TWO-YEAR GROWTH RATES AND OTHER CHARACTERISTICS OF DIVERSE CLONAL PROGENIES FROM PINUS STROBUS SEED ORCHARDS STUDIED IN MARYLAND.[1]/

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Abstract.--About 100 diverse populations of Pinus strobus were studied for two years in Maryland's State Forest Tree Nursery. Seeds were gathered from open-pollinated clones in seed orchards in Maine, Maryland, New Hampshire, New York, Pennsylvania, Tennessee, Vermont and Wisconsin. Also included were controls from some natural stands in six states and Quebec, Canada.

For each progeny, data were obtained on speed of germination, seed coat retention, number of cotyledons, and height. There was a significant variation in all these characteristics. Two-year heights ranged from 64 to 127 percent of the mean, a ratio of 1 to 2. Most clonal progenies grew faster than controls from non-selected native stands but some were poor performers. Early growth rates of seedlings were somewhat related to their average number of cotyledons (r = 0.44).

Trees from sources discussed in this paper are now planted in 9 states on 12 different sites.

Additional keywords: provenance, tree height, cotyledons, seed coats, germination

INTRODUCTION

Eastern white pine (Pinus strobus L.) is one of the most preferred species for planting in the northeastern United States and southeastern Canada. In the northeastern United States alone, forest tree nurseries produce for planting up to 13 million trees annually. This requires large quantities of high-quality seed. A great effort has been devoted to selecting outstanding individual phenotypes for use in the seed orchards (1 - 9). Few organizations, however, have studied the genetic quality of their progenies.

This paper contains information on the first clonal progeny test of sources from 11 seed orchards. The short-term objective is to inform the state tree improvers if any of their orchard clones may appear inferior. The long-term goal is to identify outstanding clones which may be useful for

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multi-state regions. The experimental design and a general discussion of one-year data were presented at the Northeastern Forest Tree Improvement Conference meeting in 1980 (4). Also, a summary of the results has been discussed at a IUFRO meeting in Germany (5). This present report includes detailed two-year data for each progeny or provenence.

METHODS

The study was initiated by the USDA Forest Service in cooperation with the University of Maryland at the suggestion of the NE-27 Group. Tree improvers in the eastern United States and Canada volunteered more than a hundred different seed lots of various sizes from 11 orchards, Including three seed orchards in Maryland. For comparison, a number of non-orchard seed lots from natural stands in Connecticut, Georgia, Maine, New York, North Carolina, Quebec and Tennessee were included.

The seed lots were subdivided for various studies, including about 90 sources for a replicated study by the senior author in Maryland (4). Seed weights were determined on the basis of 20 randomly selected filled seeds per seed lot. Lots assigned for the replicated experiment were stratified by submerging them in distilled water for 12 hours, draining, and placing in a refrigerator for 50 days at 1 C. On the 14th day they were washed with a Captan[3]/solution (2.5 g per liter of water) to prevent mold.

The nursery experiment was started at the Buckingham State Forest Tree Nursery in Harmans, Maryland, on April 18, 1979. Seeds were sown in eight randomized blocks, where each source in every block was represented by two-foot row-plots five inches apart. During the first growing season, the number of seedlings had been gradually reduced to 12 to 15 trees per plot. No additional thinning was required during the second growing season.

Speed of germination was scored on May 5 by rating the sources from "O" if no seeds had yet germinated to "20" for complete germination. On May 12 all seedlings were tallied for percentage of seedcoat shedding. Cotyledons were counted on three randomly selected seedlings in each plot on May 31. One-year and two-year heights were recorded in fall 1979 and fall 1980 by measuring four seedlings per plot: the largest seedling in each quarter of the row. Plot means were used as items in data analysis. One-year heights and other one-year data were summarized in 1980 by grouping all progenies (4). This report lists detailed information about each individual progeny studied, and includes the least significant differences based on the analysis of variance and Duncan's multiple range test. The basic structure of the analysis was as follows: 77 degrees of freedom (df) for sources, 7 df for blocks, 539 df for interaction and 623 df for total. Correlation coefficients were calculated to estimate the relationships between the studied characteristics.

3/ No endorsement of product intended.

RESULTS

Seed Weights

Viable seeds ranged in weight from 12 to 35 grams per 1000 (Table 1). The lightest seed came from Quebec (CN-30); the heaviest from the "Small Maryland" seed orchard (SM-2). In most instances, seed weights of lots from the same seed orchard were highly variable depending on their actual origin. On the average, seeds from Canada were the smallest and those from Maryland orchards the largest. Some orchard seed lots were heavier than any of the previously studied lots from the natural stands (2). This could be a cultural effect of clonal orchard management. At this time, it is not possible to separate the genetic components from the environmental factors which influenced the seed weight. However, some clones, such as "BRIGHAM PINE"4/ , had heavy seeds wherever they grew.

Time of Germination

Progenies from Canada and from some northerly orchards included many sources which germinated early. Nearly all North Carolina sources germinated late. This confirms that a longer stratification and/or favorable growth period is needed for germination of seed from southern sources than for those from northern sources. However, the time of germination was not related to any other studied characteristics (Table 2).

Seed Coat Release

In general, the seedlings from Canada and most families from Maine, New Hampshire, New York, Vermont, and Wisconsin seed orchards dropped their seed coats early, while many of those from Maryland and North Carolina retained them. The speed of seed-coat release showed no significant correlation with the speed of germination ($r = .19$), but there was a negative correlation between the seed-coat release and the height growth of seedlings ($r = -.40$); seedlings of slow growing populations dropped their seed coats first.

Number of Cotyledons

Cotyledon numbers of individual seedlings ranged from 7 to 12, and averaged 9.5. The mean number of cotyledons for different families ranged from 8.6 to 10.7. Populations with the lowest cotyledon numbers came from

4/ We propose the name "BRIGHAM PINE" to relate directly to the single dominant tree located in the Brigham Plantation at Ashton, Maryland. It was first selected by nurseryman Silas Sines in the mid 1950's and established as a promising clone by H. C. Buckingham. Since then it has been propagated at the Maryland Forest Tree Nursery both as a clone and as F_1 and F_2 seedlings.

Table 1. Characteristics of various clonal progenies and populations from natural stands (N) of eastern white pine, Pinus strobus, studied two years at the Buckingham State Forest Tree Nursery in Harmans, Maryland.

Seed Source	Weight 1,000 Seeds	Germination Speed	Seed Coats Freed	Cotyledons	Height one-year	Height two-year real	Height two-year relative to 17.2 cm
	grams	grades	%	no	- - cm - -		%
WISCONSIN							
Progenies of clones selected for resistance to Cronartium ribicola							
OR-12§	19.3	8.4	54	9.1	7.7	14.0	81
OR-44§	21.5	8.0	30	9.3	7.6	14.6	85
OR-48§	19.2	6.8	75	8.6	7.6	13.0	76
OR-66§	22.8	7.5	39	8.7	8.8	17.6	102
OR-78	13.9	9.0	51	9.0	7.6	14.1	82
OR-87§	16.9	5.8	39	9.6	7.3	12.0	70
VERMONT							
Progenies of selected clones, plus comparison clone (C) from native stand							
VT-13	25.4	4.6	66	10.4	8.4	16.4	95
VT-15	27.7	3.6	64	9.7	9.3	17.3	101
VT-20	23.1	4.9	10	9.5	8.3	17.8	103
VT-21C	22.0	6.8	49	9.2	8.1	13.5	78
VT-31	24.8	5.8	4	9.6	9.6	17.4	101
VT-32	21.9	5.0	21	10.0	9.4	16.9	96
VT-41§	19.5	4.1	53	9.4	9.1	17.5	102
VT-61	25.7	4.0	17	9.6	9.2	17.2	100
VT-71	23.6	5.0	46	10.0	9.5	17.4	101
VT-72	25.1	5.3	42	9.5	9.0	17.8	103
VT-91	25.6	4.3	44	10.3	9.6	17.3	101
NEW HAMPSHIRE							
Progenies of selected clones in New Hampshire							
NH-01	26.4	5.8	55	9.5	9.7	18.4	107
NH-02	28.9	5.0	20	10.0	8.8	16.8	98
NH-03	25.7	6.1	53	9.8	9.6	17.7	103
NH-04	23.8	7.0	70	9.9	9.2	17.6	102
NH-05	23.2	5.9	60	9.5	8.6	16.8	98
NH-06	28.6	4.8	27	9.8	9.6	17.9	104
NH-07	24.8	6.9	37	9.3	9.0	17.4	101
NH-08	28.4	5.4	10	9.8	9.4	18.1	105
NEW YORK							
Progenies from selected clones, plus controls (C) from native stands							
NY-10	21.9	5.5	42	9.4	9.1	18.1	105
NY-11§	20.7	4.1	45	9.5	9.0	17.9	104
NY-34C	17.4	3.1	13	8.6	7.4	13.6	79
NY-35C	18.0	3.8	33	8.6	7.5	13.7	80

Table 1. (Continued)

Seed Source	Weight 1,000 Seeds	Germination Speed	Seed Coats Freed	Cotyledons	Height one-year	Height two-year real	Height two-year relative to 17.2 cm
	grams	grades	%	no	- - cm - -		%
MAINE							
Progenies of selected clones in Maine, plus a control (C) from a native stand							
ME-01C	19.1	6.0	48	9.3	8.2	14.8	86
ME-02	28.8	4.5	8	10.2	8.9	15.6	91
ME-10	22.6	5.4	78	9.2	8.3	15.2	88
ME-12	27.5	5.8	31	10.0	9.3	18.0	105
ME-22	25.1	7.3	75	10.0	9.5	19.3	112
ME-23	21.1	6.4	48	9.5	8.7	15.6	91
ME-28	29.5	5.3	28	10.7	9.0	17.8	103
ME-32	20.7	5.5	69	8.8	8.1	15.8	92
ME-33	23.4	4.9	5	9.4	9.2	17.1	99
MARYLAND							
Progenies from clones, most of them selected in research plantations							
MD-02§	29.6	5.6	9	9.5	10.5	19.8	115
MD-03§	25.3	5.0	9	9.1	10.1	19.6	114
MD-08§	31.2	5.9	11	9.8	10.3	18.8	109
MD-11§	24.7	3.9	9	9.2	9.0	17.9	104
MD-13§	28.8	2.0	29	9.5	10.6	18.6	108
MD-16§	18.4	6.5	52	8.8	9.8	18.9	110
MD-17§	22.9	6.5	11	9.2	9.8	20.2	117
MD-19§	24.6	5.1	8	9.6	10.3	19.7	115
SM-02§	34.8	4.5	1	10.2	9.9	10.4	113
SM-03§	32.9	5.0	4	10.4	10.3	21.5	125
SM-07	27.5	4.5	3	10.2	9.8	18.5	108
SM-08§	29.8	4.4	5	9.7	10.0	20.0	116
SM-14§	27.1	3.6	15	9.7	10.0	18.2	106
SM-20§	22.1	6.5	28	9.2	10.0	18.5	108
GP-24§	--	--	--	--	9.5	18.2	106
GP-39	--	--	--	--	9.4	18.6	108
GP-48	--	--	--	--	9.6	18.5	108
GP-96	--	--	--	--	9.4	18.2	106
OHIO							
Population grown from a bulked seed lot (from planted trees)							
OH-01§	18.0	4.6	14	9.0	8.0	15.4	90
CONNECTICUT							
Population from a native stand							
CT-42N	21.5	4.9	14	9.4	--	16.7	97

Table 1. (Continued)

Seed Source	Weight 1,000 Seeds	Germination Speed	Seed Coats Freed	Cotyledons	Height one-year	Height two-year real	Height two-year relative to 17.2 cm
	grams	grades	%	no	- - cm - -		%
PENNSYLVANIA							
Progenies from selected clones in Pennsylvania and elsewhere							
PA-01	26.01	5.5	10	9.3	10.6	21.9	127
PA-02	24.8	6.4	63	9.5	9.7	18.1	105
PA-03	26.0	5.5	26	9.5	9.6	20.4	119
PA-04	25.8	5.4	12	9.7	9.7	17.9	104
PA-05	24.2	5.0	19	10.0	9.6	18.5	108
PA-06	25.4	4.5	12	9.8	9.3	17.9	104
PA-07	30.1	4.4	26	9.8	10.1	21.0	122
PA-08	27.0	5.6	23	9.8	10.1	20.2	117
PA-09	27.2	6.0	28	9.5	10.1	19.5	113
PA-10§	32.8	5.0	38	9.4	11.1	20.0	116
PA-11	28.3	5.5	26	9.8	9.4	18.8	109
PA-12§	21.5	4.8	9	9.4	8.6	17.1	99
PA-13	34.4	4.5	8	9.7	10.5	20.1	117
PA-14	30.8	5.8	70	9.4	9.7	19.3	112
PA-15	26.5	4.4	53	9.0	9.5	17.4	101
PA-16	30.9	6.5	34	9.5	9.8	18.6	108
PA-17	29.7	4.9	21	9.8	10.3	19.3	112
PA-18	25.3	6.4	16	9.4	9.3	19.2	112
PA-19	25.3	6.1	8	9.4	8.9	17.8	103
PA-20	26.4	5.6	41	9.8	10.0	17.4	101
TENNESSEE							
Progeny from bulked orchard seed, plus control (C) from native stand							
TN-01	24.8	2.0	20	9.5	10.4	20.6	120
TN-82C	19.3	3.6	25	9.3	9.2	18.6	108
NORTH CAROLINA							
Populations from native stands							
NC-01N	21.5	4.4	12	9.0	9.6	19.2	112
NC-85N	23.3	3.9	13	9.6	9.3	19.6	114
NC-86N	20.2	4.6	14	9.0	9.1	17.9	104
NC-87N	20.3	3.1	6	9.2	9.9	19.3	112
NC-88N	20.8	4.3	7	9.5	9.5	19.5	113
GEORGIA							
Populations from native stands							
GE-01N	--	--	--	--	8.0	15.8	92
GE-02N	--	--	--	--	7.9	17.3	101

Table 1. (Continued)

Seed Source	Weight 1,000 Seeds	Germination Speed	Seed Coats Freed	Cotyledons	Height one-year	Height two-year real	Height two-year relative to 17.2 cm
	grams	grades	%	no	- - cm - -		%
CANADA							
Populations from selected trees in natural stands of Quebec							
CN-01N	21.0	4.9	51	8.6	8.0	15.6	91
CN-02N	19.5	4.8	14	9.6	8.2	13.8	80
CN-03N	17.8	5.1	23	8.7	8.1	13.9	81
CN-27N	15.6	5.6	38	9.5	7.0	12.1	70
CN-28N	17.0	5.4	78	9.7	6.6	12.5	73
CN-29N	13.5	4.0	43	9.3	6.6	11.1	65
CN-30N	12.1	4.8	8	8.7	6.9	11.0	64
CN-31N	12.8	3.6	18	8.8	7.3	11.6	67
CN-34N	20.6	5.3	40	9.2	8.2	12.9	75
CN-35N	15.2	7.6	90	8.9	7.4	13.3	77
CN-36N	14.4	6.1	43	8.6	7.6	13.7	80
CN-37N	21.1	5.4	64	9.3	8.3	14.6	85
CN-38N	12.6	8.6	80	8.8	7.0	12.4	72
LSD	--	2.5	32.0	.9	1.6	3.3	19
F-value (0.05)	--	4.9	10.0	5.3	12.0	11.5	11.5

§ = Clones selected in plantations of unknown or non-local origin.

Table 2. Correlations among characteristics of progenies of eastern white pine, Pinus strobus, studied in Maryland.

Characteristic	Code	1	2	3	4	5	6
Seed weight	1	1.00	-.05	-.28	.65**	.81**	.76**
Speed of germination	2		1.00	.19	.05	-.07	-.20
Seed-coat release	3			1.00	-.18	-.40**	-.39**
Number of cotyledons	4				1.00	.47**	.44**
One-year height	5					1.00	.92**
Two-year height	6						1.00

**Significant at 0.01 level

Quebec, and from the New York and Wisconsin orchards; those with the highest numbers from orchards in Maine, Vermont and Maryland. Cotyledon numbers were significantly correlated with the seed weight (r = .65), but were not related to either the speed of germination or to seed-coat shedding.

Height Growth

The first-year and second-year heights of families were very strongly correlated (r = .92). In both years, the slowest growing strains were from Quebec and the fastest growing from seed orchards in Tennessee, Maryland and Pennsylvania. Second-year height variations can be seen easily when expressed as a percent of the study mean, 17.2 cm (Table 1).

Populations from the natural stands in Quebec grew at a slow rate, from 64% to 91% of the study mean. Also, five of six progenies of clones from the Wisconsin orchard grew below average in height. These clones, however, were not selected for rapid growth, but for resistance to blister rust.

All progenies from the Vermont orchard grew at an average rate except one VT-21 (or VT W-2-1) which grew slowly, only 78% of average. New Hampshire progenies were quite uniform in average height ranging from 98% to 107% of the study mean. Maine sources exhibited a distinct variation. Progeny ME-10 grew 12% less than average, while progeny ME-22 grew at 12% above average. Out of four populations from New York, the two from the native stands grew slowly; mixed progenies of selected clones grew above average. All families from the Pennsylvania orchard grew taller than average, except PA-12; which originated as a comparison tree from the same plantation in Maryland which includes the famous "BRIGHAM PINE." The families representing three Maryland seed orchards exhibited growth rates similar to those from Pennsylvania, with heights between 4% to 25% taller than the study average.

Among the two Tennessee sources, one from the native stand grew 8% tafler than average, while the seed orchard mixture grew 20% above average. Five North Carolina populations grew better than average by 4% to 14%. However, the two Georgia sources grew less well than the other southern sources; they were only average or below average.

DISCUSSION

The results proved that progenies from clonal orchards grew significantly better than sources from the native or commercial collections used for comparison. For instance, two bulk mixed progenies from New York's clonal seed orchard grew 25% faster than two commercial seedlots representing New York's natural stands; and the progeny from bulked seed of clones growing in a Tennessee orchard grew 12% faster than seed commercially collected in a natural stand, just 50 miles distant. Clonal progenies from the Wisconsin orchard may have grown slowly because they were initially selected for qualities other than fast growth. Of special interest is the "Comparison clone"

(PA-12) in the Pennsylvania orchard, selected in the same Maryland plantation as (PA-10) -- the "BRIGHAM PINE"; this smaller, straight stemmed PA-12 ortet yielded progeny, that were 17% shorter than "BRIGHAM PINE" progeny. Such cases considered together indicate that progenies of selected clones are in general superior to those from non-selected trees and the white pine breeders in the northeast already have a number of clones which should yield 10% of extra growth. With 15 million trees planted annually, if each tree's value when cut were increased by only 10 cents, this could mean a gain of $1,500,00. This gain would be much higher if trees would have 10% more wood, and if selected superior clones would be used for seed production for 10 or 50 years.

This study also indicated that there was a significant variation in growth rates among different families from within clonal seed orchards. Some progenies grew slowly giving reason to believe that they may prove inferior. Among such clones that need special scrutiny are No. 21 in the Vermont orchard, No. 10 in Maine's orchard, and No. 12 in Pennsylvania's orchard. Tests, now outplanted in nine states, should indicate clones that may exceed and those which may fail to match the commercial standards. Substantial improvement may be likely if the sources that appear most promising are utilized. Especially, if PA-01 and PA-07 from Pennsylvania, SM-03 from Maryland, and TN-01 from Tennessee continue to perform 20% above the study mean.

Other characteristics, such as seed weights, germination rates, and speed of releasing seed coats may be largely of academic interest. Perhaps of more practical value is the information that there was a moderate correlation between the cotyledon number and the average height of seedlings (r = .44). This suggests that selection of families yielding seedlings with more numerous cotyledons might provide an early indication of trees of superior growth potential. Also if clones may be characterized as having genetically-controlled heavier seeds than other clones, these may also provide promising progenies and superior growth. Seedlings of sources dropping seed-coats earlier than others may suggest that they come from some northern regions and thus their growth rates may be less than average. The point-by-point practical highlights of the results follow:

1. Two-yean growth rates closely paralleled those measured for the first year.

2. Selected sources grew better than the native (non-selected) controls chosen for comparison from the same state.

- New York seed orchard mixes grew significantly (25%) taller than two commercially collective native seed lots. These Adirondack standards grew 20% less than the test average. Additional state trials maintaining clonal identities are recommended.

- All selected clonal progeny from Maine outgrew the native control source. The best source was 12% taller than the test average and 26% taller than the local control. Several clones, however, need to be carefully evaluated to see if their below average performance

continues in field trials.

° Vermont clonal sources all grew about average except #21 (Vermont W-2-1) which grew 22% below average. This selection was judged phenotypically poor by state personnel after the orchard was established. Rather than immediately rogue this clone, it was agreed that performance of the progeny should serve as the final indicator of clonal value.

The Tennessee seed lots (one from E. Thor's arboretum and the other from a natural stand in Pickett County), grew taller than average. However, the selected seed orchard mix grew 20% above average compared to 8% for the commercial source collected less than 50 miles away.

3. Southern sources were not uniformly better. While Tennessee and North Carolina sources were all above average, the Georgia sources were not so promising. The slowest growing North Carolina source was from Transylvania County (bordering on South Carolina); also, previously reported as a slowly growing source (7).

4. Wisconsin seed from clones selected for resistance to blister rust rather than for rapid growth, did not demonstrate rapid growth.

5. Quebec trees were clearly unable to make use of Maryland's long growing season. They responded by achieving only half of the height of the best growing sources. Even when seeds from selected individuals were supplied, the reduced growth of northern seed sources remained evident.

6. Half of all clones included in Pennsylvania's orchard performed considerably better (12% or more) than average; some were 22% and 27% better. Two of the five "PA" selections from New York contributed little toward improved height performance of Pennsylvania's orchard progeny. Progeny PA-12 from the Brigham (Maryland) plantation grew no better than the test average, and were 17% slower growing than PA-10, the progeny of real "BRIGHAM PINE." We propose that the name "BRIGHAM PINE(S)" be applying only to the superior tree and its progeny.

7. All of Maryland's three seed orchards provided above average performers. However, not all clones were included in this progeny test as not all produced seed. Clonal selections from provenence study plantations continue to provide outstanding progeny (3).

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