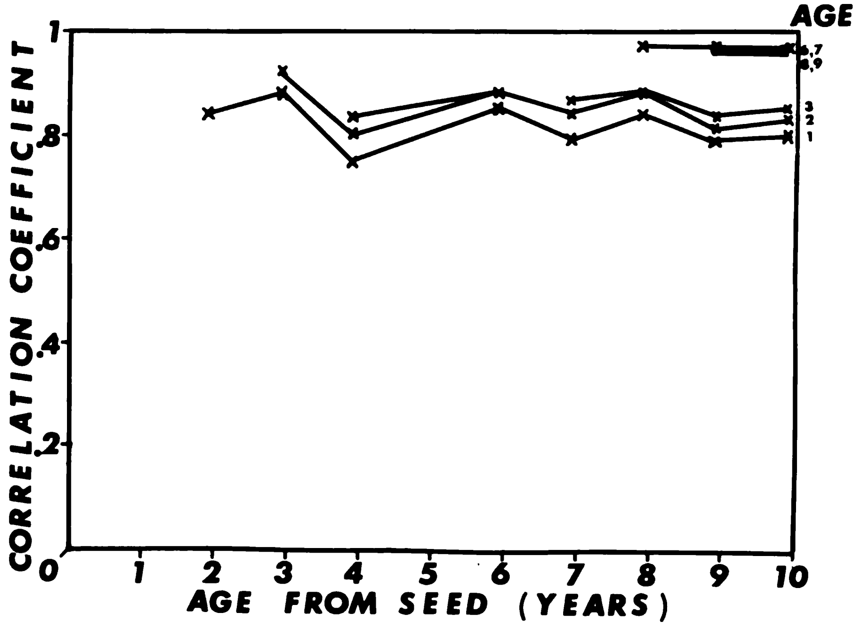
4. There are differences in site quality between the plantations of the two studies, although they are minor in comparison to the other sources of variation.

Range-wide study.-- The three plantations stocked with seedlings from the range-wide study were remarkably similar in height growth. Apparently, site quality differences between the plantations within this group were of minor importance in their effect on growth rate. For this reason, the analysis of individual plantations within this study were combined with little loss of information.

Source differences in height growth were clearcut in the nursery (Wright, 1963). More important from the standpoint of early selection, these early differences in the nursery were indicative of future performance in the field. Figure shows the simple correlation matrix for mean source height in different years from seed, pooled for the three plantations. To find the value of the simple correlation coefficient between height at age one and height at age four, for example, simply locate the "age 1" curve on the right-hand side of the graph and follow it to the "X" above age four on the lower axis. The value of the "X" on the left-hand axis is the correlation coefficient between the two variables.

Figure 1. Simple correlations between source mean heights in the Scotch pine range-wide study. Each "X" represents a pooled value for plantations 2-61, 11-61, and 12-61.

Figure 2. Simple correlations between individual-tree heights in the Scotch pine range-wide study. Each "X" represents a pooled value for plantations 2-61, 11-61, and 12-61.


AGE
CORRELATION COEFFICIENT
0
.2
.4
.6
.8
1
1
2
3
4
5
6
7
8
9
10
AGE FROM SEED (YEARS)

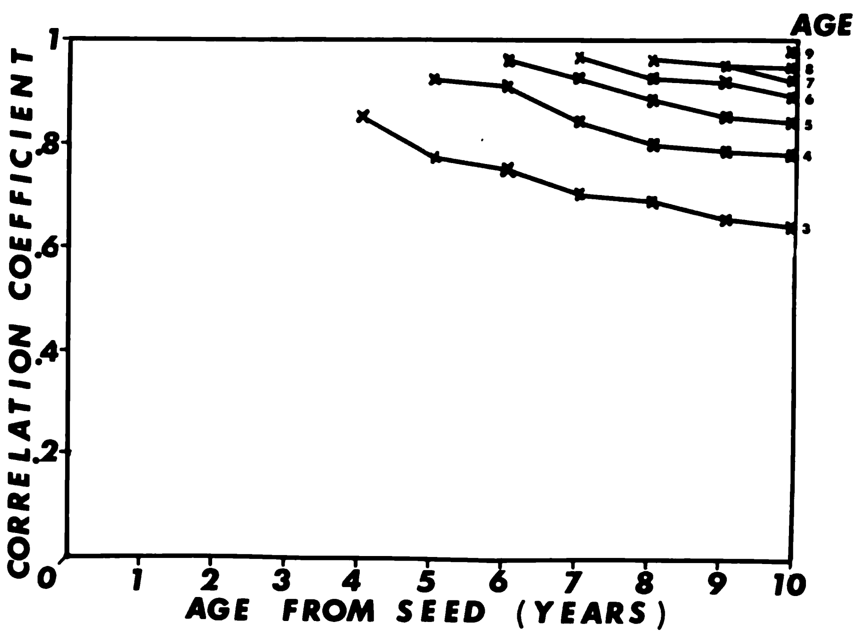
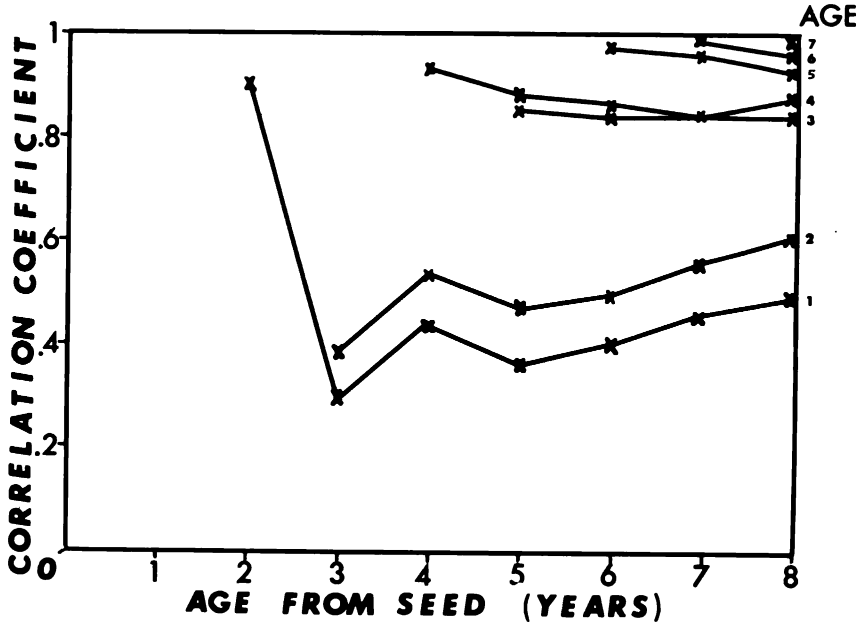
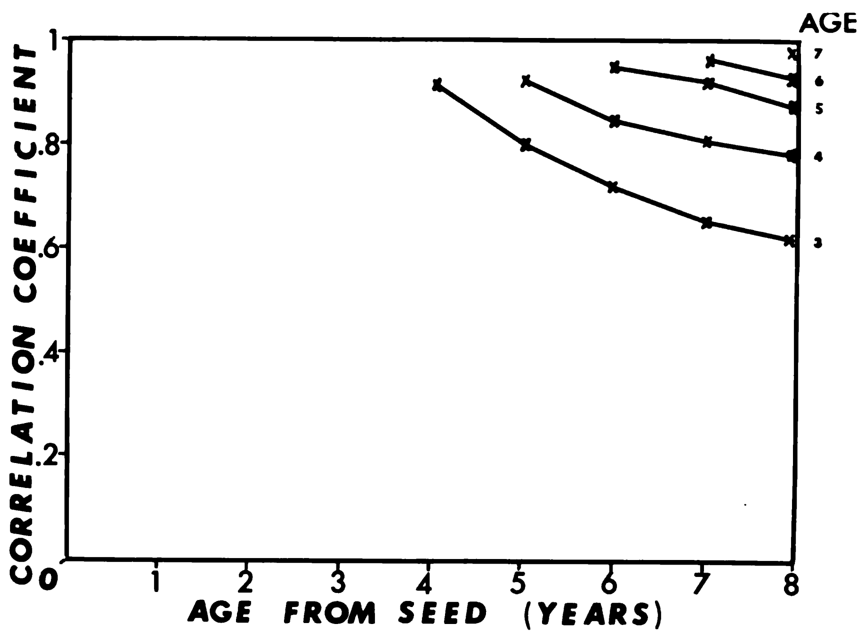

AGE
9
8
7
6
5
4
3
CORRELATION COEFFICIENT
0
.2
.4
.6
.8
1
1
2
3
4
5
6
7
8
9
10
AGE FROM SEED (YEARS)

Figure 3. Simple correlations between source mean heights in the Scotch pine northern latitude study. Each "X" represents a pooled value for plantations 15-62 and 17-62.

Figure 4. Simple correlations between individual-tree heights in Scotch pine plantation 15-62.


AGE
CORRELATION COEFFICIENT
1
.8
.6
.4
.2
0
1
2
3
4
5
6
7
8
AGE FROM SEED (YEARS)


AGE
CORRELATION COEFFICIENT
1
.8
.6
.4
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0
1
2
3
4
5
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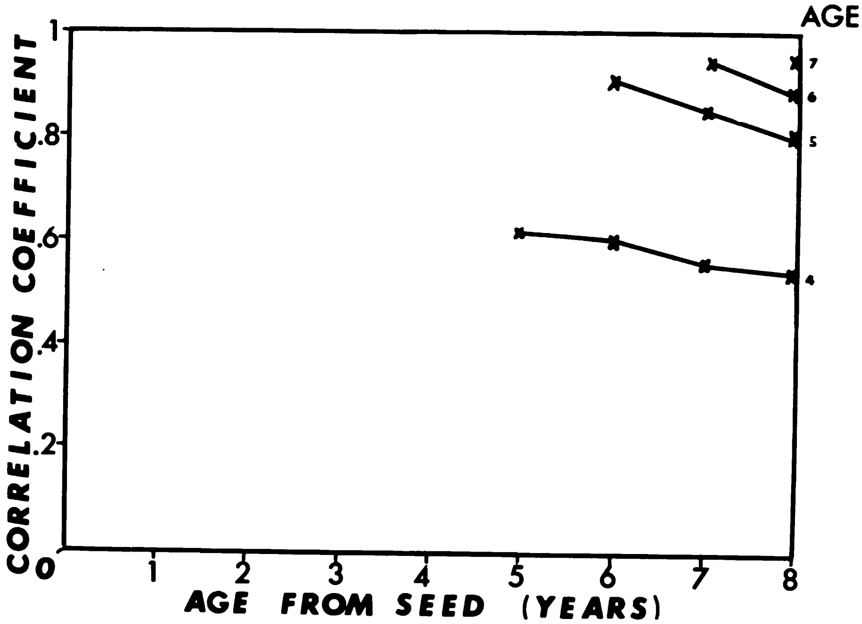
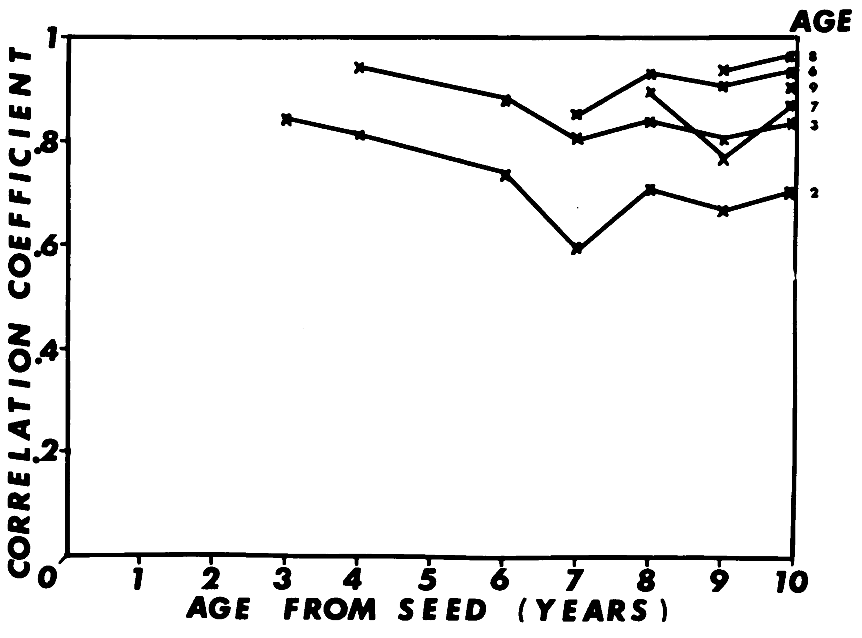
7
8
AGE FROM SEED (YEARS)

Figure 5. Simple correlations between individual-tree heights in Scotch pine plantation 17-62.

Figure 6. Simple correlations between source mean heights in white pine plantation 3-60.



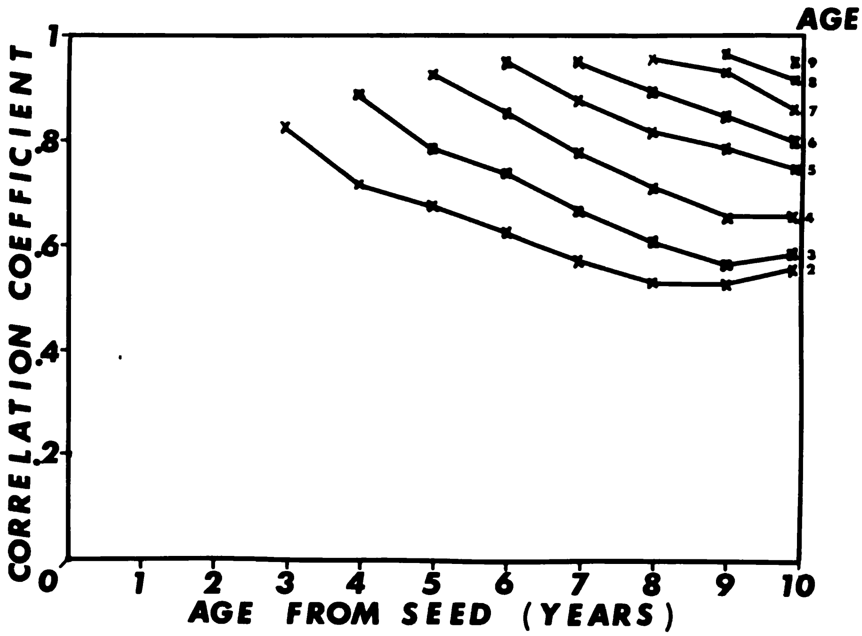
AGE
7
6
5
4
CORRELATION COEFFICIENT
1
.8
.6
.4
.2
0
1
2
3
4
5
6
7
8
AGE FROM SEED (YEARS)



AGE
8
6
9
7
3
2
CORRELATION COEFFICIENT
1
.8
.6
.4
.2
0
1
2
3
4
5
6
7
8
9
10
AGE FROM SEED (YEARS)

Figure 7. Simple correlations between individual-tree heights in white pine plantation 3-60.

Figure 8. Simple correlations between source mean heights in ponderosa pine plantation 1-62.



AGE
CORRELATION COEFFICIENT
AGE FROM SEED (YEARS)
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.2
.4
.6
.8
1
1
2
3
4
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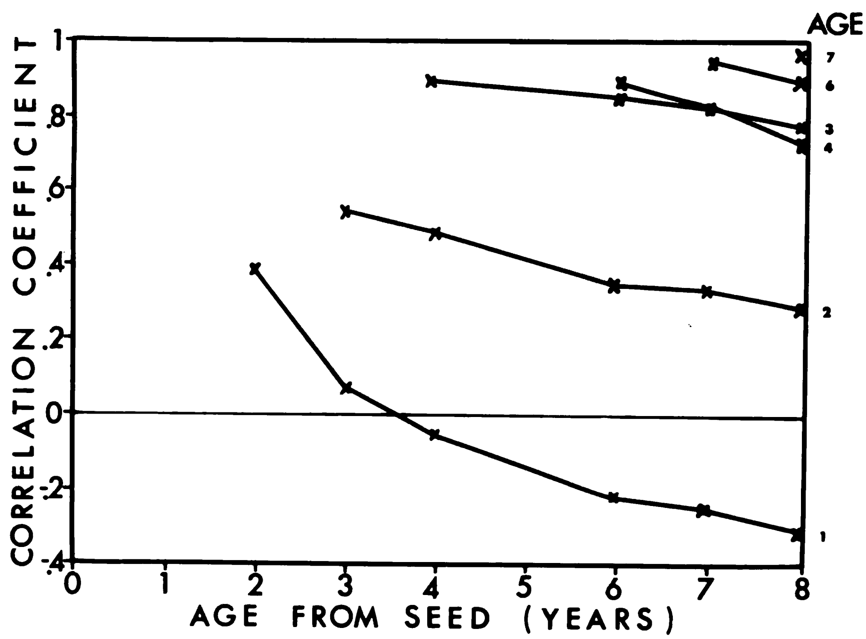
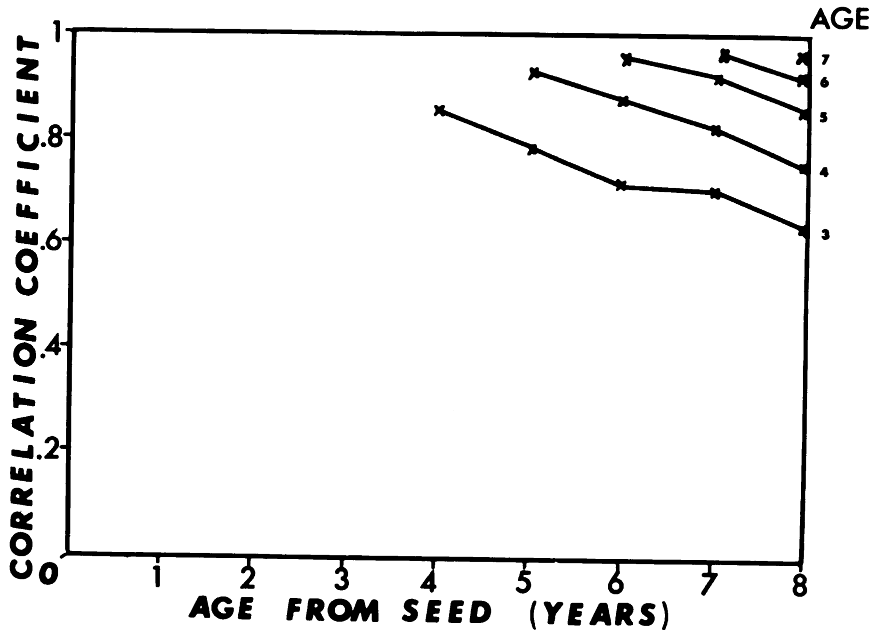
6
7
8
9
10



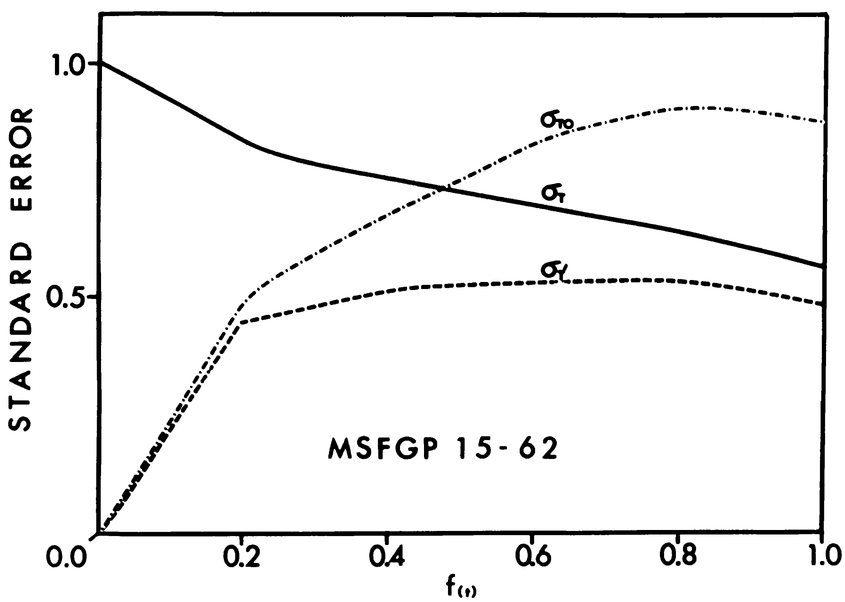
AGE
CORRELATION COEFFICIENT
AGE FROM SEED (YEARS)
-.4
-.2
0
.2
.4
.6
.8
1
0
1
2
3
4
5
6
7
8

Figure 9. Simple correlations between individual-tree heights in ponderosa pine plantation 1-62.

Figure 10. Results of Pearce's analysis for Scotch pine plantation 15-62.

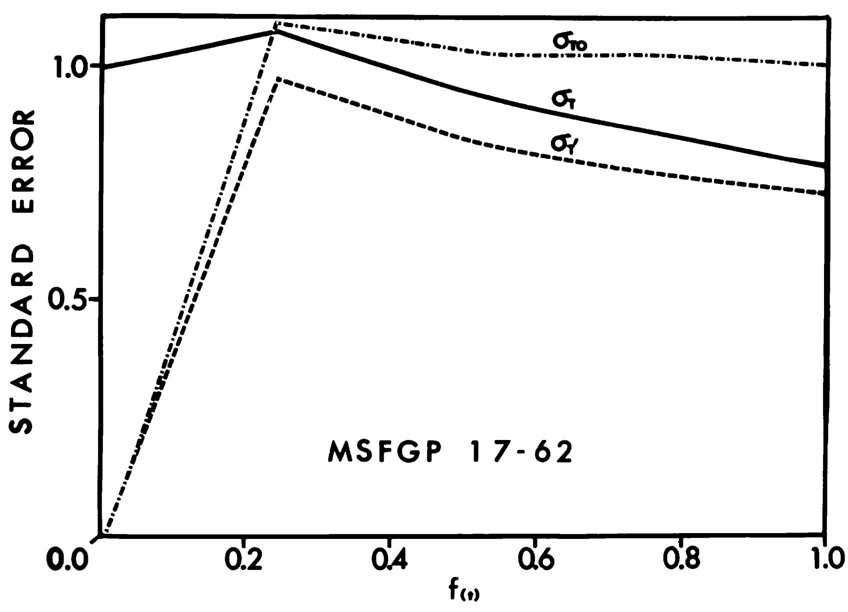


AGE
CORRELATION COEFFICIENT
AGE FROM SEED (YEARS)



STANDARD ERROR
MSFGP 15-62

Figure 11. Results of Pearce's analysis for Scotch pine plantation 17-62.



STANDARD ERROR
1.0
0.5
0.0
0.2
0.4
0.6
0.8
1.0
f(1)
σTO
σT
σY
MSFGP 17-62

Table 3. Number of sources maintaining a selection differential of one standard deviation (S. D.) above the mean height in seven provenance tests.

Plantation number	Sources sampled	Sources selected originally	Sources maintaining one S. D. selection differential in			Correlation coefficient[a]
			1964	1966	1968	
	number	number	number			r
1-62	53	9	2	2	1	0.271*
2-61	15	9	5	---	6	0.758**
3-60	109	1	1	1	1	0.729**
11-61	72	6	3	---	4	0.847**
12-61	76	15	10	11	10	0.906**
15-62	46	7	2	2	4	0.603**
17-62	51	8	1	3	1	0.615**

*Significant at the 0.05 level.
**Significant at the 0.01 level.

[a]Correlation coefficient between source mean height the last year in the nursery and mean height of the same source in 1968, including all sources in each plantation.

Table 4. Number of individual trees maintaining a selection differential of one standard deviation (S. D.) above the mean height in seven provenance tests.

Plantation number	Trees sampled	Trees selected originally	Trees maintaining one S. D. selection differential in			Correlation coefficient[a]
			1964	1966	1968	
	number	number		number		r
1-62	98	16	16	11	5	0.766**
2-61	126	11	11	9	8	0.738**
3-60	70	18	6	7	7	0.544**
11-61	98	17	12	10	10	0.835**
12-61	153	36	33	21	22	0.749**
15-62	236	12	12	5	3	0.789**
17-62	425	67	67	35	29	0.554**

**Significant at the 0.01 level.

[a]Correlation between height the first year in the field and corresponding height in 1968, including all trees in each plantation.

The close correspondence between nursery performance and field performance shows that selection of superior sources in the nursery was feasible. To view these results from another standpoint, I considered those sources which were at least one standard deviation above the mean height at the end of the nursery phase and followed their performance in later years in each field test. The results appear in Table 3. Of the top sources included in each of the three plantations, approximately two-thirds maintained their superior position through the 1968 growing season.

I performed the same analyses as for source means on the data from 500 individual trees in the same three plantations. The results appear in Figure 2 and in Table 4. Comparison with Figure 1 shows that the correlations between height at different ages were lower for the individual-tree data than for the source means analysis. This is further reflected in the smaller fraction (five-eighths) of selected trees which had maintained their height superiority through the 1968 growing season.

Multiple regression analyses were performed on both the source means and the individual-tree data to determine the preciseness with which future height and annual increment could be predicted from previous height measurements. The general significance of these analyses can be summarized as follows:

1. Height at ages 1, 2, and 3 accounted for 67 to 83 percent of the variation in total height among sources at age 10 (R^2 = .67, .74, and .83 for plantations 2-61, 11-61, and 12-61 respectively).
2. Total height for the first and second year in the field accounted for 56 to 68 percent of the variation among individual trees at age 10 (R^2 = .68, .59, and .56 for plantations 2-61, 11-61, and 12-61 respectively).
3. Annual increment in 1968 could not be predicted accurately (R^2 = less than .30) from previous increments either for source means or individual-tree data (one exception: R^2 = .49 and .53 for source and individual-tree data respectively in plantation 2-61).
4. At least 92 percent of the variation in total height at age 10 for source and individual-tree data could be predicted from only three previous height measurements spaced at three-year intervals.

Northern latitude study.-- Differences in height growth between sources was not pronounced in the nursery (Wright, 1963). This was due in part to the fewer number of sources sampled from a more limited part of the natural range. Simple correlation coefficients between heights at different ages were similar enough to allow pooling for the source mean data from the two plantations. These appear in Figure 3.

The figure reveals that the nursery height was not a good indicator of future height growth in the field for this study. However, heights in the field after the end of the first year were closely related (r values above 0.80). The fact that these plantations were fall planted could have resulted in the low correlations between nursery and field height.

Table 3 shows the same relationship in a different way. Only about one-third of the sources maintained at least one standard deviation above the mean height both in the nursery and in the field after eight years of growth.

Individual-tree analyses for the two plantations were too disimilar to allow pooling. Figures 4 and 5 show the simple correlations for heights at different ages for plantations 15-62 and 17-62 respectively. The differences in the two figures are not great; plantation 15-62 showing slightly higher correlations than plantation 17-62. Part of this difference may be due to the increased mortality in the latter plantation as a result of poor weed control.

Table 4 reveals that even though the correlations were lower in plantation 17-62, a greater proportion of the trees above the selection criterion initially had maintained that position by age 8. Comparison of Figures 4 and 5 with Figure 3 suggests that individual-tree correlations are higher than the source mean height correlations. Table 4 shows that selection of individual trees in the field would have been more feasible than source selection in this study.

Multiple regression analyses were performed on the source and individual-tree data as in the range-wide study. In general they show:

1. Height at age 1 and 2 accounted for 39 to 41 percent of the variation between total height of source means at age 8 (R^2 = .41 and .39 for plantation 15-62 and 17-62 respectively).
2. Height the first and second year in the field accounted for 45 to 66 percent of the variation in individual-tree heights at age 8 (R^2 = .66 and .45 for plantation 15-62 and 17-62 respectively).
3. Height increment in the nursery accounted for 50 to 77 percent of the variation in eighth-year height increment between sources (R^2 = .77 and .50 for plantation 15-62 and 17-62 respectively).

<u>White pine</u>.-- The white pine plantation is the fastest growing plantation in the study. Excellent planting stock and good site conditions were in part responsible for the rapid growth. In addition, white pine, unlike Scotch or ponderosa pine, is native to lower Michigan and has an inherently fast growth rate. The combined factors resulted in an average height at age 10 of 4.8 meters.

Differences between sources in the nursery were significant, although relatively small. Figure 6 shows the simple correlations between heights at different years. These results show that nursery performance was not highly indicative of future performance. Also, correlations between early and late performance in the field are somewhat erratic; a condition not noted in the previous Scotch pine data.

Only one source, from Tennessee, met the selection criterion (one standard deviation above the mean) in the nursery. This source maintained it's position through age 10 in the field.

Why the erratic behavior in the correlations between source mean heights in this study? Further investigation revealed that only two sources were responsible for this result; Georgia and Ontario. The Georgia source initially ranked second in total height, but steadily declined in rank and now occupies the seventh position. In contrast, the Ontario source ranked sixth initially and now ranks second. The rank of the remaining 11 sources remained essentially unchanged.

Seventy individual trees were measured within plantation 3-68. The simple correlation coefficients between heights at different ages are shown in Figure 7. To show these results in a different light, I followed the height growth of those trees which were superior in height the first year in the field. The results (Table 4) show that individual-tree data are more reliable than source mean data in this plantation.

Multiple regression analysis was performed on source and individual-tree data as before. They show that:

1. Nursery height accounted for 53 percent of the variation in source mean height at age 10.
2. Height the first and second year in the field accounted for 36 percent of the variation between individual-tree height at age 10.
3. Tenth-year height increment could not be predicted accurately from previous annual increments with the individual-tree data (R^2 = .14).
4. Tenth-year height increment was predictable from previous annual increments for source mean data (R^2 = .80).
5. Three previous height measurements spaced at three year intervals were all the measurements needed to obtain essentially the same amount of information on height variation provided by all previous height measurements.

Ponderosa pine.-- From the standpoint of early selection methods, this plantation is the most interesting of the ones studied. The reason for this is the fact that visible evidence of non-adaptation, in the form of winter injury, i present in this species when planted in lower Michigan.

Wells (1964) noted the prescence of winter injury in some ponderosa pine origins during the nursery phase. The sources included in the southern ecotypes were more severely damaged by winter injury in the nursery than sources from the northern ecotypes. This relationship remained true in the plantations. Wells also reported that sources from the southern part of the range, the same ones which suffered the heaviest winter injury, were also the fastest growing at age one. This relationship changed drastically after the sources were outplanted. Apparently the effects of winter injury were so severe in the field that the southern ecotypes could no longer maintain the rapid rate of growth they exhibited their first year.

Figure 7 illustrates the change in height growth which occurred after outplanting. Note the negative correlations between height at age one in the nursery and subsequent field heights. This condition was brought about by the sharp decline of the southern ecotypes after outplanting along with a steady increase in relative performance of the injury-free northern ecotypes. The graph also reveals that the effects of winter injury had largely stabilized by the end of the third year from seed. In general, the correlations between winter injury and total height for source means was highly significant, ranging between -0.48 -0.68 (with a rating of 20 for severe winter injury and zero for none).

With these correlations one would expect little or no success with attempts to select superior sources on the basis of early height growth without regard for the effects of winter injury. Table 4 supports this expectation. Only one of the original nine sources maintained it's original superiority.

The results of the individual tree correlations appear in Figure 8 and Table 5. Due to the stabilized effects of winter injury, the individual-tree correlations appear much larger than the source means correlations. Also, a larger proportion of the select individuals maintained their original superiority than was the case with source means.

Multiple regression analyses revealed the following:

1. A combination of winter injury and nursery height accounted for 88 percent of the variation in total height between source means at age 8.
2. First and second year height in the field accounted for 70 percent of the variation in total height between individual trees at age 8.
3. Total height in the third, sixth, and seventh year accounted for 73 percent of the variation between individual trees in eighth-year height.

Pearce's analysis.-- The results of Pearce's analysis of variance and covariance for plantations 15-62 and 17-62 appear in Figures 10 and 11. The main objective of this analysis was to evaluate the effectiveness of the method in early evaluation studies. For this reason, the analysis was restricted to these plantations. Analysis of all the tests by this method would require extensive computer time.

The graphs were constructed in the following manner. All standard errors were made relative to σ_T at time 0. Time 0 corresponds to age 2 from seed for trees in each planting. The three relative standard errors at each time t were then plotted over time. The time scale is such that f(0) and f(1.0) correspond to age 2 and age 8 respectively for each plantation. The former represents age of trees at time of establishment and the latter corresponds to current time.

The results for plantation 15-62 are similar to that obtained by Pearce (1960) in apples. The slope of the σ_T curve is negative, showing that the smaller trees at time of outplanting have grown faster than the taller trees. This is analagous to a convergence of growth curves, for trees which were short and tall at time of outplanting, when plotted on semi-log paper.

The curve for σ_{TO} is steadily rising, except for a short period near the end of the time interval. This shows that the trees were growing at different growth rates for most of the time interval.

The σ_T' curve is slowly converging with the σ_T curve. The point where the two meet signals the end of the influence of initial height on relative growth rate. In other words, covariance adjustment no longer affects the size of σ_T. From this point on, the trees would perform on their own merit, no longer influenced by short-term nursery effects.

Figure 11 is obviously different. The curve for does not rise, indicating the trees do not have different growth rates thus far. The rate of convergence for σ_{TO} and σ_T should be negligible in this case. Inspection of the graph shows this to be true. Therefore, the present heights are merely magnifications of the initial heights, and most of the variation in present height in this planting is related to initial size differences. One would expect the simple correlations between height at different ages after outplanting to be high. This is true for both plantings, with the correlation coefficients between heights after age three ranging from 0.79 to 0.99.

What does the analysis contribute to the results of the simple correlation and multiple regression analyses presented previously? First, it shows the tremendous effect of initial nursery effects on future results. Temporary nursery effects have thus far overshadowed the seed source effect in these plantings. Second, the planting site can be shown to influence relative growth rate. The extreme stresses in one plantation did have a lasting effect on the performance of surviving trees. Finally, this analysis can show the exact time or age at which nursery influences have ceased. This point has not been reached in either of the plantations analysed.

PRACTICAL APPLICATION OF RESULTS

The forest researcher is faced with a difficult question: can he safely make an early evaluation of the tree's performance in the field? Based on these results as well as those of previous studies, the answer for height growth is a qualified yes.

The major qualification appears to be whether or not the species under test is suitably adapted to the test environment. The ponderosa pine in this study is a good example. This species shows evidence of non-adaptation to test sites in lower Michigan in the form of winter injury. The result was a negative correlation between height growth in the nursery and later growth in the field. However, once the basis for this performance was recognized and taken into account, future height growth was highly predictable.

A second qualification is: how precise are the test conditions? The northern latitude study in Scotch pine gave different results in the nursery than in the field. In contrast, the range-wide Scotch pine study gave essentially the same results in the nursery as in the field. A major difference between the two studies was the low precision of the former compared to the latter. High mortality and highly variable growth in field tests should be considered danger signals for early evaluation of height growth.

A final qualification is necessary: has the species under test exhibited strong age-age correlations in height growth in previous studies when planted under suitable test conditions? Previous experiments in Scotch pine, and to a much lesser extent ponderosa pine, have shown strong age-age correlation in height growth. Until such experience has been accumulated for other species, early evaluation of height growth in these species should be approached with caution.

Even when the qualifications appear to be satisfied, as in the range-wide Scotch pine study, early selection will not be perfectly reliable. The mistakes made in early selection must be balanced against the expected gains for the long run.

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Appendix A

Scotch pine provenance test No. 11-61.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 11-61
Scotch pine provenance test

1. Source means analyses (72 sources)

Key to Variables

Variable Number	Date Measured	Description of Variables
1	--	source number
2	10/18/62	leader growth of plot 1962 (cm)
3	10/18/62	leader growth of best tree 1962 (cm)
4	6/24/65	height 1965 (in.)
5	9/19/68	height 1968 (ft. X 4)
6	1959	nursery height 1959 (cm)
7	1960	nursery height 1960 (cm)
8	1961	nursery height 1961

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.095	0.023
3	0.120	0.028
4	1.021	0.288
5	2.193	0.624
6	0.092	0.020
7	0.278	0.066
8	0.483	0.109

Simple Correlation Coefficients

Variables							
2	1.00						
3	0.95	1.00					
4	0.90	0.90	1.00				
5	0.86	0.84	0.98	1.00			
6	0.67	0.66	0.82	0.85	1.00		
7	0.71	0.71	0.87	0.90	0.96	1.00	
8	0.75	0.74	0.90	0.93	0.92	0.96	1.00
	2	3	4	5	6	7	8

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
5	2,3,4,6,7,8,9,10	0.9527
5	2,4 ("Best Equation")*	0.9495
5	7,8	0.7394
5	7,8,9	0.7416
5	7,8,9,10	0.7437

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses (98 trees)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	10/10/68	mean height of plot 1968 (ft. X 4)
3	10/10/68	height 1968 (ft. X 4)
4	10/10/68	height 1967 (ft. X 4)
5	10/10/68	height 1966 (ft. X 4)
6	10/10/68	height 1965 (ft. X 4)
7	10/10/68	height 1964 (ft. X 4)
8	10/10/68	height 1963 (ft. X 4)
9	--	increment 1968 (cm)
10	--	increment 1967 (cm)
11	--	increment 1966 (cm)
12	--	increment 1965 (cm)
13	--	increment 1964 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	1.796	0.475
3	2.224	0.475
4	1.737	0.360
5	1.325	0.284
6	0.948	0.227
7	0.594	0.159
8	0.361	0.110
9	0.488	0.170
10	0.412	0.107
11	0.377	0.090
12	0.354	0.100
13	0.233	0.083

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.61	1.00							
4	0.61	0.96	1.00						
5	0.62	0.92	0.97	1.00					
6	0.57	0.87	0.93	0.96	1.00				
7	0.53	0.77	0.83	0.88	0.93	1.00			
8	0.37	0.64	0.71	0.74	0.79	0.87	1.00		
9	0.40	0.78	0.56	0.52	0.48	0.38	0.27	1.00	
10	0.41	0.77	0.78	0.61	0.56	0.45	0.41	0.49	1.00
11	0.53	0.71	0.73	0.73	0.52	0.44	0.36	0.43	0.52
12	0.47	0.79	0.81	0.80	0.81	0.54	0.42	0.50	0.58
13	0.51	0.62	0.65	0.70	0.74	0.76	0.34	0.37	0.31
	2	3	4	5	6	7	8	9	10
11	1.00								
12	0.50	1.00							
13	0.36	0.48	1.00						
	11	12	13						

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
3	4,5,6,7,8 (all)	0.9165
3	4,8 ("Best Equation")*	0.9162
3	7,8	0.5913
3	6,7,8	0.7844
3	5,6,7,8	0.8607
9	10,11,12,13,(all)	0.3397
9	10,12 ("Best Equation")*	0.3088

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

Appendix B

Scotch pine provenance test No. 2-61.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 2-61
Scotch pine provenance test

1. Source means analyses (109 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2	1962	leader growth for plot 1962 (cm)
3	1962	leader growth of best tree in plot(CM)
4	1964	height 1964 (ft. X 10)
5	10/01/68	height 1968 (ft. X 4)
6	10/01/68	height 1967 (ft. X 4)
7	1959	nursery height 1959
8	1960	nursery height 1960
9	1961	nursery height 1961
10	--	increment 1960 (cm)
11	--	increment 1961 (cm)
12	--	increment 1962 1963 1964 (cm)
13	increment	increment 1968 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.127	0.034
3	0.159	0.044
4	0.859	0.223
5	2.703	0.700
6	2.183	0.554
7	0.092	0.019
8	0.277	0.065
9	0.484	0.109
10	0.185	0.047
11	0.207	0.051
12	0.375	0.145
13	0.519	0.217

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.92	1.00							
4	0.79	0.80	1.00						
5	0.72	0.74	0.96	1.00					
6	0.75	0.77	0.94	0.96	1.00				
7	0.50	0.54	0.76	0.76	0.74	1.00			
8	0.54	0.56	0.80	0.79	0.77	0.96	1.00		
9	0.58	0.61	0.83	0.82	0.80	0.91	0.95	1.00	
10	0.54	0.56	0.79	0.78	0.75	0.90	0.99	0.95	1.00
11	0.55	0.58	0.75	0.74	0.74	0.73	0.76	0.92	0.75
12	0.77	0.77	0.91	0.86	0.84	0.48	0.51	0.52	0.51
13	0.37	0.39	0.65	0.72	0.50	0.51	0.56	0.55	0.57
	2	3	4	5	6	7	8	9	10

11	1.00		
12	0.46	1.00	
13	0.46	0.58	1.00
	11	12	13

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
5	2,3,4,6,7,8,9	0.9598
5	2,6,4 ("Best Equation")*	0.9590
5	7,8	0.6301
5	7,8,9	0.6729
5	4,7,8,9	0.9293
13	2,3,10,11,12	0.4931
13	10,11 ("Best Equation")*	0.3261
13	10,11,12	0.4395

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses (126 trees)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	10/01/68	mean height of plot 1968 (ft. X 4)
3	10/01/68	height 1968 (ft. X 4)
4	10/01/68	height 1967 (ft. X 4)
5	10/01/68	height 1966 (ft. X 4)
6	10/01/68	height 1965 (ft. X 4)
7	10/01/68	height 1964 (ft. X 4)
8	10/01/68	height 1963 (ft. X 4)
9	10/01/68	height 1962 (ft. X 4)
10	--	increment 1968 (cm)
11	--	increment 1967 (cm)
12	--	increment 1966 (cm)
13	--	increment 1965 (cm)
14	--	increment 1964 (cm)
15	--	increment 1963 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	2.632	0.759
3	3.059	0.852
4	2.340	0.674
5	1.864	0.522
6	1.402	0.406
7	0.971	0.294
8	0.667	0.214
9	0.400	0.140
10	0.660	0.228
11	0.535	0.182
12	0.462	0.149
13	0.430	0.140
14	0.304	0.105
15	0.267	0.101

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.95	1.00							
4	0.94	0.98	1.00						
5	0.92	0.96	0.98	1.00					
6	0.89	0.95	0.96	0.98	1.00				
7	0.86	0.90	0.92	0.95	0.97	1.00			
8	0.78	0.83	0.85	0.89	0.92	0.96	1.00		
9	0.69	0.74	0.77	0.80	0.82	0.88	0.92	1.00	
10	0.80	0.83	0.71	0.69	0.66	0.64	0.57	0.48	1.00
11	0.84	0.87	0.87	0.78	0.75	0.69	0.60	0.55	0.66
12	0.79	0.83	0.83	0.84	0.71	0.68	0.60	0.57	0.63
13	0.78	0.83	0.86	0.85	0.86	0.72	0.66	0.55	0.58
14	0.80	0.84	0.85	0.84	0.84	0.84	0.66	0.57	0.63
15	0.70	0.73	0.74	0.77	0.83	0.83	0.84	0.57	0.53
	2	3	4	5	6	7	8	9	10
11	1.00								
12	0.69	1.00							
13	0.73	0.63	1.00						
14	0.71	0.69	0.67	1.00					
15	0.52	0.48	0.64	0.60	1.00				
	11	12	13	14	15				

Multiple Regression Analyses

Dependent Variable	Independent Variable	R square
3	4,5,6,7,8,9	0.9665
3	4 ("Best Equation")*	0.9648
3	8,9	0.6862
3	7,8,9	0.8343
3	6,7,8,9	0.8936
10	11,12,13,14,15	0.5322
10	11,12,15 ("Best Equation")*	0.5240
10	13,14,15	0.4531

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

Appendix C

Scotch pine provenance test No. 12-61.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both sources means and individual tree data.

Plantation MSFGP 12-61
Scotch pine provenance test

1. Source means analyses (76 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2	10/10/62	leader growth for plot (cm)
3	10/09/62	leader growth for best tree in plot (cm)
4	10/29/62	height 1964 (in.)
5	5/20/67	height 1966 (in.)
6	1/26/68	height 1967 (ft. X 5)
7	1959	height 1968 (ft. X 4)
8	1960	nursery height 1959
9	1961	nursery height 1960
10	--	nursery height 1961
11	--	increment 1968 (cm)
12	--	increment 1967 (cm)
13	--	mean increment for 1965 and 1966 (cm)
14	--	increment 1959 (cm)
15	--	increment 1960 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.111	0.027
3	0.142	0.036
4	0.843	0.218
5	1.746	0.412
6	2.555	0.635
7	2.866	0.675
8	0.092	0.018
9	0.282	0.062
10	0.491	0.105
11	0.312	0.104
12	0.808	0.239
13	0.452	0.102
14	0.209	0.049
15	0.189	0.045

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.90	1.00							
4	0.87	0.77	1.00						
5	0.84	0.75	0.98	1.00					
6	0.82	0.72	0.97	0.98	1.00				
7	0.83	0.72	0.97	0.98	0.99	1.00			
8	0.71	0.60	0.87	0.86	0.85	0.85	1.00		
9	0.71	0.60	0.89	0.89	0.89	0.89	0.95	1.00	
10	0.75	0.63	0.91	0.90	0.91	0.91	0.90	0.96	1.00
11	0.32	0.22	0.34	0.36	0.31	0.45	0.35	0.33	0.33
12	0.75	0.64	0.90	0.89	0.96	0.93	0.79	0.84	0.86
13	0.77	0.69	0.91	0.98	0.95	0.95	0.80	0.84	0.85
14	0.71	0.59	0.82	0.81	0.82	0.81	0.74	0.79	0.93
15	0.69	0.58	0.88	0.88	0.88	0.88	0.90	0.99	0.95
	2	3	4	5	6	7	8	9	10

11	1.00				
12	0.21	1.00			
13	0.35	0.84	1.00		
14	0.28	0.78	0.70	1.00	
15	0.31	0.83	0.84	0.78	1.00
	11	12	13	14	15

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
7	2,3,4,5,6,8,9,10 (all)	0.9819
7	5,6 ("Best Equation")*	0.9806
7	8,9	0.7955
7	8,9,10	0.8296
11	12,13,14,15 (all)	0.1705
11	13 ("Best Equation")*	0.1251
11	15,14	0.1001

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree Analyses (153 trees)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	9/20/68	mean height of plot 1968 (ft. X 4)
3	9/20/68	height 1968 (ft. X 4)
4	9/20/68	height 1967 (ft. X 4)
5	9/20/68	height 1966 (ft. X 4)
6	9/20/68	height 1965 (ft. X 4)
7	9/20/68	height 1964 (ft. X 4)
8	9/20/68	height 1963 (ft. X 4)
9	9/20/68	height 1962 (ft. X 4)
10	9/20/68	height 1961 (ft. X 4)
11	--	increment 1968 (cm)
12	--	increment 1967 (cm)
13	--	increment 1966 (cm)
14	--	increment 1965 (cm)
15	--	increment 1964 (cm)
16	--	increment 1963 (cm)
17	--	increment 1962 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	2.991	0.768
3	3.483	0.839
4	2.730	0.702
5	2.041	0.529
6	1.484	0.412
7	0.980	0.297
8	0.648	0.202
9	0.398	0.133
10	0.264	0.094
11	0.752	0.240
12	0.689	0.281
13	0.557	0.172
14	0.504	0.142
15	0.332	0.118
16	0.250	0.096
17	0.234	0.070

Simple Correlation Coefficients

Variables									
2	1.00								
3	0.92	1.00							
4	0.90	0.97	1.00						
5	0.88	0.93	0.93	1.00					
6	0.87	0.92	0.93	0.96	1.00				
7	0.83	0.89	0.90	0.92	0.97	1.00			
8	0.80	0.85	0.85	0.87	0.92	0.96	1.00		
9	0.73	0.75	0.75	0.79	0.84	0.87	0.92	1.00	
10	0.64	0.62	0.62	0.67	0.70	0.72	0.74	0.86	1.00
11	0.57	0.66	0.45	0.53	0.49	0.47	0.46	0.42	0.37
12	0.58	0.66	0.74	0.45	0.53	0.50	0.47	0.39	0.28
13	0.64	0.66	0.64	0.77	0.57	0.52	0.48	0.43	0.40
14	0.77	0.81	0.82	0.85	0.86	0.72	0.66	0.59	0.51
15	0.73	0.79	0.81	0.84	0.86	0.87	0.70	0.63	0.54
16	0.67	0.73	0.74	0.74	0.73	0.81	0.83	0.55	0.37
17	0.52	0.59	0.60	0.69	0.64	0.70	0.75	0.74	0.31
	2	3	4	5	6	7	8	9	10

11	1.00						
12	0.19	1.00					
13	0.40	0.16	1.00				
14	0.48	0.43	0.56	1.00			
15	0.48	0.46	0.48	0.69	1.00		
16	0.39	0.45	0.42	0.56	0.60	1.00	
17	0.30	0.36	0.28	0.45	0.47	0.54	1.00
	11	12	13	14	15	16	17

Multiple Regression Analyses

Dependent Variable	Independent Variable	R square
3	4,5,6,7,8,9,10	0.9425
3	4,5 ("Best Equation")*	0.9422
3	9,10	0.5638
3	8,9,10	0.7124
3	7,8,9,10	0.7892
11	12,13,14,15,16,17	0.2824
11	13,14 ("Best Equation")*	0.2501
11	16,17	0.1621
11	15,16,17	0.1979

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

Appendix D

Scotch pine provenance test No. 15-62.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 15-62
Scotch pine provenance test

1. Source means analyses (46 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2*	9/19/68	height 1968 (ft. X 10)
3	10/20/68	height 1968 (ft. X 10)
4	10/20/68	height 1967 (ft. X 10)
5	10/20/68	height 1966 (ft. X 10)
6	10/20/68	height 1965 (ft. X 10)
7	10/20/68	height 1964 (ft. X 10)
8	10/20/68	height 1963 (ft. X 10)
9	1961	nursery height 1961 (cm)
10	1962	nursery height 1962 (cm)
11	--	increment 1968 (cm)
12	--	increment 1967 (cm)
13	--	increment 1966 (cm)
14	--	increment 1965 (cm)
15	--	increment 1964 (cm)
16	--	increment 1963 (cm)
17	--	increment 1962 (cm)

*This measurement based on mean of 4-tree plot. All others are based on the tallest tree in the plot.

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	1.302	0.354
3	1.454	0.339
4	1.025	0.296
5	0.698	0.194
6	0.475	0.132
7	0.317	0.085
8	0.226	0.062
9	0.044	0.011
10	0.151	0.043
11	0.429	0.109
12	0.328	0.109
13	0.222	0.067
14	0.158	0.057
15	0.092	0.032
16	0.075	0.060
17	0.106	0.034

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.96	1.00							
4	0.94	0.99	1.00						
5	0.90	0.98	0.99	1.00					
6	0.87	0.95	0.97	0.98	1.00				
7	0.84	0.92	0.93	0.95	0.96	1.00			
8	0.77	0.85	0.86	0.89	0.90	0.95	1.00		
9	0.55	0.46	0.43	0.37	0.31	0.35	0.30	1.00	
10	0.67	0.60	0.58	0.50	0.45	0.47	0.38	0.91	1.00
11	0.96	0.97	0.94	0.90	0.87	0.86	0.79	0.52	0.65
12	0.95	0.96	0.95	0.89	0.86	0.83	0.74	0.52	0.67
13	0.89	0.94	0.94	0.94	0.87	0.86	0.79	0.45	0.54
14	0.77	0.83	0.86	0.87	0.90	0.73	0.67	0.21	0.35
15	0.75	0.82	0.82	0.81	0.81	0.82	0.62	0.35	0.52
16	0.31	0.44	0.47	0.55	0.60	0.63	0.75	-0.36	-0.33
17	0.68	0.63	0.60	0.52	0.48	0.50	0.40	0.86	0.99
	2	3	4	5	6	7	8	9	10

11	1.00						
12	0.93	1.00					
13	0.89	0.89	1.00				
14	0.74	0.77	0.74	1.00			
15	0.77	0.77	0.76	0.65	1.00		
16	0.34	0.28	0.42	0.44	0.25	1.00	
17	0.66	0.70	0.55	0.38	0.56	-0.31	1.00
	11	12	13	14	15	16	17

Multiple Regression Analyses

Dependent Variable	Independent Variable	R square
3	4,5,6,7,8,9,10	0.9929
3	4,6 ("Best Equation")*	0.9922
3	9,10	0.4128
3	8,9,10	0.8310
11	12,13,14,15,16,17	0.9038
11	12,13 ("Best Equation")*	0.8924
11	16,17	0.7712
11	15,16,17	0.8149

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	10/20/68	mean height of plot 1968 (ft. X 10)
3	10/20/68	height 1968 (ft. X 10)
4	10/20/68	height 1967 (ft. X 10)
5	10/20/68	height 1966 (ft. X 10)
6	10/20/68	height 1965 (ft. X 10)
7	10/20/68	height 1964 (ft. X 10)
8	10/20/68	height 1963 (ft. X 10)
9	--	increment 1968 (cm)
10	--	increment 1967 (cm)
11	--	increment 1966 (cm)
12	--	increment 1965 (cm)
13	--	increment 1964 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	1.278	0.370
3	1.420	0.397
4	0.996	0.298
5	0.676	0.202
6	0.459	0.140
7	0.311	0.094
8	0.221	0.072
9	0.424	0.116
10	0.321	0.112
11	0.217	0.080
12	0.147	0.066
13	0.909	0.041

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.90	1.00							
4	0.87	0.98	1.00						
5	0.82	0.94	0.97	1.00					
6	0.77	0.88	0.92	0.96	1.00				
7	0.70	0.79	0.82	0.86	0.92	1.00			
8	0.55	0.64	0.67	0.72	0.80	0.91	1.00		
9	0.84	0.90	0.80	0.73	0.67	0.60	0.48	1.00	
10	0.83	0.92	0.90	0.78	0.72	0.62	0.48	0.82	1.00
11	0.74	0.83	0.85	0.86	0.67	0.57	0.44	0.67	0.71
12	0.64	0.76	0.79	0.81	0.82	0.53	0.40	0.57	0.64
13	0.62	0.68	0.69	0.70	0.70	0.69	0.33	0.54	0.58
	2	3	4	5	6	7	8	9	10

11	1.00		
12	0.62	1.00	
13	0.54	0.52	1.00
	11	12	13

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
3	4,5,6,7,8	0.9744
3	4,5 ("Best Equation")*	0.9741
3	8,7	0.6581
3	6,7,8	0.7947
3	5,6,7,8	0.8912
9	10,11,12,13	0.6942
9	10,11 ("Best Equation")*	0.6509

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

Appendix E

Scotch pine provenance test No. 17-62.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 17-62
Scotch pine provenance test

1. Source means analyses (51 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2	4/06/64	height 1963 (in. X 2)
3	6/30/65	height 1965 (in.)
4	10/01/68	height 1966 (ft. X 4)
5	10/01/68	height 1967 (ft. X 4)
6	10/01/68	height 1968 (ft. X 4)
7	1961	nursery height 1961 (cm)
8	1962	nursery height 1962 (cm)
9	--	increment 1968 (cm)
10	--	increment 1967 (cm)
11	--	increment 1966 (cm)
12	--	mean increment 1964 and 1965 (cm)
13	--	increment 1962 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.221	0.047
3	0.602	0.129
4	0.859	0.176
5	1.156	0.224
6	1.578	0.300
7	0.043	0.001
8	0.145	0.043
9	0.421	0.084
10	0.298	0.058
11	0.257	0.057
12	0.381	0.096
13	0.102	0.034

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.80	1.00							
4	0.79	0.98	1.00						
5	0.81	0.96	0.98	1.00					
6	0.82	0.93	0.96	0.99	1.00				
7	0.54	0.42	0.44	0.47	0.62	1.00			
8	0.61	0.53	0.53	0.56	0.62	0.92	1.00		
9	0.78	0.77	0.81	0.87	0.93	0.61	0.69	1.00	
10	0.72	0.71	0.75	0.85	0.89	0.49	0.56	0.90	1.00
11	0.61	0.75	0.88	0.87	0.86	0.39	0.44	0.75	0.70
12	0.59	0.96	0.93	0.89	0.85	0.31	0.41	0.65	0.60
13	0.62	0.54	0.54	0.58	0.62	0.87	0.99	0.69	0.57
	2	3	4	5	6	7	8	9	10
11	1.00								
12	0.71	1.00							
13	0.45	0.43	1.00						

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
6	2,3,4,5,7,8	0.9917
6	4,5,8 ("Best Equation")*	0.9913
6	7,8	0.3917
6	2,7,8	0.7047
9	10,11,12,13	0.8860
9	10,11,12 ("Best Equation")*	0.8842
9	12,13	0.6379

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses (425 trees)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	4/06/64	height 1963 (in. X 2)
3	6/30/65	height 1965 (in.)
4	10/01/68	height 1966 (ft. X 4)
5	10/01/68	height 1967 (ft. X 4)
6	10/01/68	height 1968 (ft. X 4)
7	10/01/68	stem dieback (0=none, 1=some dieback)
8	--	mean increment 1964 and 1965 (cm)
9	--	increment 1966 (cm)
10	--	increment 1967 (cm)
11	--	increment 1968 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.216	0.074
3	0.596	0.205
4	0.854	0.268
5	1.148	0.333
6	1.564	0.425
7*	0.289	0.958
8	0.380	0.170
9	0.257	0.122
10	0.295	0.102
11	0.415	0.131

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.62	1.00							
4	0.60	0.90	1.00						
5	0.57	0.85	0.96	1.00					
6	0.55	0.80	0.91	0.97	1.00				
7	-0.01	-0.22	-0.29	-0.28	-0.26	1.00			
8	0.32	0.94	0.83	0.78	0.73	-0.27	1.00		
9	0.26	0.29	0.68	0.68	0.65	-0.26	0.24	1.00	
10	0.30	0.42	9.53	0.73	0.78	-0.15	0.38	0.44	1.00
11	0.34	0.42	0.49	0.60	0.78	-0.13	0.36	0.37	0.66
	2	3	4	5	6	7	8	9	10

*Not transformed

Multiple Regression Analyses

Dependent Variable	Independent Variable	R square
6	2,3,4,5,7	0.9499
6	2,4,5 9'best Equation")*	0.9499
6	2,3	0.6428
6	2,3,4	0.8283
6	7	0.0689

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to tne equation.

Appendix F

White pine provenance test No. 3-60.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 3-60
White pine provenance test

1. Source means analyses (15 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2	11/16/61	height 1961 (in. X 2)
3	7/24/62	height 1962 (ft. X 10)
4	1964	height 1964 (cm)
5	9/16/65	height 1965 (in.)
6	10/13/66	height 1966 (ft. X 10)
7	10/19/67	height 1967 (ft. X 10)
8	10/09/68	height 1968 (ft. X 4)
9	1960	height in nursery 1960 (cm)
10	--	increment 1961 (cm)
11	--	increment 1962 (cm)
12	--	increment (mean) 1963 and 1964 (cm)
13	--	increment 1965 (cm)
14	--	increment 1966 (cm)
15	--	increment 1967 (cm)
16	--	increment 1968 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.467	0.085
3	0.767	0.124
4	1.727	0.190
5	2.579	0.330
6	3.201	0.285
7	4.131	0.342
8	4.780	0.374
9	0.238	0.065
10	0.229	0.045
11	0.300	0.046
12	0.480	0.041
13	0.851	0.192
14	0.622	0.123
15	0.930	0.132
16	0.645	0.149

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.97	1.00							
4	0.90	0.95	1.00						
5	0.82	0.82	0.86	1.00					
6	0.86	0.91	0.96	0.93	1.00				
7	0.81	0.87	0.92	0.78	0.93	1.00			
8	0.85	0.89	0.95	0.88	0.97	0.92	1.00		
9	0.86	0.83	0.76	0.60	0.73	0.69	0.73	1.00	
10	0.66	0.64	0.60	0.70	0.58	0.54	0.56	0.17	1.00
11	0.76	0.89	0.89	0.68	0.85	0.86	0.82	0.64	0.52
12	0.62	0.70	0.88	0.77	0.84	0.81	0.86	0.53	0.41
13	0.52	0.47	0.50	0.86	0.65	0.44	0.58	0.27	0.60
14	-0.21	-0.09	-0.10	-0.53	-0.18	0.04	-0.11	0.09	-0.52
15	0.14	0.30	0.31	0.03	0.24	0.59	0.27	0.21	0.14
16	0.28	0.22	0.27	0.41	0.31	0.01	0.40	0.25	0.16
	2	3	4	5	6	7	8	9	10

11	1.00					
12	0.72	1.00				
13	0.29	0.44	1.00			
14	0.14	-0.10	-0.81	1.00		
15	0.38	0.26	-0.27	0.50	1.00	
16	0.08	0.30	0.43	-0.37	-0.67	1.00

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
8	2,3,4,5,6,7,9	0.9786
8	6 ("Best Equation")*	0.9468
8	2,9	0.7218
8	2,3,9	0.7936
8	2,3,4,9	0.9061
16	10,11,12,13,14,15	0.8020
16	12,15 ("Best Equation")*	0.7007
16	10,11	0.0266
16	10,11,12	0.1494
16	10,11,12,13	0.2474

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses (70 trees)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	10/09/68	mean height of plot 1968 (ft. X 4)
3	10/09/68	height 1968 (ft. X 4)
4	10/09/68	height 1967 (ft. X 4)
5	10/09/68	height 1966 (ft. X 4)
6	10/09/68	height 1965 (ft. X 4)
7	10/09/68	height 1964 (ft. X 4)
8	10/09/68	height 1963 (ft. X 4)
9	10/09/68	height 1962 (ft. X 4)
10	10/09/68	height 1961 (ft. X 4)
11	10/09/68	height 1960 (ft. X 4)
12	--	increment 1968 (cm)
13	--	increment 1967 (cm)
14	--	increment 1966 (cm)
15	--	increment 1965 (cm)
16	--	increment 1964 (cm)
17	--	increment 1963 (cm)
18	--	increment 1962 (cm)
19	--	increment 1961 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	4.916	0.591
3	5.375	0.632
4	4.443	0.624
5	3.520	0.503
6	2.763	0.448
7	1.963	0.370
8	1.366	0.288
9	0.880	0.245
10	0.497	0.158
11	0.272	0.110
12	0.932	0.195
13	0.923	0.183
14	0.758	0.131
15	0.800	0.148
16	0.600	0.126
17	0.487	0.107
18	0.382	0.130
19	0.225	0.089

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.84	1.00							
4	0.87	0.95	1.00						
5	0.84	0.91	0.97	1.00					
6	0.80	0.87	0.93	0.97	1.00				
7	0.75	0.80	0.85	0.89	0.95	1.00			
8	0.67	0.77	0.79	0.82	0.89	0.96	1.00		
9	0.56	0.68	0.67	0.71	0.78	0.87	0.93	1.00	
10	0.43	0.58	0.56	0.61	0.67	0.74	0.79	0.88	1.00
11	0.45	0.55	0.52	0.52	0.57	0.63	0.68	0.73	0.83
12	-0.06	0.19	-0.11	-0.16	-0.16	-0.13	-0.05	0.05	0.08
13	0.68	0.75	0.74	0.56	0.51	0.46	0.44	0.35	0.25
	2	3	4	5	6	7	8	9	10

Simple Correlation Coefficients (cont.)

Variable	2	3	4	5	6	7	8	9	10
14	0.46	0.52	0.54	0.53	0.30	0.16	0.01	0.05	0.04
15	0.56	0.62	0.69	0.70	0.64	0.38	0.31	0.18	0.17
16	0.64	0.60	0.70	0.74	0.76	0.75	0.53	0.43	0.36
17	0.56	0.50	0.59	0.59	0.61	0.58	0.55	0.21	0.12
18	0.54	0.58	0.59	0.60	0.66	0.74	0.79	0.82	0.45
19	0.20	0.34	0.35	0.43	0.48	0.52	0.56	0.65	0.73

Variable	11	12	13	14	15	16	17	18	19
11	1.00								
12	0.12	1.00							
13	0.36	0.04	1.00						
14	0.05	-0.05	0.39	1.00					
15	0.13	-0.18	0.40	0.50	1.00				
16	0.31	-0.26	0.34	0.24	0.41	1.00			
17	0.17	-0.24	0.39	0.16	0.41	0.43	1.00		
18	0.36	-0.01	0.36	0.03	0.14	0.38	0.26	1.00	
19	0.24	-0.01	-0.01	0.02	0.15	0.26	0.01	0.35	1.00

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
3	4,5,6,7,8,9,10,11	0.9201
3	4,7,9 ("Best Equation")*	0.9175
3	10,11	0.3540
3	9,10,11	0.4825
12	13,14,15,16,17,18,19	0.1413
12	16 ("Best Equation)*	0.0705
12	18,19	0.0000
12	17,18,19	0.0634

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05) to the equation.

Appendix G

Ponderosa pine provenance test No. 1-62.-- Simple correlation coefficients and multiple regression analyses of height and annual increment for both source means and individual tree data.

Plantation MSFGP 1-62
Ponderosa pine provenance test

1. Source means analyses (53 sources)

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	source number
2	11/14/64	height 1962 (in.)
3	10/06/66	height 1966 (ft. X 10)
4	12/11/67	height 1967 (ft. X 4)
5	10/10/68	height 1968 (ft. X 4)
6	4/10/64	winterburn 1964 (0=none, 24=severe)
7	11/22/63	height 1963 (in. X 6)
8	1961	nursery height 1961 (cm)
9	1962	nursery height 1962 (cm)
10	1962	winterburn 1962 (0=none, 20=severe)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	0.473	0.107
3	1.002	0.195
4	1.227	0.251
5	1.627	0.332
6*	0.363	0.448
7	0.280	0.061
8	0.046	0.011
9	0.155	0.039
10*	0.077	0.070

*Not transformed

Simple Correlation Coefficients

Variable									
2	1.00								
3	0.88	1.00							
4	0.84	0.94	1.00						
5	0.78	0.91	0.97	1.00					
6	-0.48	-0.53	-0.60	-0.58	1.00				
7	0.91	0.86	0.84	0.79	-0.37	1.00			
8	-0.05	-0.23	-0.24	-0.28	0.58	0.07	1.00		
9	0.49	0.36	0.34	0.27	-0.08	0.54	0.38	1.00	
10	-0.52	-0.57	-0.60	-0.58	0.90	-0.41	0.65	-0.04	1.00
	2	3	4	5	6	7	8	9	10

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
5	2,3,4,6,7,8	0.9806
5	3,4,8 ("Best Equation)*	0.9745
5	6,7	0.8217
5	6,7,8	0.8814

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

2. Individual-tree analyses

Key to Variables

Variable Number	Date Measured	Description of Variables
1	--	tree number
2	9/19/68	mean height of plot 1968 (ft. X 4)
3	10/05/68	height 1968 (ft. X 4)
4	10/05/68	height 1967 (ft. X 4)
5	10/05/68	height 1966 (ft. X 4)
6	10/05/68	height 1965 (ft. X 4)
7	10/05/68	height 1964 (ft. X 4)
8	10/05/68	height 1963 (ft. X 4)
9	10/05/68	height 1962 (ft. X 4)
10	10/05/68	height 1961 (ft. X 4)
11	--	increment 1968 (cm)
12	--	increment 1967 (cm)
13	--	increment 1966 (cm)
14	--	increment 1965 (cm)
15	--	increment 1964 (cm)
16	--	increment 1963 (cm)
17	--	increment 1962 (cm)

Statistics on Variables Transformed to Meters

Variable Number	Mean	Standard Deviation
2	2.201	0.656
3	2.596	0.741
4	2.012	0.580
5	1.512	0.438
6	1.145	0.345
7	0.792	0.240
8	0.561	0.179
9	0.423	0.135

Statistics on Variables Transformed to Meters (cont.)

Variable Number	Mean	Standard Deviation
10	0.305	0.108
11	0.508	0.184
12	0.504	0.172
13	0.336	0.112
14	0.353	0.126
15	0.231	0.087
16	0.138	0.062
17	0.118	0.069

Simple Correlation Coefficients

Variables									
2	1.00								
3	0.94	1.00							
4	0.92	0.99	1.00						
5	0.89	0.96	0.98	1.00					
6	0.87	0.94	0.96	0.99	1.00				
7	0.84	0.91	0.93	0.95	0.97	1.00			
8	0.81	0.90	0.88	0.90	0.92	0.96	1.00		
9	0.79	0.83	0.84	0.85	0.87	0.91	0.96	1.00	
10	0.67	0.72	0.72	0.72	0.73	0.78	0.82	0.86	1.00
11	0.89	0.90	0.84	0.79	0.76	0.73	0.72	0.70	0.63
12	0.84	0.88	0.87	0.76	0.74	0.71	0.68	0.69	0.60
13	0.80	0.87	0.87	0.87	0.78	0.72	0.68	0.65	0.56
14	0.78	0.85	0.87	0.89	0.88	0.74	0.68	0.63	0.51
15	0.66	0.73	0.76	0.78	0.79	0.80	0.59	0.55	0.47
16	0.62	0.68	0.69	0.73	0.76	0.77	0.80	0.59	0.49
17	0.49	0.50	0.53	0.54	0.56	0.56	0.60	0.61	0.13
	2	3	4	5	6	7	8	9	10

Simple Correlation Coefficient (cont.)

Variables							
11	1.00						
12	0.81	1.00					
13	0.76	0.72	1.00				
14	0.68	0.66	0.76	1.00			
15	0.55	0.57	0.61	0.64	1.00		
16	0.56	0.46	0.53	0.60	-.50	1.00	
17	0.38	0.40	0.40	0.44	0.33	0.38	1.00
	11	12	13	14	15	16	17

Multiple Regression Analyses

Dependent Variable	Independent Variables	R square
3	4,5,6,7,8,9,10	0.9842
3	4,6 ("Best Equation")*	0.9834
3	9,10	0.6970
3	8,9,10	0.7515
3	7,8,9,10	0.8250
11	12,13,14,15,16,17	0.7342
11	12,13,16 ("Best Equation")*	0.7334
11	16,17	0.3469
11	15,16,17	0.4254
11	14,15,16,17	0.5132

*Determined by stepwise deletion of variables included in the equation immediately preceeding. Deleted variables did not contribute significantly (0.05 level) to the equation.

Appendix H

Scotch pine provenance test No. 15-62.-- Pearce's analysis of variance and covariance.

Plantation MSFGP 13-62
Scotch pine provenance test

Pearce's Analyses of Variance and Covariance

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	replicate number
2	10/20/68	height 1968 (ft. X 10)
3	10/20/68	height 1967 (ft. X 10)
4	10/20/68	height 1966 (ft. X 10)
5	10/20/68	height 1965 (ft. X 10)
6	10/20/68	height 1964 (ft. X 10)
7	10/20/68	height 1963 (ft. X 10)
150	--	*variable 2 minus variable 7
151	--	*variable 3 minus variable 7
152	--	*variable 4 minus variable 7
153	--	*variable 5 minus variable 7
154	--	*variable 6 minus variable 7

* Indicated subtractions made after transformation to meters.

Statistics on Variables Transformed to Meters and then to Logarithm of Base 10

Variable Number	Mean	Standard Deviation
2	0.13522	0.12391
3	-0.02113	0.13217
4	-0.18986	0.13218
5	-0.35889	0.13557
6	-0.52801	0.14181
7	-0.68125	0.16108
150	0.05939	0.13217
151	-0.13472	0.14735
152	-0.36966	0.15646
153	-0.65827	0.17434
154	-1.09713	0.22367

Analysis of Variance for X(7) Height 1963

Source of Variation	D.F.	Mean Square	F Value
Replicate	4	0.012495	0.61
Source	57	0.043854	2.16**
Between plot	175	0.020296	
Total	236		

Analysis of Variance for X(6) Height 1964

Replicate	4	0.002351	0.17
Source	57	0.039883	2.86**
Between plot	175	0.013923	
Total	236		

Analysis of Variance for X(5) Height 1965

Replicate	4	0.005037	0.44
Source	57	0.039984	3.53**
Between plot	175	0.011325	
Total	236		

Analysis of Variance for X(4) Height 1966

Replicate	4	0.006527	0.75
Source	57	0.044270	5.08**
Between plot	175		
Total	236		

Analysis of Variance for X(3) Height 1967

Replicate	4	0.007178	0.89
Source	57	0.046423	5.79**
Between plot	175	0.008023	
Total	236		

Analysis of Variance for X(2) Height 1968

Replicate	4	0.016886	2.66**
Source	57	0.042104	6.64**
Between plot	175	0.006338	
Total	236		

Analysis of Covariance for X(6) Height 1964

Source of Variation	D.F.	Mean Square	F Value
Replicate	4	0.00118602	0.36
Source	57	0.00681865	2.05**
Covariate (1963 Ht.)	1	1.85692661	557.38**
Between plot	174	0.00333151	
Total	236		

Analysis of Covariance for X(5) Height 1965

Replicate	4	0.00095405	0.18
Source	57	0.01335038	2.52**
Covariate (1963 Ht.)	1	1.06080471	200.39**
Between plot	174	0.00529377	
Total	236		

Analysis of Covariance for X(4) Height 1966

Replicate	4	0.00366008	0.63
Source	57	0.01996929	3.44**
Covariate (1963 Ht.)	1	0.51530045	88.71**
Between plot	174	0.00580833	
Total	236		

Analysis of Covariance for X(3) Height 1967

Replicate	4	0.00355779	0.59
Source	57	0.02428621	4.05**
Covariate (1963 Ht.)	1	0.36080973	60.17**
Between plot	174	0.00599646	
Total	236		

Analysis of Covariance for X(2) Height 1968

Replicate	4	0.01182516	2.39
Source	57	0.02333757	4.71**
Covariate	1	0.24839533	50.21**
Between plot	174	0.00494750	
Total	236		

Analysis of Variance for X(154) Ht. 1964-Ht. 1963

Source of Variation	D.F.	Mean Square	F Value
Replicate	4	0.004221	0.87
Source	57	0.006869	1.41*
Between plot	175	0.004869	
Total	236		

Analysis of Variance for X(153) Ht. 1965-Ht. 1963

Replicate	4	0.003231	0.34
Source	57	0.013332	1.41*
Between plot	175	0.009437	
Total	236		

Analysis of Variance for X(152) Ht. 1966-Ht. 1963

Replicate	4	0.006741	0.50
Source	57	0.016602	1.22
Between plot	175	0.013554	
Total	236		

Analysis of Variance for X(151) Ht. 1967-Ht. 1963

Replicate	4	0.004379	0.28
Source	57	0.020048	1.30
Between plot	175	0.015382	
Total	236		

Analysis of Variance for X(150) Ht. 1968-Ht. 1963

Replicate	4	0.007245	0.45
Source	57	0.019754	1.24
Between plot	175	0.015901	
Total	236		

A single asterisk indicates significance at the 0.05 level. The indicated subtractions were made after transformation to Log Base 10.

Appendix I

Scotch pine provenance test No. 17-62.-- Pearce's analysis of variance and covariance.

Plantation Msfgp 17-62
Scotch pine provenance test

Pearce's Analyses of Variance and Covariance

Key to Characters

Variable Number	Date Measured	Description of Variables
1	--	replicate number
2	4/06/64	height 1963 (in. X 2)
3	6/30/65	height 1965 (in.)
4	10/01/68	height 1966 (ft. X 4)
5	10/01/68	height 1967 (ft. X 4)
6	10/01/68	height 1968 (ft. X 4)
150	--	* variable 6 minus variable 2
151	--	* variable 5 minus variable 2
152	--	* variable 4 minus variable 2
153	--	* variable 3 minus variable 2

* Indicated subtractions made after transformation to meters.

Statistics on Variables Transformed to Meters
and Then to Logarithm of Base 10

Variable Number	Mean	Standard Deviation
2	-0.69010	0.15318
3	-0.25392	0.16874
4	-0.09233	0.14919
5	0.03971	0.13883
6	0.17641	0.129399
150	0.10907	0.13927
151	-0.05629	0.15772
152	-0.23097	0.19086
153	-0.45503	0.24247

Analysis of Variance for X(2) Height 1962

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.059140	3.79**
Source	55	0.065414	4.19**
Between plot	355	0.015560	
Total	424		

Analysis of Variance for X(3) Height 1965

Replicate	14	0.099769	5.48**
Source	55	0.074456	4.09**
Between plot	355	0.018204	
Total	424		

Analysis of Variance for X(4) Height 1966

Replicate	14	0.061608	4.52**
Source	55	0.067046	4.91**
Between plot	355	0.013643	
Total	424		

Analysis of Variance for X(5) Height 1967

Replicate	14	0.043049	3.70**
Source	55	0.061553	5.29**
Between plot	355	0.011627	
Total	424		

Analysis of Variance for X(6) Height 1968

Replicate	14	0.029076	3.01**
Source	55	0.058171	6.02**
Between plot	355	0.009658	
Total	424		

The above analyses were done on data transformed to Log Base 10 of height in meters. A single asterisk represents an F-value significant at the 0.05 level and a double asterisk represents significance at the 0.01 level.

Analysis of Covariance for X(3) Height 1965

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.069348	4.69**
Source	55	0.027611	1.87**
Covariate (1963 Ht.)	1	1.227543	83.00**
Between plot	354	0.014788	
Total	424		

Analysis of Covariance for X(4) Height 1966

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.045124	4.11**
Source	55	0.024639	2.34**
Covariate (1963 Ht.)	1	0.956420	87.10**
Between plot	354	0.010980	
Total	424		

Analysis of Covariance for X(5) Height 1967

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.038641	4.02**
Source	55	0.023466	2.44**
Covariate (1963 Ht.)	1	0.727153	75.69**
Between plot	354	0.009606	
Total	424		

Analysis of Covariance for X(6) Height 1968

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.029811	3.64**
Source	55	0.023129	2.82**
Covariate (1963 Ht.)	1	0.529379	64.63**
Between plot	354	0.008190	
Total	424		

The above analyses were done on data transformed to Log Base 10 of height in meters, including the covariate. The between plot differences represent between tree differences because of the one-tree plots in this plantation. A single asterisk represents an F-value significant at the 0.05 level, and a double asterisk represents significance at the 0.01 level. As before, no substitutions were needed or made for missing plots.

Analysis of Variance for X(150) Ht, 1968-Ht 1963

Source of Variation	D.F.	Mean Square	F Value
Replicate	14	0.073104	4.69**
Source	55	0.015762	1.01
Between plot	355	0.015584	
Total	424		

Analysis of Variance for X(151) Ht, 1967-Ht, 1963

Replicate	14	0.068717	4.32**
Source	55	0.017323	1.09
Between plot	355	0.015896	
Total	424		

Analysis of Variance for X(152) Ht, 1966-Ht, 1963

Replicate	14	0.056812	3.49**
Source	55	0.020343	1.25
Between plot	355	0.016254	
Total	424		

Analysis of Variance for X(153) Ht, 1965-Ht, 1963

Replicate	14	0.067947	3.56**
Source	55	0.021937	1.15
Between plot	355	0.019094	
Total			

The above data were analysed after being transformed to Log Base 10 of height in meters. A single asterisk represents an F-value significant at the 0.05 level, and a double asterisk represents an F-value significant at the 0.01 level. As before, no substitutions were made or needed for missing plots.

VITA

Warren Louis Nance was born in San Diego, California, July 5, 1944. At the age of nine his family moved to Jackson, Mississippi. There he completed grade school and graduated from Central High School in 1962. Mr. Nance enrolled the same year at Mississippi State University, State College, Mississippi and majored in Forestry. He received his Bachelor of Science degree in 1966.

Mr. Nance worked for the U. S. Forest Service as research technician for the Southern Hardwoods Laboratory, Stoneville, Mississippi before enrolling in the graduate program of the School of Forestry at Michigan State University in 1968.

Nance is married to the former Charlotte Ann Coulter and is the father of one child, Robert Louis, age 2. He is presently employed by the U. S. Forest Service, Institute of Forest Genetics, Gulfport, Mississippi.