SUGAR MAPLE PROVENANCE STUDY: WEST VIRGINIA OUTPLANTING 6-YEAR RESULTS

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ABSTRACT

As part of a range-wide sugar maple (Acer saccharum Marsh.) provenance study, seedlings from 15 provenances each represented by 7 or 8 parent trees, were outplanted on a previously forested site on the Fernow Experimental Forest near Parsons, West Virginia. After 6 years survival is 97 percent. Tree heights vary from 3.5 meters for the Lewis County, New York, provenance to 2.5 meters for the Cass County, Minnesota, provenance. 1973 height growth ranged from 86.2 cm for the Franklin County, Vermont, provenance to 60.1 cm for the Cass County, Minnesota, provenance. Incidence of cold injury was slight as was damage from insects or diseases. Deer browsing, which can be a problem in some parts of the species' range, was light during the first few years but most trees are now out of deer reach.

INTRODUCTION

As part of the Northeastern Station's Range-wide Sugar Maple Provenance Study, an outplanting was established on the Fernow Experimental Forest, near Parsons, West Virginia, in the spring of 1968. The objective of the study is to inquire into the nature and extent of the variation within and between provenances and also to compare juvenile growth with growth of more mature stages. This paper presents some interim results on the performance of the various provenances in West Virginia at the end of six growing seasons. Other outplantings were established in Burlington, Vermont, Houghton, Michigan, Middle Grove, New York, and near Quebec city in Canada.

Sugar maple (Acer saccharum Marsh.) is an important species in the Central Appalachian Region's mixed hardwood stands. For example, as of January 1, 1970[2] the net volume of growing stock of hard maple in West Virginia, which is primarily sugar maple, was 760 million cubic feet of which 1,751 million board feet (Int. 1/4-inch rule) was in sawtimber. It is a very important commercial species ranking in value with black cherry (Prunus serotina Ehrh.) and white ash (Fraxinum americana L.), and usually above red oak (Quercus rubra L.) and yellow-poplar (Liriodendron tulipifera L.)

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2 U.S.D.A. Forest Service. The outlook for timber in the United States, FRR-20, 367 p., 1973.

METHODS

The outplanting is located on a previously forested site on Fork Mountain at an elevation of 2,800 feet. The area has an easterly aspect and the slope varies between 5 and 10 percent. Mean annual temperature is 48° F, and the average length of growing season is 145 days. Average annual precipitation is 58 inches.

Before cutting, the area supported a 60-year-old stand of second growth hardwoods consisting of red oak, yellow-poplar, sugar maple, sweet birch (Betula lenta L.), white ash, and other species. Sawlogs and pulpwood were skidded from the area and all other stems were cut. Tops and other brush were pushed to the lower side of the study area with a minimum of surface disturbance.

Soil on the area is mapped as DeKalb channery loam and is derived from acid sandstone and siltstone. It is well-drained and moderately low in fertility. Red oak site index for the area is 75.[3]

Five contiguous blocks, each 130 by 45 feet, were laid out in the area with the long dimension parallel to the contour. 2-0 seedlings from 14 provenances (Table 1) each represented by 7 or 8 parent trees were planted at a spacing of 5 by 5 feet in 2-tree-row plots. Because of poor germination in the nursery phase of the study, there were no West Virginia seedlings available for outplanting. Two natural seedlings about the same average height and age as the other provenance seedlings were selected adjacent to each block for comparison. Provenances were completely randomized in each block.

Each tree was mulched with a 30-inch square of 4-mil black plastic. A 6-inch diameter cylinder of 1/4-inch mesh hardware cloth, 18 inches high, was placed around the base of each tree as protection against mice and rabbits. During the first 6 years of the outplanting, competing vegetation was controlled by hand mowing each summer.

The first height and stem caliper measurements were taken at the end of the second outplanted season. Height has been remeasured annually. Survival was tallied at the end of the first growing season and each year thereafter.

RESULTS

Survival.--At the end of 6 growing seasons, survival was 97 percent for all blocks and provenances (Table 2). There was no significant difference in survival between blocks or provenances at the 1 percent level.

Survival in blocks IV and V was not quite as good as in the others, which was probably due in part to a much more dense stand of competing vegetation. Most of the mortality, however, occurred during the first 2

3 Schnur, G. Luther. Yield, stand, and volume tables for even-aged upland oak forests, USDA Tech. Bull. #560, 87 pp., 1937.

Table 1.--Description of sugar maple provenance.

Provenance number[a]	County and State	Latitude	Longitude	Elevation (feet)
15	Ingham Co., Michigan	42° 45'	84° 30'	600-1400
17	Berkshire Co., Mass.	42° 30'	73° 15'	1500
18	Sullivan Co., N. H.	43° 27'	72° 23'	400
19	Addison Co., Vt.	43° 55'	72° 50'	900-1000
20	Lewis Co., N. Y.	44° 00'	75° 23'	900
23	Franklin Co., Maine	44° 00'	70° 08'	560
28	Iron Co., Michigan	46° 15'	88° 33'	1550
29	Quebec, Canada	46° 45'	71° 00'	350
31	Cass Co., Minn.	47° 15'	94° 30'	1300
34	Mille Lacs Co., Minn.	46° 03'	93° 40'	1300
35	Franklin Co., Vt.	44° 48'	72° 57'	600
36	Chittenden Co., Vt.	44° 29'	72° 53'	700-800
37	Rutland Co., Vt.	43° 27'	72° 54'	1550-1650
38	Bennington Co., Vt.	42° 57'	73° 10'	900-1100
WV[b]	Tucker Co., W. Va.	39° 04'	79° 40'	2800

[a] Seeds were collected from 7 or 8 trees in each provenance and the identity of the parents was maintained in the outplanting.

[b] Two, 2-year-old natural seedlings adjacent to each block were designated for study because West Virginia source planting stock was not available.

Table 2.--Average survival of sugar maple by block and provenance at the end of six growing seasons.

Provenance No.	Block					For all blocks
	I	II	III	IV	V	
	Percent					
15	93	100	94	100	86	94
17	100	100	100	100	94	99
18	100	88	100	100	100	97
19	100	94	94	100	100	98
20	94	100	100	100	100	99
23	100	100	100	100	93	98
28	100	100	100	100	100	100
29	100	93	100	92	100	97
31	100	100	86	100	93	95
34	100	94	94	92	81	91
35	100	100	100	94	94	98
36	100	100	100	94	100	99
37	100	100	100	83	100	96
38	100	100	100	90	100	98
WV	100	100	100	100	50	90
All	99	98	98	96	95	97

growing seasons and was confined to extremely small seedlings that never recovered even though they were released each year. Some mortality occurred in all provenances except provenance 28 (Iron County, Michigan). Excluding the small sample from West Virginia, the highest mortality (9 percent) occurred in seedlings from provenance 34 in Mille Lacs County, Minnesota. Only a slight incidence of cold injury was observed and it was not correlated with provenance.

Deer browsing which can be a problem in some areas was light to moderate during the first 2 years. No trees were killed by repeated browsing. Gnawing by mice and rabbits was not a problem. The base of each stem was protected by a cylinder of 1/4-inch mesh hardware cloth and this may have minimized this kind of damage. The protective cylinders were removed at the end of the sixth growing season.

Total Height.--At the end of 6 growing seasons total height ranged from 3.5 meters for the Lewis County, New York, provenance to 2.5 meters for the Cass County, Minnesota, provenance (Table 3). The Lewis County, New York, provenance was 14 percent taller than the mean height for all blocks whereas the Cass County, Minnesota, provenance was 20 percent lower. The analysis showed that provenances were significantly different (1 percent level) in total height. Provenances which did not differ significantly in total height by the Newman-Keul's range test are shown in Table 3. With the exception of the Franklin County, Maine, and the Ingham County, Michigan, provenances, all of the provenances that were more than 3.0 meters tall at the end of 6 years were from areas between latitude 42°-30' and 46°-45' and longitude 71°-00' and 75°-30' in the northeastern United States and Canada.

The range in total height between parents within a provenance was quite large (Table 3). However in many cases the ranges are misleading. When an analysis of variance was calculated treating parents within a provenance as separate groups and disregarding block effects, we found that there was no significant difference (5 percent level) in total height within 6 of the provenances (Table 3).

1973 Height Growth.--1973 height growth ranged from 86.2 cm for provenance 35, Franklin County, Vermont, to 60.1 cm for provenance 31, Cass County, Minnesota (Table 4). Height growth for the Franklin County, Vermont, provenance was 10 percent higher than the mean 1973 growth and the Cass County provenance was about 24 percent lower.

1973 height growth for provenances as a percent of the mean 1973 height growth per block was significant at the 1 percent level of confidence. Provenances which did not differ significantly in mean 1973 height growth are shown in Table 4.

Rank correlation analysis has shown that the ranking of provenances according to 1973 height growth is very strongly related (significant above the 1 percent level) with a ranking for total height growth averaged over the 6-year study period.

The best growth made in the West Virginia outplanting is in the provenances that originated in the northeastern part of the range exclusive of Maine. Of the 5 fastest growing provenances, all came from areas with

Table 3.--Average total height, percent of mean block height and total height range, and variation within provenance at the end of 6 growing seasons.

Provenance	Average height[a]	Within provenance range[a]	Height as percent of mean height[b]	Variation within provenances: Signi-ficance[c]	Variation within provenances: $S_{\bar{x}}$
	m.	m.	Pct.		cm.
20 Lewis Co., N. Y.	3.5	1.1 - 5.6	114 a	N.S.	35.0
36 Chittenden Co., Vt.	3.5	0.9 - 5.3	113 ab	N.S.	38.0
17 Berkshire Co., Mass.	3.3	0.7 - 5.2	106 abc	N.S.	41.9
15 Ingham Co., Mich.	3.3	1.6 - 5.1	105 abcd	*	29.2
18 Sullivan Co., N. H.	3.3	1.2 - 4.9	105 abcd	**	30.8
35 Franklin Co., Vt.	3.3	1.0 - 5.1	105 abcd	N.S.	35.5
37 Rutland Co., Vt.	3.2	0.4 - 5.0	104 abcd	**	30.6
19 Addison Co., Vt.	3.1	0.9 - 4.7	101 bcd	N.S.	33.8
38 Bennington Co., Vt.	3.1	0.3 - 4.6	98 cde	*	35.8
29 Quebec, Canada	3.0	0.8 - 5.0	97 cde	**	37.1
28 Iron Co., Mich.	2.9	1.3 - 5.3	95 de	*	39.0
34 Mille Lacs Co., Minn.	2.8	1.0 - 4.3	89 ef	N.S.	31.6
23 Franklin Co., Me.	2.7	0.8 - 4.5	86 f	**	35.6
WV Tucker Co., W. Va.	2.5	1.2 - 3.7	82 f	[d]	--
31 Cass Co., Minn.	2.5	0.7 - 4.3	80 f	*	34.4
Mean height	3.1				

[a] For all parents over all blocks.

[b] For all parents and all blocks using 100 percent as mean height. Provenances with same letter do not differ significantly at the 5 percent level of confidence.

[c] N.S. = non-significant
* = significant 5 percent level
** = significant 1 percent level

[d] No parent information

Table 4.--Average 1973 height growth data and within provenande range and variation.

Provenance	Average 1973 height growth[a]	Within provenance range[a]	Height growth as percent of mean height[b]	Variation within provenance: Significance[c]	Variation within provenance: $S_{\bar{x}}$
	cm.	cm.	Pct.		cm.
35 Franklin Co., Vt.	86.2	37 - 130	110 a	N.S.	7.2
20 Lewis Co., N. Y.	86.1	22 - 110	110 a	N.S.	7.4
36 Chittenden Co., Vt.	85.6	50 - 117	109 ab	N.S.	7.1
18 Sullivan Co., N. H.	82.5	43 - 123	105 ab	**	6.2
19 Addison Co., Vt.	81.8	43 - 121	104 ab	N.S.	7.3
17 Berkshire Co., Mass.	81.7	24 - 121	104 ab	N.S.	9.5
37 Rutland Co., Vt.	81.7	47 - 100	104 ab	N.S.	5.1
15 Ingham Co., Mich.	80.2	50 - 132	102 ab	**	6.1
28 Iron Co., Mich.	77.2	34 - 125	98 bc	**	6.9
38 Bennington Co., Vt.	74.1	30 - 106	94 c	N.S.	7.1
34 Mille Lacs Co., Minn.	73.9	31 - 110	94 cd	N.S.	8.4
29 Quebec, Canada	72.5	14 - 120	92 cd	N.S.	9.1
23 Franklin Co., Me.	70.5	4 - 123	90 cd	N.S.	9.7
WV Tucker Co., W. Va.	67.7	55 - 83	86 d	d	---
31 Cass Co., Minn.	60.1	2 - 120	76 e	N.S.	9.1

[a] For all parents over all blocks.

[b] For all parents and all blocks using 100 percent as mean 1973 height growth. Provenances with same letter do not differ significantly at the 5 percent level of confidence.

[c] N.S. = non-significant
* = significant 5 percent level
** = significant 1 percent level

[d] No parent information.

a latitude between 42°-30' and 45°-00' and longitude between 72°-30' and 75°30'. There was no apparent correlation between growth and provenance elevation.

Using the technique described for total height, 1973 growth within provenance was significant at the 1 percent level of confidence for the Sullivan County, New Hampshire, Ingham County, Michigan, and Iron County, Michigan provenances (Table 3).

DISCUSSION

After six growing seasons, survival among all provenances is very good. Of the small amount of mortality that did occur some may be attributed to poor planting stock, inadequate planting technique, or other factors not related to provenance. A few of the trees died from cold injury and there were scattered instances of leader dieback, but these effects were not significant. Our observations on survival and cold injury suggest that the West Virginia climate at the outplanting site was not an important selection factor.

We observed that seedlings that were quite small, 10 to 20 centimeters high at outplanting time, grew very little and had poor survival even though they were released from competing vegetation each year. The few that had survived are about at their original height and have made very little growth. Since our planting stock originated from open-pollinated flowers, we suspect that the poor performance of these particular seedlings is probably an expression of inbreeding depression associated with selfing.

Deer browsing, fortunately, has not been a serious problem in our plantation. A few of the trees were nipped in the first 2 or 3 years, but now the tops of most trees are out of reach of the deer. Similarly, damage from mice and rabbits has been negligible.

At the end of 6 years the best height growth has been made by provenances from eastern New York, northwestern Massachusetts, Vermont and southwestern New Hampshire. Provenances from farther south and west are not doing as well, and this includes our local source from Tucker County, West Virginia, which in 1973 grew about 14 percent slower than the average growth for all blocks.

Because of the possible carry-over that early environmental factors such as nursery effects, variable-sized planting stock and planting shock may have had on total height growth, we also looked at provenance performance in terms of only the growth that occurred during the last growing season of 1973. This resulted in some shifting of positions when the ranking of provenances according to current years' growth was compared with that for average 6-year height. However, it should be pointed out correlation analysis has shown that these ranks are strongly related. We have also observed some shifting of positions from year to year when comparing annual rankings of provenances for total height growth, which may indicate that it is still too early to make definite judgments regarding provenance superiority.

With reference to the 1973 height growth data, on the average, the range in variation between provenances was about 26 centimeters. Although this difference is statistically significant, its magnitude does not seem to mean much from a silviculturist's point of view. Our analyses have shown that within-provenance 1973 height growth was significant in only 3 of the 14 provenances in the study. This is in contrast to 8 found in analysis of the 6-year total height data and would indicate greater uniformity in the individual performances of provenances as the plantation becomes older.

Briefly summarizing, at the West Virginia location we have found that there was little difference between the sugar maple provenances in survival and cold damage. There are indications that selfs were included in the outplanting material, but these are rapidly dropping out of the plantation. There are significant differences in height growth between certain provenances that may indicate genetic variability, but the range in variation is relatively small. With the exception of the Cass County, Minnesota, provenance, all are doing better than the local West Virginia provenance. Within-provenance differences in last year's height growth compared with that over a 6-year period, indicate an improvement in the uniformity of the within-provenance performances as the plantation matures.

DISCUSSION

Gabriel - Would you care to comment on the results of your experiment and what it would mean in terms of selecting in the nursery beds.

Demeritt - I would guess that the seedling environment in the nursery would be intermediate between the harsh environment of direct-seeding and the optimum environment in the greenhouse. I have a feeling that we probably can get rid of most of the influence of seed weight in the nursery after two years, as long as the seedling density is quite low. I don't think we can be rid of the influence of seed weight in a very dense broadcast seeded nursery bed in the same time period.

Ledig - Just last week at the WFGA meeting, Roy Stonecypher reported the results of some of the Weyerhaeuser tests with Douglas fir. There were 26 families planted out on a couple different sites, quite different, and there was good correlation ranking from one site to the next for height. The genotype-environment interaction was not significant. But when the seedlings were grown in a third test under what were considered optimum conditions, there was absolutely no correlation with results under the field conditions. The progeny which ranked number 1 in the optimum test environment ranked in the bottom in the field test.

Gabriel - Isn't it a genotypic response to the environment?

Ledig - Yes, that's what it is statistically. Fertilizer-genotypic interactions have been reported by Goddard with slash pine in Florida and by Curl in with poplar in Tennessee, and such interactions are nothing new. Optimum conditions in the Weyerhaeuser case meant fertilization and irrigation and the results for progeny ranking were unlike anything you get under normal forest conditions.

Demeritt - I have data from Scotch pine seedlings grown in Styrofoam blocks; I then put half the material in a nursery bed and half in pots. The pots were placed outside adjacent to a greenhouse. Seedlings were almost twice as tall in pots as in the nursery.

Westfall - Just a comment expanding on what Tom said. We got the same thing at Michigan State in the blue spruce provenance tests. The rankings in the greenhouse were totally different than they were out in the nursery.

Demeritt - Was that by family or by provenance?

Westfall - By provenance.

Gerhold - The next question is then which set of data do you use?

Morgenstern - Just one question: Could there be a difference in greenhouse light and outside light?

Demeritt - There was no additional light in the greenhouse, thus the same photoperiod. There would be temperature differences.

Morgenstern - What you are saying is that essentially this must have had something to do with temperature at the place of origin?

Demeritt - Yes, there were three sources within the State of New Hampshire. There would be differences because two of them were from the middle part of the State. One of the northern sources did better than the southern source.

Farmer - Some of our recent work in Northern red oak indicates that seed size is not a major factor if you are growing plants under optimum conditions. You get wide variation in seed size both between and within families in Northern red oak. If you grow them under optimum conditions, this seed size difference works itself out farily quickly. My other comment would be to Fred Valentine. In Populus deltoides we also noticed this early flowering in males relative to females, on the average about a year earlier.

Kung - In your conclusion you mentioned that you recognized differences in seed size, and you said that the variable should be taken out so that the experiment will be more accurate. Now, it's a question of whether one should adjust his observation by the seed weight or seed size. I believe that if there is a family difference, or geographic difference among seed size, then your observations should not be adjusted. But suppose that there are differences of seed size or seed weight from one year to the other year, then you should adjust your data. Because geographic variation or family variation of seed weight or seed size does exist. If a family with larger seed grows faster, there may be some genetic correlation between seed size and growth rate within the same family. In this case, I don't believe that growth rate should be adjusted by seed size.

Demeritt - I think what you are indicating is that we better know the cause of differences in initial seed weight. My feeling is that there are genetic and environmental factors controlling initial seed weight.

Gansel - I think what you are really finding out here is that under intensive care you are getting basically a maximum genetic expression and in the other case you are getting environmental influence on the poplars. Now, what you are really interested in probably in a progeny test is the potential and then you can always modify your silvicultural practices to try to get some of this potential gain, but it is very risky saying that these trees will perform in the field as they do under greenhouse conditions.

Demeritt - I wouldn't want to extrapolate with this two-year data, but reversals and inherent differences within sources do show up at this time.

Gansel - I think your information would be much better if you left it in the field for four or five years--then your ranking would be closer to expected field performance.

Fowler - How common are hermaphrodites in your poplar materials? Are they more common in young materials that are flowering for the first time?

Valentine - I have found at least a half dozen or ten hermaphrodites, but they are basically predominately male or predominantly female. We have done some selfing, but I don't have any figures on frequency in offspring. I am sure that I don't have anything like the frequency that Lester reported - 20-30 percent. I have also checked nearly 300 trees in the Adirondack population and while I haven't sexed all of them yet, I have found two hermaphrodites so far.

Dorn - In your first picture you have drawn areas where you collect your seed and where you're supposed to plant. Do you have any idea of where your optimum growth for this particular species is?

Rauter - Well, I feel that it would be in the center of that climatic region. Although we use a single line there are borders around that line where there is a comparable climatic region below or above the sites which would be in the center.

Dorn - Do you have a standard set-up where it can be moved so far south or so far north?

Rauter - Yes. If we are short on seed for an area, we will sometimes move seed one site region, but we are desperately trying to avoid this. We are attempting to keep within the site region. The one thing that we really have been trying to do with our field people is to identify the stands so that we can keep track of the material from the time it is collected, through the seed plant, and through the nursery so that it can be outplanted as close as possible to the area that it was originally taken from.

Dorn - You probably could improve the program if you select trees only in the optimum growing zone. You may want to bring them south, but you probably would not want to bring them north. I wondered if you had a maximum distance maybe to say bring them north or south.

Rauter - The limits are literally the borders of the site region.

Dorn - But what I was referring to is if your selection was in the very northern part of the site region, you might plant it so many miles north of its origin.

Rauter - When we start outplanting our plus-tree progenies from our controlled pollination program, I would like to have three outplanting sites for each site region and possibly a fourth which could be converted to a seedling seed orchard. On the basis of results from these outplantings we will be able to give some more concrete answers. Kris Morgenstern has done provenance work in spruce, and already has some information available.

Hunt - What do you lose when you move a tree, say a black spruce, from north to south? What would be the main loss if you moved trees in the other direction - south to north? Do you anticipate that inter zonal crossing with the different strains will reduce these losses?

Rauter - Do you mean crossing trees from one site region to another?

Hunt - Yes.

Rauter - We really do not anticipate doing this in our program.

Weeping blue spruce with witches broom in National Arboretum, Washington, D. C.