VARIATION OF CLONAL PROGENIES FROM *PINUS STROBUS* SEED ORCHARDS IN THE NORTHEASTERN UNITED STATES GROWN IN MARYLAND'S NURSERY[1/]

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ABSTRACT.--First-year growth characteristics of open-pollinated eastern white pine progenies from seed orchards in seven northeastern states were compared. Seed weight was significantly correlated with first-year height growth. Clones that consistently show poor performance after the first year should be removed to attain the full genetic potential of the seed orchard's crop.

Eastern white pine (*Pinus strobus* L.) is one of the more widely planted trees in eastern Canada and the Northeastern United States. More than 15 million are planted annually. Consequently, this species deserves a high priority for research on genetic improvement. Much research is under way to select outstanding geographic strains (Genys et al. 1978; Wright et al. 1979). Also genetic improvement of *P. strobus* is in progress to produce pest-resistant strains (Gerhold et al. 1964). From a practical point of view, it is important to establish seed orchards with the most outstanding clones. To reduce the risk of inbreeding, it is sound practice to include at least 20 non-related clones in each orchard. When trees start producinc viable seeds, the clonal progenies must be tested to identify and eventually remove parent trees that yield seeds with inferior characteristics.

There are various methods for testing clonal progenies, ranging from quick and simple to expensive and precise (Wright 1976; Rohmeder and Schönbach 1959). The most reliable information on specific combining ability of different clones would be obtained by crossing each clone with

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every other clone. A simpler method, yielding less precise information since the pollen source is unknown, tests the wind-pollinated progenies from each maternal clone. This report is based on this latter type of test.

One strength of our study is that for the first time we are able to compare traits of progenies from 10 separate seed orchards in 7 Northeastern states. We believe they include much outstanding germ plasm. Results of this study are based on a design with eight blocks, which yielded precise estimates of progeny and seed source means.

The short-term objective of this study is to alert state tree improvers to clones in their orchards that may appear to be inferior. The long-term goal of this study is to identify which outstanding clones may be used to improve stock in several states.

METHODS

Arrangements for this study were made by the USDA Forest Service, Northeastern Area State and Private Forestry, in August 1978, with strong endorsement from the NE-27 Group. Tree improvers in the eastern United States and Canada were asked for sample quantities of seed from clones or selected trees (at least 2,000 seeds per sample). More than a hundred separate lots of various sizes were received from 10 different orchards, including 3 orchards in Maryland (Table 1). Also, a number of nonorchard seedlots were received from Connecticut, Maine, New York, North Carolina, Ohio, Quebec, and Tennessee for comparison. The lots were subdivided for three types of testing: (1) those to be grown in greenhouses in Maine (57 sources) and Quebec (26 sources), (2) those grown in large non-replicated nursery blocks in Maryland's tree nursery (30 sources), and (3) those for a replicated experiment by the senior author (90 sources).

Seed weights were determined on the basis of 20 randomly selected filled seeds. They were checked for soundness by crushing. Seeds were submerged in distilled water for 12 hours, then drained and stratified for 50 days at 34°F. After 2 weeks of stratification they were washed with a captan solution to prevent mold.

The nursery evaluation trial was established at the Buckingham State Forest Tree Nursery at Harmans, Maryland, on April 18, 1979. The planting was in randomized blocks with row plots. These row plots were 2 feet long across the seedbed with 5 inches between rows. By the end of the first growing season, the seedlings had been reduced to 12 to 16 per 2-foot plot.

Table 1. --Sources of P. strobus seedlots included in this study

Study code	Origin	Seed lots: Total	Seed lots: Set in 8 blocks	Source of seeds
PA	Pennsylvania; includes clonal selections from N.Y. and Md.	20	17	Selected clones
CN	Quebec	19	12	Selected native individuals
VT	Vermont	10	8	Selected clones
MD	Harmans, Maryland	9	6	Selected clones
SM	Harmans, Maryland	15	5	Selected clones
GP	Gunpowder State Park, Maryland	18	2	Selected clones
GE	Georgia	2	2	Native stands[a]
ME	Maine	8	5	Selected clones
OI	Searsmont, Maine	1	1	Native stands[a]
NH	New Hampshire	8	5	Selected clones
OR	Oconto River, Wisconsin	6	6	Selected clones
NY	New York	2	2	Mixed selected clones
34	Adirondacks, New York	1	1	Native stand[a]
42	Pachaug State Forest, Conn.	1	1	Native stand[a]
NC	North Carolina	6	5	Native stands[a]
TN	University of Tennessee Oak Ridge, Tenn.	2	1	Arboretum, mixed
OH	Findley State Park, Ohio	1	1	Plantation from native Ohio seed[a]
Total		129	80	

[a] Controls included: Connecticut, Maine and Ohio plus commercial sources from New York (Adirondack), Georgia (2 separate collections from 2 counties), and North Carolina (6 separate collections from 6 counties).

Germination speed was scored on May 5, rating the sources from 0 where no seeds germinated to 20 for complete germination. A week later, the seedlings were tallied for seedcoat retention or shedding. (Percentages of each type were calculated.) On May 31, when the cotyledons were fully open, their numbers were counted on three randomly selected seedlings in each plot.

In the fall, first-year height growth was measured on the largest seedling in each quarter of the row plot. (Runty seedlings were not expected to survive much beyond the first year.) Row-plot means were used as observations for calculations.

There is considerable variation among the progeny means. Hence, these data are summarized by grouping all progenies within the different orchards (or sources) rather than rating the performance of individual progenies.

RESULTS

Seed weights

The weight of seedlots ranged from 10 to 35 grams per thousand. The lightest seedlot came from a selected Quebec tree (CN-13) and the heaviest from Genys' small seed orchard in Harmans, Maryland (SM-2). As expected, seed weights of lots collected from the same seed orchard varied greatly, depending on their original provenance (Table 2). On the average, seeds from Canada were the lightest (smallest) and those from Maryland the heaviest (largest). Some orchard seedlots were heavier than those from the natural stands (Genys 1963).

Time of germination

The stratification period (50 days at 34°F), as described in the methods, was adequate for all but the southernmost sources. Only eight lots failed to germinate. They may have been collected too early, or improperly handled or stored.

Speed of germination varied significantly. On the average, progenies from Canada and from northerly orchards included more populations that germinated early. On the other hand, nearly all progenies from North Carolina germinated late. Speed of germination was not correlated with any of the other four characteristics studied (Tables 2 and 3).

Table 2.--Variation in characteristics of clonal progenies of eastern white pine *(Pinus strobus)* from 10 seed orchards compared with other sources, based on 1-year study in Maryland.

Source of seed lots (number of progenies studied in 8 blocks)	Weight of 1000 seeds (Grams)	Time of Germination[a/] (Score)	Seeds without seed coats[b/] (Percent)	Number of Cotyledons per seedling	One-year Height (% of mean, 9.0 cm)	
	Range	Range	Range	Range	Range	Mean[c/]
Quebec, Canada (12)	10 - 21	7 - 17	7 - 90	8.6 - 9.6	73 - 92	84
Wisconsin (6)	14 - 23	12 - 17	30 - 75	8.6 - 9.6	81 - 85	84
Maine (5)	- 30	10 - 14	5 - 77	8.8 - 10.7	92 - 105	99
Maine (Control) (1)	- 19	6	48	8.3	91	91
New Hampshire (5)	23 - 29	10 - 14	20 - 70	9.3 - 10.1	96 - 107	103
Vermont (8)	20 - 28	7 - 14	4 - 66	9.2 - 10.3	93 - 107	102
New York (2)	21 - 22	6 - 11	42 - 45	8.4 - 9.5	100 - 101	101
New York (Control)(1)	17	3	11	8.5	82	82
Connecticut (1)	22	5	14	9.4	95	95
Pennsylvania (17)	22 - 34	9 - 13	7 - 70	9.0 - 10.0	96 - 113	109
Ohio (1)	18	9	14	9.0	89	89
Maryland I (6)	18 - 31	7 - 13	2 - 52	8.8 - 9.8	100 - 116	110
Maryland II (5)	22 - 35	7 - 13	1 - 28	9.2 - 10.4	104 - 114	110
Maryland III (2)	-	-	-	-	104 - 106	105
Tennessee (1)	19 - 25	7	25	9.3	116	116
North Carolina (5)	20 - 23	6 - 9	6 - 13	9.0 - 9.6	101 - 110	105
Georgia (2)	-	3	7 - 35	9.1 - 9.2	87 - 90	88

a/ Germination score on May 5, 1979: <8 = slow, 10 = average, >12 = rapid.

b/ Percent of seedlings that had dropped seed coats by May 12, 1979.

c/ $\overline{X}$ of percentages for groups of progeny from seed orchards or sources.

Table 3.--Correlations among characteristics of progenies of eastern white pine, *Pinus strobus*, studied in Maryland.

Characteristic	Code	1	2	3	4	5
Seed weight	1	1.00	-.05	-.28	.65	.81*
Time of germination	2		1.00	.19	.05	-.07
Seed-coat release	3			1.00	-.18	-.40
Number of cotyledons	4				1.00	.47
One-year height growth	5					1.00

*Significant at 0.05 level.

Seed coat release

Table 2 indicates that there is significant variation among seedlings in dropping their seed coats. Progenies from the northern seed orchards developed quickly and dropped their seed coats early, while many of those from the South (Georgia and North Carolina) developed slowly. Contrary to expectation, the speed of seed-coat release showed no significant correlation with the speed of germination (r = .19).

Number of cotyledons

The mean number of cotyledons per seedling for all progenies was 9.5; with a standard deviation of 0.5. The progeny means ranged from 8.4 to 10.7. Individual seedlings were found with cotyledon numbers as low as 7 and as high as 12. Populations with the highest cotyledon numbers came from seed orchards in Maine, Maryland, and Vermont; those with the lowest numbers, from Wisconsin and Quebec. Cotyledon numbers were significantly correlated with the seed weights (r = .65), but showed no relationship to either the speed of germination or the advance in releasing seed coat.

Height growth

One-year height means varied from 6.6 cm (Source 31 from Quebec) to 11.1 cm (Clone 10 from Pennsylvania). Orchard mean heights varied widely and there was a statistically significant difference in height among progenies within the same orchards. For example, there were progenies from Pennsylvania that grew 22 percent slower than the best-growing progeny, and some from the Vermont orchard that grew 13 percent slower. Among those from the Maryland orchard, some grew 13 percent slower, and some of the Maine progenies grew 12 percent slower than the best. These differences in growth rates among different clonal progenies from the same orchard give reason to suspect that some clones may be inferior. Continued tests seem warranted, and poor performers should be prime candidates for roguing and replacement. Such decisions can best be made after this trial and field outplantings yield reliable results over 10 to 15 years. At this time, clones in need of additional observation are: Clone No. 5 in New Hampshire, Clones No. 11 and 20 in Maryland, Clone No. 12 in Pennsylvania, Clone No. 10 in Maine, and Clone No. 13 in Vermont.

There was a high correlation between mean heights and seed weight (r = .81). This suggests that for eastern white pine, seed size is a significant factor affecting first-year growth. We can associate clones yielding heavy seed with characteristics for rapid growth. This was not the case for all species: in European larch, geographic sources that grew rapidly had small seeds (Denys 1960).

First-year height was somewhat correlated with the number of cotyledons per seedling (r = .47). Thus, tall seedlings may be expressing their early advantage of a large number of cotyledons and perhaps greater photosynthesizing area.

DISCUSSION

This test and the field plantings will be observed for several decades. The authors are aware of the limitations in drawing any long-term conclusions from first-year growth data. Still, several observations are justified:

1. The study indicates that "unselected" seedlots from native stands (included for comparison) grew about 10 percent slower than the average for half-sib progeny from selected clones. It was expected that progenies from northern stands (Quebec) might grow at a slow rate. However, that some southern sources (such as Georgia) grew slower than several selected clones from northern orchards. Thus, origin alone does not seem to substitute for selection. Selection within provenances will be of continuing importance.

2. Several clonal progenies from all orchards studied included some source or sources that grew relatively slowly. Additional studies are needed to confirm this performance. Roguing orchards to remove such clones may significantly increase the overall genetic potential of their crop.

3. One-year heights of the same progenies planted in different blocks showed correlation coefficients ranging from r = .50 to r = .65. By increasing the number of blocks, we were able to reduce the impact of some unknown differences within the nursery seedbed. While only 2 percent of the variation is traceable to differences between blocks, a 6-percent gain in efficiency can be demonstrated by blocking the eight replicates. Differences as small as 16 percent can be statistically significant (at the 0.05 level).

SUMMARY

A progeny test incorporating materials from 10 different seed orchards is now in progress. About 50 clones, some common to several states, are being evaluated. Such testing has rarely been undertaken for lack of funds, interest, expertise, or suitable numbers of clones and comparison sources.

These results will continue to reinforce empirical observations regarding eastern white pine performance in the Northeast.

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