

GENETIC ANALYSES FOR HEIGHT AND DIAMETER GROWTH OF 9-YEAR-OLD
RED MAPLE PROGENIES IN FIVE PLANTATIONS

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Abstract.--Several growth measurements were made on nine-year-old red maple progenies growing in Ohio, Indiana, Michigan, Minnesota, and Wisconsin. Significant differences occurred among stands and among families within stands for caliper (measured 6 in above base of tree), height, and diameter at breast height (DBH) in most plantations. Seedlings from north central seed sources (the southern two-thirds of the Lake States and of New England) generally were above average in height and caliper in all plantations, whereas those from southern sources were below average. East central sources were average in height but above average in caliper and DBH. Heritabilities (h^2) for height on a within stand single tree basis varied from .02 in Indiana and Minnesota to .42 in Michigan. The highest heritability values for DBH and caliper were .23 and .25, respectively. Heritabilities calculated on a basis in which stands were disregarded were much higher. Growth performance of the same progenies growing in most plantations was significantly correlated. However, the presence of some degree of genotype-plantation interaction did occur and was mostly a result of unique progeny response in growth in Wisconsin and Minnesota. This interaction will complicate but will not preclude the development of effective breeding and selection strategies for growth improvement of red maple.

Additional keywords: Acer rubrum, selection, tree breeding.

A range-wide provenance test of red maple (Acer rubrum L.) has revealed a wide degree of genetic variation in numerous traits examined in laboratory and field studies. Variation among progenies grown from seed collected from different stands and identified according to different parent trees within stands was first examined in nursery bed studies near Delaware, Ohio (Townsend 1977). Seedlings transplanted from the nursery bed to five NC-99 regional test sites showed wide variation at the age of five years in heights, fall color, and stem form (Townsend et al. 1979). Other studies have indicated that sufficient genetic variation exists to select for such traits as cold hardiness, early or late

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bud break, and precocity and frequency of flowering (Townsend et al. 1982).

This paper reports on geographic patterns, analyses of variance and heritabilities for height and diameter measurements of nine-year-old red maple progenies growing in Ohio, Michigan, Indiana, Wisconsin, and Minnesota.

MATERIALS AND METHODS

Seed collected from 51 stands located throughout the species' range was brought to Delaware, Ohio, where replicated nursery bed tests were established in 1972. Details of latitude, longitude, and elevation can be found in previous papers (e.g. Townsend et al. 1982). Nursery-grown seedlings were used to establish, either in 1974 or 1975, progeny tests in Ohio (51 stands represented), Michigan (39 stands represented), Indiana (21 stands), Wisconsin (24 stands), and Minnesota (16 stands).

In all plantations seedling identity was maintained not only by stand of origin but also by parent tree within stands. All plantations followed a randomized block design. In Ohio and Michigan, open-pollinated families served as the experimental unit randomized in each block. In Indiana and Minnesota, seedlings from each stand were planted together as a "major" plot in each block, with open-pollinated families within stands forming cohesive "minor" plots. The Wisconsin planting was similar except that seedlings from all families within a given stand were completely randomized throughout the plot for a given stand.

All growth measurements were made and recorded on individual trees in the fall of 1980 or before growth began in 1981. Height was measured in all plantations and caliper, which is the diameter of the main stem 6 in above the root collar, was measured in all sites except Indiana. Diameter at breast height (DBH) was recorded on those trees taller than breast height in Ohio, Indiana, and Minnesota. Genetic analyses were carried out using both LSML76, the "mixed model least squares" program developed by the junior author (Harvey 1982) and SAS GLM (SAS Institute 1979).

RESULTS AND DISCUSSION

Differences among plantations in average growth after nine years were quite marked (Table 1). The Minnesota planting showed the highest average growth, Wisconsin the lowest, and Michigan and Ohio were appreciably taller than Indiana. In contrast, these same trees when only 5 years old were largest in Ohio and Michigan, and smallest in Wisconsin and Minnesota (Townsend et al. 1979). The Minnesota trees therefore have gone from the shortest to the tallest average height between five and nine years old, increasing their height nearly five-fold during that time. However, less variation among progenies in growth traits was found in Minnesota than in other states (Table 1).

Table 1. Height, caliper, DBH, and ratio of height to caliper of nine-year-old red maple progenies growing in five locations.

Seed source No. and State or province	Height				Caliper				DBH			Height/Caliper				
	OH	MI	IN	WI	MN	OH	MI	WI	MN	OH	IN	MN	OH	MI	WI	MN
	(% of Plantation Mean)															
Northern seed lots:																
165 NF	95	82	69	71	102	89	84	64	102	82	79	109	101	94	108	95
167 NB	92	104	87	95	98	86	100	97	96	76	64	100	103	103	97	103
166 QU	103	96	80	90	103	96	100	82	100	94	86	104	103	93	103	101
156 ON	91	80				91	89			82			100	91		
155 ON	106	100	95	100	101	95	93	109	92	100	86	87	105	109	85	108
163 ME	116	110	94	117	99	116	107	121	108	127	107	96	94	101	95	92
152 ME	109	105	114	98		109	107	106		118	107		96	96	90	
161 VT	110	96				93	91			91			107	104		
157 MN	105	80	72	93	100	95	73	85	94	97	57	96	107	109	110	106
159 MN	95	87		116		71	69	115		73			122	125	93	
162 MI	106	94	104	95	100	110	100	100	104	115	107	100	93	93	90	92
\bar{X}	102	94	89	97	100	96	92	98	99	96	87	99	103	102	97	100
Northern Central seed lots:																
144 RI	96	98				96	100			97			94	97		
146 CT	113	113		124		127	118	148		142			85	97	83	
151 NH	115	105	119	114	99	120	111	124	100	136	129	100	93	94	86	101
160 NY	107	109	100	91	103	100	98	85	96	109	107	96	103	112	113	109
149 PA	123	119		107	99	112	104	97	96	127			105	112	115	103
164 ON	126	113	112	109		116	104	103		136	107		100	109	103	
137 MI	117	127	116	105		116	122	106		124	100		96	103	95	
141 MI	121	124	127	99		118	124	91		136	121		98	98	105	
145 WI	120	99	93	132	100	105	93	136	100	127	79	104	109	109	93	98
155 WI	119	104	106	122	109	107	98	130	112	124	100	117	107	106	90	97
139 MN	122	97	104	120	105	111	87	124	108	133	100	109	105	112	90	95
\bar{X}	116	110	111	112	103	112	105	114	102	126	105	104	99	104	97	100
West Central seed lots:																
142 PA	101	98		83		98	98	76		94			100	101	106	
143 PA	106	99				100	104			100			101	93		
154 PA	109					109				115			96			
135 WV	99	90				95	87			91			101	103		
134 OH	110	101	108	101	92	112	102	115	96	118	86	96	94	96	80	98
128 OH	101	89	99	99	91	100	93	88	96	97	93	87	96	94	113	94
133 IN	108	85				118	93			121			87	90		
\bar{X}	105	94	103	100	92	105	96	93	96	105	90	91	96	96	100	96
East Central seed lots:																
138 NJ	112					134				142			80			
127 DE	116					120				130			91			
122 VA	105	112	109	67	95	123	124	42	102	127	157	91	83	88	144	104
119 VA	95	110				109	107			109			93	101		
140 WV	125					100				106			119			
158 VA	101	85				96	91			100			105	94		
117 KY	112	86				127	136			145			87	94		
123 TN	84	86				88	91			70			93	94		
136 TN	89	99				102	98			94			93	101		
118 TN	101	123				109	120			106			91	98		
\bar{X}	104	102	109	67	95	111	110	42	102	113	157	91	93	95	144	104
Southern seed lots:																
113 NC	69					89				61			93			
116 NC	93	85				88	84			70			103	97		
124 NC	82	80	83	37		82	87	54		70	79		96	93	103	
121 NC	73					75				58			98			
132 GA	64					71				61			100			
111 GA	69					64				36			107			
110 AL	48					59				30			111			
106 MS	30					66				51			109			
120 MO	99	89	97			95	84			94	86		101	103		
112 AR	84					79				64			105			
115 AR	70	91				114	100			91			78	88		
103 LA	100					86				88			111			
\bar{X}	76	86	83	57		81	89	54	--	65	82	--	101	95	103	
Actual plantation mean	278	298	215	174	318	56	45	33	50	33	14	23	54	68	59	66
Stand																
Significance**	**	**	**	**	NS	**	**	**	NS	**	**	NS	**	**	**	NS

*, Significant at the 0.05 level; **, significant at the 0.01 level; and NS, not significant

Seedlings from the north central seed lots (southern Lake States and southern two-thirds of New England) generally showed above average height, caliper and DBH in all plantations whereas trees from southern seedlots were below average in these same measurements (Table I). Progenies from the northern, west central and east central seed sources were generally about average in height in all plantations, but specific exceptions did occur. For example, seedlings representing stands from Bethel, Maine (163 ME) and Alfred, Maine (152 ME) were above average not only in height but also DBH and caliper in most plantations, and perhaps are more closely associated in growth potential with north central rather than northern stands (Table 1). Most of the fastest growing progenies in all plantations were from north central sources, such as Stayner, Ontario (164 ON); Storrs, Connecticut (146 CN); East Lansing, Michigan (137 MI); and Bradford, Pennsylvania (149 PA).

Trees in Ohio were larger in caliper than those trees in Minnesota and Michigan, even though these two plantations showed the greatest average height (Table 1). The shorter, stockier nature of trees in Ohio is also reflected in their lower average height to caliper ratio. Ohio has more southern progenies than Minnesota and Michigan, but the winter injury to the tops of the southern seedlings (Townsend et al. 1982) does not explain the relatively low height to caliper ratio found in Ohio because southern progenies have about the same ratio as northern progenies (Table 1). When five years old, the red maple progenies from east central sources were far above average in height in all five plantations (Townsend et al. 1979). The decrease in height growth performance of these east central sources, relative to other regions between five years and nine years old, can partly be explained by the greater winter injury sustained by these trees compared to trees from other seed lots during these four years (Townsend et al. 1982).

Tables 2, 3, and 4 present the format used for the analyses of variance and give the expected mean squares for the various plantations. Trees with missing DBH or caliper measurements were omitted for these analyses. Note that a component labeled "common environment" is included in the expected mean squares for all plantations. Because trees from the same open-pollinated family represent the randomized experimental unit in each block in Ohio and Michigan, the "common environment" component is used to take into account that part of the plot variance not due to family x block interaction but instead is a result of common environmental effects on trees of the same family growing in the same plot (Table 2). The family x block interaction contributes to the plot variance but because it cannot be separated from the common environmental effect, is enclosed in the same parentheses in the expected mean squares.

For Indiana and Minnesota data, two "common environment" components were developed: one (σ_1) for the environment common to trees of the same family in the same sub-sub plot, the other (σ_2) for the environment shared by trees of the same stand in a given sub-plot (Table 3). Because each tree from all families

Table 2. Form of the analyses of variance and expected mean squares for the Ohio and Michigan plantations.

Source of variation	df		Expected Mean Squares ^c
	OH	MI	
Stands (S)	50	38	$\sigma_w^2 + k_5(\sigma_c^2 + \sigma_{fB:s}^2) + k_8\sigma_{sB} + k_{11}\sigma_{f:s}^2 + k_{12}\sigma_s^2$
Families:Stands(FS)	81	54	$\sigma_w^2 + k_4(\sigma_c^2 + \sigma_{fB:s}^2) + k_{10}\sigma_{f:s}^2$
Blocks (B) ^a	5	9	$\sigma_w^2 + k_3(\sigma_c^2 + \sigma_{fB:s}^2) + k_7\sigma_{sB}^2 + k_9k_B^2$
Stands x Blocks (SXB)	242	254	$\sigma_w^2 + k_2(\sigma_c^2 + \sigma_{fB:s}^2) + k_6\sigma_{sB}^2$
FB:S ^b	370	141	$\sigma_w^2 + k_1(\sigma_c^2 + \sigma_{fB:s}^2)$
Trees:SFB	2127	440	σ_w^2

^aBlock effects are assumed to be fixed

^b σ_c^2 is the variance due to common environmental effects for trees of the same family as grown in the same block (plot).

^c Coefficients of Variance components for Ohio:

$$k_1 = 3.8787 \quad k_8 = 9.5662$$

$$k_2 = 3.7681 \quad k_{10} = 21.5296$$

$$k_4 = 3.8123 \quad k_{11} = 21.4947$$

$$k_5 = 3.7996 \quad k_{12} = 55.9582$$

$$k_6 = 9.5177$$

Coefficient for Michigan:

$$k_1 = 1.8393 \quad k_8 = 3.6563$$

$$k_2 = 1.8940 \quad k_{10} = 6.6663$$

$$k_4 = 1.8638 \quad k_{11} = 12.5217$$

$$k_5 = 1.9386 \quad k_{12} = 23.7654$$

$$k_6 = 2.8719$$

Table 3. Form of the analyses of variance and expected mean square for the Indiana and Minnesota plantations

Source of variation	df		Expected Mean Squares ^c
	IN	MN	
<u>Whole Plots</u>			
Stands (S)	20	13	$\sigma_w^2 + k_5(\sigma_{c1}^2 + \sigma_{Bf:s}^2) + k_8(\sigma_{c2}^2 + \sigma_{SB}^2) + k_{11}\sigma_{f:s}^2 + k_{12}\sigma_s^2$
Blocks(B) ^a	4	5	$\sigma_w^2 + k_3(\sigma_{c1}^2 + \sigma_{Bf:s}^2) + k_7(\sigma_{c2}^2 + \sigma_{SB}^2) + k_9k_B^2$
S X B	77	26	$\sigma_w^2 + k_2(\sigma_{c1}^2 + \sigma_{f:s}^2) + k_6(\sigma_{c2}^2 + \sigma_{SB}^2)$
<u>Sub-Plots</u>			
Families	42	28	$\sigma_w^2 + k_4(\sigma_{c1}^2 + \sigma_{Bf:s}^2) + k_{10}\sigma_{f:s}^2$
BF:S ^b	131	122	$\sigma_w^2 + k_1(\sigma_{c1}^2 + \sigma_{Bf:s}^2)$
<u>Sub-Sub Plots</u>			
Trees :S B	274	93	σ_w^2

^aBlock effects are assumed to be fixed.

^b σ_1^2 is the variance due to common environmental effects for trees of the same family as grown in the same sub-sub plot; σ_c^2 is the common environmental effect for trees of the same stand as grown in the same sub-plot. With standard conditions, $\sigma_{c1}^2 + \sigma_{c2}^2 + \sigma_{c2}^2$ (see Table 2).

^cCoefficients for Indiana:

$$\begin{aligned}
 k_1 &= 1.8196 & k_8 &= 5.5942 \\
 k_2 &= 2.2285 & k_{10} &= 7.5467 \\
 k_4 &= 1.8711 & k_{11} &= 10.2245 \\
 k_5 &= 2.3214 & k_{12} &= 25.9677 \\
 k_6 &= 5.1500 & &
 \end{aligned}$$

Coefficients for Minnesota:

$$\begin{aligned}
 k_1 &= 1.2809 & k_8 &= 4.1730 \\
 k_2 &= 1.5362 & k_{10} &= 6.9457 \\
 k_4 &= 1.3645 & k_{11} &= 8.5758 \\
 k_5 &= 1.6755 & k_{12} &= 22.9206 \\
 k_6 &= 3.8562 & &
 \end{aligned}$$

Table 4. Form of the analyses of variance and expected mean squares for the Wisconsin plantation .

Sources of variation	df	Expected mean squares ^b
Whole Plots Stands(S)	23	$\sigma_w^2 + \sigma_{c1}^2 + k_5\sigma_{Bf:s}^2 + k_8(\sigma_{c2}^2 + \sigma_{sB}^2) + k_{11}\sigma_{f:s}^2 + k_{12}\sigma_s^2$
Blocks (B) ^a	3	$\sigma_w^2 + \sigma_{c1}^2 + k_3\sigma_{Bf:s}^2 + k_7(\sigma_{c2}^2 + \sigma_{sB}^2) + k_9K_B^2$
S X B	67	$\sigma_w^2 + \sigma_{c1}^2 + k_2\sigma_{Bf:s}^2 + k_6(\sigma_{c2}^2 + \sigma_{sB}^2)$
Sub-Plots		
Family:Stands(F:S)	42	$\sigma_w^2 + \sigma_{c1}^2 + k_4\sigma_{Bf:s}^2 + k_{10}\sigma_{f:s}^2$
B:FS	85	$\sigma_w^2 + \sigma_{c1}^2 + k_1\sigma_{Bf:s}^2$
Trees:SFB	239	$\sigma_w^2 + \sigma_{c1}^2$

^aBlock effects are assumed to be fixed. See footnote on Table 3.

^bCoefficients of Variance Components for Wisconsin:

$k_1 = 1.7743$	$k_8 = 5.3361$
$k_2 = 2.2814$	$k_{10} = 5.4991$
$k_4 = 1.9084$	$k_{11} = 8.3390$
$k_5 = 2.5855$	$k_{12} = 19.0880$
$k_6 = 4.4318$	

was completely randomized within each plot representing a stand, the (σ^2_{cl}) component in Wisconsin has unity as its coefficient (Table 4).

Variance component estimates expressed as a percentage of the total variance are shown in Table 5. Significant stand effects were present for most traits in all plantations except in Minnesota, where the stand x block effect (which includes common environmental effects also) rather than the stand effect was significant. Significant differences among open-pollinated families within stands were shown for height in Ohio, Michigan, and Wisconsin (Table 5). Where significant, the percent of the total variance due to stands varied from 8 to 14%; the corresponding significant percentages for families within stands ranged from 5 to 9%. The family within stand component for height was also non-significant in Indiana and Minnesota at five years of age (Townsend et al. 1979). The common environmental effects for height, which includes family x block interaction, were significant and sizeable in three of the four plantations where these two sources of variation were confounded.

Caliper and DBH were usually affected significantly by stand of origin but only in Ohio did the family within stand component significantly influence these two traits. The ratio, height/DBH, was less often affected by genetic sources of variation (stands or families) than was the ratio of height to caliper. The "common environment" effect contributed heavily to caliper variation in most plantations.

Growth performance of seedlings (from the same stand or family within stands) growing in all plantations usually was significantly correlated (Table 6). Exceptions did occur, however. For example, neither stand nor family correlations in height between progenies in Michigan and Minnesota, Indiana and Wisconsin, and Indiana and Minnesota were significant. Some genotype-environment interaction therefore did occur and will complicate to some degree breeding of red maple for all environments.

Heritabilities on a within stand single tree basis varied greatly among plantations, with ranges of .02 to .42 for height and less extreme ranges for the other traits (Table 7). The ratio of height to DBH generally had lower heritabilities than height/caliper. Heritabilities without regard to stands are generally somewhat higher and reflect the greater potential gains one could make by selecting potential parents from many stands (Table 7). With loblolly pine (*Pinus taeda* L.), LaFarge (1974) has also found considerable variation among stands or provenances, in addition to that among parents within stands.

Growth parameters were highly correlated genetically and phenotypically (Table 8). The ratio height/DBH was negatively correlated with height in many locations. Genetic correlations are high enough between height, caliper, and DBH that selection for one of these traits will

Table 5. Components of variance expressed as a percentage of the total variance.

Components	Height					Caliper				DBH		
	OH	MI	IN	WI	MN	OH	MI	WI	MN	OH	IN	MN
	(% of total variance)											
Stands	13**	14**	8**	14**	--	12**	18**	15**	--	12**	11**	--
Families:Stands	5**	9**	--	5*	1	5**	3	5	--	5**	--	6
Stands x Blocks	^a --	--	7*	4*	16**	1	--	--	23**	1	11**	17**
Common Environment	18**	18**	11**	--	3	11**	14**	--	18**	11**	7	--
Trees: SFB	64	59	74	77	80	71	65	80	59	71	70	77
	Height/Caliper				Height/DBH							
	OH	MI	WI	MN	OH	IN	MN					
	(% of total variance)											
Stands	12**	6**	7**	-	11**	4	--					
Families:Stands	3**	9**	6	6*	3*	--	1					
Stands x Blocks	2*	--	8*	13**	1	--	--					
Common Environment	4	12*	--	--	10**	29**	--					
Trees:SFB	79	74	78	81	75	67	99					

*, ** Significant at the 0.05 and 0.01 levels, respectively.

^a A dash (--) indicates 0.5 per cent or less.

Table 6. Correlation coefficients between plantations of means of red maple progenies a.

Plantations Compared	Height	Caliper	DBH	Height/Caliper	Height/DBH
OH and MI	.59** (.52**)	.80** (.55**)	---	.74** (.45**)	---
OH and IN	.50* (.46**)	---	.64** (.53**)	---	.57* (.22)
OH and WI	.70** (.59**)	.32 (.42**)	---	-.14 (.04)	---
OH and MN	.32 (.38)	.45 (.40**)	.04	.27 (.41**)	.20 (.19)
MI and IN	.74** (.60**)	---	---	---	---
MI and WI	.34 (.29*)	.05 (.15)	---	-.14 (-.04)	---
MI and MN	.00 (.13)	.21 (-.04)	---	.36 (.17)	---
IN and WI	.15 (.05)	---	---	---	---
IN and MN	-.23 (-.03)	---	-.15	---	.14 (.20)
WI and MN	.28 (.41**)	.28 (.42**)	---	.31 (.05)	---

*,** Significant at the 0.05 and 0.01 level. A dash (---) indicates that no data were common to both plantations.

a Top value is correlation between stand means. Value underneath in parentheses is correlation between family means.

Table 7. Heritability (h^2) Estimates On A Within Stand Single Tree Basis and On A Between Stand Basis For Nine-Year-Old Red Maples.

Trait		Plantation				
		Ohio	Michigan	Indiana	Wisconsin	Minnesota
Height	Within Stands	.25±.06	.42±.13	.02±.13	.25±.17	.02±.17
	Between Stands ^a	.34±.05	.50±.13	.10±.09	.36±.15	.02±.05
Caliper	Within Stands	.24±.06	.15±.09	-	.25±.17	neg.
	Between Stands	.33±.05	.30±.11	-	.37±.15	neg.
DBH	Within Stands	.22±.06	-	.01±.13	-	.23±.21
	Between Stands	.32±.05	-	.02±.09	-	.23±.14
Height/Caliper	Within Stands	.14±.05	.37±.13	-	.25±.17	.23±.21
	Between Stands	.24±.05	.41±.12	-	.30±.14	.23±.14
Height/DBH	Within Stands	.11±.05	-	neg.	-	.03±.17
	Between Stands	.20±.05	-	.04±.05	-	.03±.05

^a Calculated from $(\sigma_s^2 + 4\sigma_{f:s}^2)/\sigma_p^2$, where σ_s^2 is the variance component for stands, $\sigma_{f:s}^2$ is the family within stand variance component and σ_p^2 is the total phenotypic variance.

Table 8. Estimates of genetic and phenotypic correlations between growth traits of nine-year-old red maple progenies in several north central locations ^a

Traits	Caliper				DBH			Height/Caliper				Height/DBH		
	OH	MI	WI	MN	OH	IN	MN	OH	MI	WI	MN	OH	IN	MN
Height	.88 [±]	.61 [±]	1.17 [±]	-- ^b	.93 [±]	--	--	-.12 [±]	.54 [±]	-.98 [±]	--	-1.00 [±]	--	--
	.06	.22	.20		.04			.30	.23	1.03		.49		
	.78	.72	.86	.63	.85	.91	.83	-.00	.19	-.30	-.16	-.63	-.61	-.68
Caliper					1.01 [±]	--	--	-.61 [±]	.31 [±]	-.86 [±]	--	-.95 [±]	--	--
					.01			.37	.42	1.02		.48		
					.88	--	.66	-.59	-.48	-.64	-.73	-.64	--	-.71
DBH								-.54 [±]	--	--	-.40 [±]	-.94 [±]	--	-.84 [±]
								.33			.84	.51		1.12
								-.32	--	--	-.24	-.75	-.72	-.73
Height/Caliper												.13 [±]	--	1.34 [±]
												.37	--	.51
												.27	--	.58

^a Calculated on a within stand basis. Stand x block interaction is assumed to equal zero. Listed vertically, the first value is the genetic correlation with standard error, and the second number is the phenotypic correlation.

^b Not estimable because of negative variance component estimates for families or because data were not available.

simultaneously affect another in the same direction.

CONCLUSION

Variation among stands and families in height and diameter of nine-year-old red maple progenies offers tremendous opportunity for genetic advances in growth potential of this species. Genotype-environment interaction was present, mostly because of the presence of differential growth response of the same progenies in the northern (Minnesota and Wisconsin) compared to some of the southern planting sites. However, heritabilities generally are sufficiently high to allow rapid progress in selection and breeding of this species. We are currently determining selection indices and breeding values that will enable us to plan and carry out an efficient advanced generational crossing system.

LITERATURE CITED

- Harvey, W. R. 1982. Mixed model capabilities of LSML 76. *Jour. of Animal Science* 54:1279-1285.
- LaFarge, T. 1974. Genetic variation among and within three loblolly pines stands in Georgia. *Forest Science* 20: 272-275.
- SAS Institute. 1979. SAS User's Guide. SAS Institute Inc., Box 8000, Cary N.C.
- Townsend, A. M. 1977. Characteristics of red maple progenies from different geographic areas. *J. Amer. Hort. Sci.* 102:461-466.
- Townsend, A. M., Wright, J. W., Kwolek, W. F., Beineke, W. F., Lester, D. T., Mohn, C. A., and Dodge, A. F. 1979. Geographic variation in young red maple grown in north central United States. *Silvae Genetica* 28:33-36.
- Townsend, A. M., Wright, J. W., Beineke, W. F., Guries, R. P., and Mohn, C. A. 1982. Early patterns of flowering, winter injury, and flushing of red maple progenies grown in five locations. *Canad. J. For Research* 12:814-821.