GEOGRAPHIC VARIATION OF RED PINE SURVIVAL, GROWTH AND PRODUCTIVITY IN A MINNESOTA FIELD TEST [1]

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Abstract. Forty-eight red pine (*Pinus resinosa*) seed lots from various geographic origins were evaluated after 25 years for survival, tree height, diameter, total volume and volume produced per acre. Differences in seed lot means were of statistical significance for all growth variables and of practical significance in the case of volume per acre produced. Seed lot means were positively correlated with longitude, although specific seed lots from eastern longitudes were very productive. Age-age correlations indicated that height and diameter at age 17 accounted for 40 and 50 percent of the variation among seed lot means in volume produced per acre at age 25.

Additional keywords: geographic variation, volume productivity, age-age correlation, *Pinus resinosa*.

In 1959 and 1960 a range-wide provenance test of red pine (*Pinus resinosa*) was initiated as a part of the regional project NC-51 (now NC-99) to study the species' geographic variation and provide seed source information for reforestation efforts in the north central states. Wright et al. (1972) presented first and 6 or 8 year (in the field) survival and height growth data for eight plantings in Michigan, Wisconsin, Minnesota, Indiana and Nebraska. Across these plantings trees from Michigan's lower peninsula consistently grew most rapidly, although individual seed lots from other regions performed as well or slightly better. This paper reports survival, growth and yield data through 25 years from seed of a Minnesota planting in this study.

MATERIAL AND METHODS

Seed collection details and nursery performance of these seed lots were reported by Wright et al. (1972) and Wright et al. (1963). Seed lots were stand collections containing seed from 10 or more trees. Seedlings (3-0) derived from 48 seed lots were supplied by Michigan State University for testing in Minnesota. The geographic distribution of these seed lots is presented in Figure 1.

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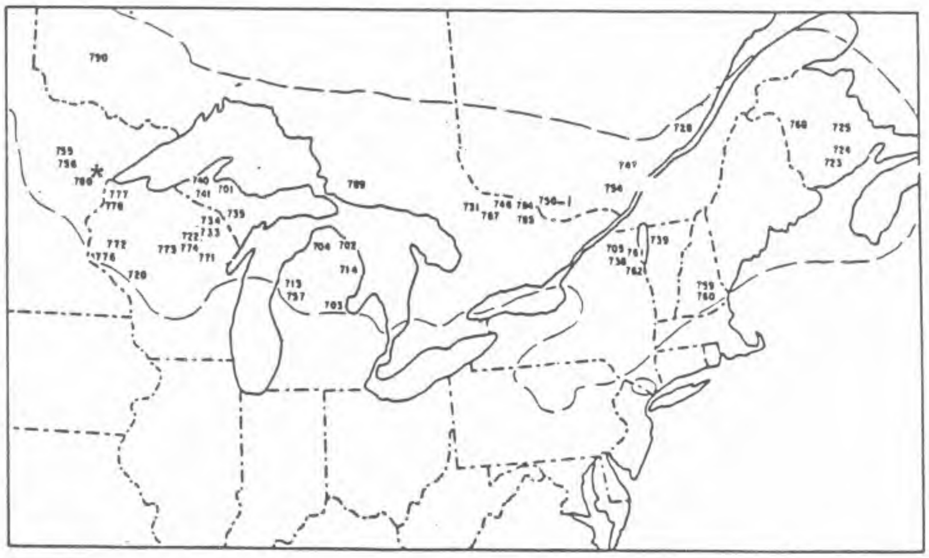

Figure 1. Location and seed lot numbers of seed lots tested in a Minnesota planting of the NC-99 red pine provenance test. denotes boundary of the natural range of red pine. * denotes test site location.

In the spring of 1963, the seedlings were planted near Cloquet, Minnesota (46.7°N, 93.5°W) in a randomized complete block design with 48 seed lots as treatments, 5 replications and 4-tree row plots. Spacing was 8 X 8 feet and two border rows were planted around the entire test.

Total tree height was measured on each surviving tree in the spring of 1964 (age 4) and the fall of 1970 (age 11) and 1976 (age 17) and on every second tree per plot in the fall of 1984 (age 25). Diameter at breast height was measured on each surviving tree in the fall of 1976 and 1984.

Total tree volume was calculated for individual trees using 25-year height and diameter. Adjusted volume per acre was calculated by multiplying the average volume per tree by the number of surviving trees per acre for each seed lot. The following volume equations were used in volume calculations:

Volume in cubic feet = $.00229*D^2*H$ and

Volume in cords = $-.0058+.00002512*D^2*H$, where D is diameter at breast height in inches and H is total tree height in feet (Buckman 1959).

Analyses of variance using plot means were computed on all growth variables and F-tests performed to test for differences among seed lot means. A chi-square test was performed on 25-year survival data to test for independence of seed lots and survival. Simple and multiple correlation coefficients were calculated with the measured or calculated values of growth or productivity as dependent variables and latitude and/or longitude as independent variables. Simple correlation coefficients between variables were calculated using both seed lot and plot means. For all analyses, unless indicated otherwise, the .05 probability level was used for significance.

RESULTS AND DISCUSSION

Seed Lot Variation and Geographic Trends

Table 1 presents the test mean, range of seedlot means, calculated test statistic for testing for differences among seed lot mean§ and the percent of total variance, adjusted for replications, attributed to seed lots for each variable. Table 2 presents the simple and multiple correlation coefficients between seed lot means and latitude and/or longitude of seed lot origin.

Survival. Test mean survival at 25 years (from seed) was 94 percent. All mortality ocurred in the first 8 years after planting. Seed lot mean survival ranged from 75 to 100 percent, with 19 seed lots having 100 percent survival. The chi-square statistic was significant at approximately the .10 probability level, suggesting a possible effect of seed lot on survival (Table 1). Survival was not significantly correlated with either latitude or longitude of seed lot origin (Table 2).

Height, Diameter and Volume Growth. Site index base age 50 of the test site was 70 feet (Hahn and Carmean 1982, calculated with test mean 25th year height) which is representitive of a good red pine site in northeastern Minnesota. Stand closure began at approximately age 11 (8 years in the field).

Differences among seed lot means were significant for all height measurements. The relative amount of variance attributable to seed lots decreased with age, although differences at age 25 were still significant (Table 1).

These data partially support Franklin's (1979) proposed model for change in genetic variance over time, in that the relative variance among seed lots decreased until stand closure. However, the continued decreasing trend in relative variance among seed lots after the onset of crowding (basal area per acre at age 25 was approximately 150 sq ft) is not consistent with Franklin's hypothesis.

Simple correlations of longitude of origin with seed lot means were significant and positive for height at age 11, 17 and 25 (Table 2). Longitude explained approximately 25 percent of the variation in height at and after age 11. Simple correlations of each height variable with latitude and height at age four with longitude were not significant. The

Table 1. Test mean, range of seed lot means, test statistic for testing seed lot effect and percent of variance due to seed lots in a Minnesota planting of the NC-99 red pine provenance test.

	Test Mean	Range of Seed Lot Means	F	Percent of Variance Due to Seed Lot
Height (cm)				
age 4	27	17 - 33	5.47*	47.2
age 11	257	207 - 304	3.56*	33.9
age 17	604	504 - 668	2.51*	23.2
age 25	1127	1304 - 1201	2.04*	17.2
Diameter (cm)				
age 17	10.5	8.1 - 11.9	2.94*	28.0
age 25	15.7	12.0 - 17.4	2.75*	25.9
Tree Vol. (cu ft)				
age 25	3.8	2.4 - 4.9	2.21*	19.5
Adj. Vol./Acre (cds)				
age 25	22.8	13.1 - 32.0	2.44*	24.4
			Chi^2	
Survival (%)				
age 25	94	75 - 100	59.6	--

Note: 47 and 188 df associated with F and 47 df with Chi^2
* significant at .05 probability level

Table 2. Simple (r) and multiple (R) correlation coefficients between survival and growth variables and latitude and/or longitude of seed lot origin. Correlation coefficients are based on seed lot means in a Minnesota planting of the NC-99 red pine provenance test.

	Latitude r	Longitude r	Lat.and Long. R
Height			
age 4	-.15	.16	.27
age 11	.11	.50*	.50*
age 17	.13	.51*	.51*
age 25	.04	.44*	.46*
Diameter			
age 17	.17	.43*	.43*
age 25	.24	.39*	.41*
Tree Vol.			
age 25	.14	.39*	.39*
Adj. Vol./Acre			
age 25	.11	.36*	.37*
Survival			
age 25	-.03	-.01	.16

Note: 46 df associated with r and 45 with R
* significant at .05 probability level

correlation coefficients suggest that in general western seed lots (closer to Minnesota) were faster growing than eastern seed lots.

Differences among seed lot means were significant for diameter at age 17 and 25. The percent of variation among diameter means attributable to seed lots does not appear to be declining over time as rapidly as that for height (Table 1).

Simple correlation coefficients based on seed lot means were significant and positive for diameter at age 17 and 25 with longitude of origin (Table 2). Longitude explained approximately 16 percent of the variation in diameter at and after age 17.

Differences among seed lot means for total volume per tree (age 25) were significant (Table 1). Mean volume of the highest yielding seed lot was two times as large as the lowest yielding seed lot and 30 percent larger than the test mean. Of the five most vigorous seed lots, two were considered to be of local origin (755 and 756, see Figure 1) and three non-local (722 from north central Wisconsin, 757 from lower Michigan and 751 from western Quebec). The three other local seed lots 777, 778 and 780 ranked 18th, 19th and 45th, respectively. Wright et al. (1972) found seed lot 756 to be ranked first in average total height of the 77 seed lots tested at three or more locations.

Differences among seed lot means for adjusted volume per acre (age 25) were significant and the seed lot effect accounted for a higher percentage of variation than it did for the tree volume estimates (Table 1). Although average tree volume of seed lot was not significantly correlated with survival the coefficient was positive (Table 3) indicating the possibility of better survival among the more vigorous seed lots. This correlation resulted in the greater relative range in seed lot means for adjusted volume per acre than volume per tree.

Both volume per tree and adjusted volume per acre were significantly and positively correlated with longitude and correlations with latitude were positive but not significant (Table 2). Longitude explained approximately 15 percent of the variation in the two volume variables. The significant positive correlations of all growth variables with longitude suggests that western seed lots (closer to Minnesota) should be planted in northeastern Minnesota when untested material must be used.

Age-Age and Between Variable Correlations

Table 3 presents the correlation coefficient matrices, based on plot means above the diagonal and seed lot means below. Height at age four was significantly, positively correlated with all subsequent growth variables based on plot means, but only with height at age 11 based on seed lot means. Although significant, fourth year height explains only nine percent of the variation in 11th year height and less than four percent in 25th year adjusted volume per acre. Height at age 11 and 17 were significantly, positively correlated with height at age 25, and both explained about 50 percent of the variation in seed lot means of 25th year height.

Table 3. Simple correlation matrices of survival and growth variables in a Minnesota planting of the NC-99 red pine provenance test. Correlations are based on plot means above diagonal (XX) and seed lot means below.

	H4	H11	H17	H25	D17	D25	V25	AV/A25
Height								
age 4	XX	.31*	.25*	.22*	.28*	.24*	.17*	.19*
age 11	.30*	XX	.73*	.55*	.76*	.67*	.52*	.51*
age 17	.16	.84*	XX	.62*	.83*	.79*	.57*	.50*
age 25	.12	.71*	.70*	XX	.61*	.58*	.77*	.72*
Diameter								
age 17	.28	.91*	.86*	.72*	XX	.88*	.67*	.59*
age 25	.21	.83*	.85*	.72*	.95*	XX	.72*	.62*
Tree Vol.								
age 25	.07	.67*	.64*	.90*	.74*	.75*	XX	.91*
Adjusted Vol./Acre								
age 25	.13	.67*	.59*	.86*	.70*	.70*	.95*	XX
Survival								
age 25	.22	.28	.06	.17	.19	.12	.17	.46*

Note: 238 df associated with correlation above diagonal and 46 df below
* significant at .05 probability level

The lack of improved correlation of early height with height at age 25 from age 11 to 17 is probably associated with tree development and stand closure (Lester and Barr 1966). Prior to age 11 many developmental changes are known to take place in forest tree species resulting in early tree performance that is poorly correlated with later performance (Pharis 1976). Additionally, tree performance in the early years is assessed in the absence of between tree competition. Unfortunately data between ages 5 and 10 were not available and correlation with subsequent measurements could not be estimated. Although possible, it is doubtful that data taken much earlier than age 11 would have been strongly correlated with height at age 25.

Height at ages 11 and 17 were also significantly, positively correlated with volume per tree and adjusted volume per acre at age 25 (Table 3). Similar to the early-late height correlations, little change in the correlation of early height with age 25 productivity occurred between ages 11 and 17.

Diameter at age 17 was as strongly correlated with 25th year height, as were 11th and 17th year heights, and was nearly perfectly correlated with 25th year diameter (Table 3). Diameter at age 17 was also significantly, positively correlated with volume per tree and adjusted volume per acre and explains approximately 50 percent of the variation among seed lot means for both volume variables. These correlations suggest that diameter at age 17 may be a better indicator of age 25 productivity than height at age 17, however height at age 11 was nearly as effective as diameter at age 17.

CONCLUSIONS

The significant variation in growth and yield among red pine seed lots of differing geographic origin found in this test is of large enough magnitude to be of practical importance for reforestation planning in northeastern Minnesota. The seed lot variability did not demonstrate a strong geographic trend, although in general seed lots of western origin (closer to test site) performed better than eastern seed lots.

Wright et al. (1972) finding that seed lots from Michigan's lower peninsula were significantly taller 6 or 8 years after planting over a wide range of sites is generally supported by these 25 year results. The six lower peninsula seed lots included in this test were 11.7 percent more productive in adjusted cords per acre than the plantation average at 25 years of age.

The best geographic areas for red pine seed collection for planting in northeastern Minnesota appear to be north central to northeast Wisconsin, north central Minnesota and the lower peninsula of Michigan. The six seedlots of north central to northeast Wisconsin and one seed lot of adjacent upper Michigan origin were 19.4 percent more productive in adjusted cords per acre than the test average while the two seed lots from north central Minnesota were 27.8 percent more productive. The poor performance of northeast Minnesota seed lot 780 (same county as test site) and west central Wisconsin seed lots 772, 776 and 720 indicate the importance of large stand-to-stand variation within areas of good performing seed lots. These four seed lots were 18.5 percent below the test mean in adjusted cords produced per acre.

Age-age correlations strongly suggest that seed lot selection for volume production based on nursery and/or first year field measurements will not be effective. No conclusion can be made as to the effectivness of selection between ages 5 and 10. Height measured at approximate stand closure (age 11) was reasonably well correlated with 25 year volume production and was as closely correlated as height and diameter measured several years later (age 17).

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