Second-year versus Ninth-year Height Growth in Sugar Maple Provenance Tests

by

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Is juvenile vigor of a tree of any value as an indicator of the tree's growth potential? The answer to this question would be most useful for any provenance and progeny testing.

It is desirable to view any analysis of early height growth with caution and skepticism, because of the many things that can happen to alter the relative vigor of trees in experimental plantations.' Yet there is ample evidence that the effects of local environmental factors such as photoperiod and duration of frost-free period begin to create pronounced patterns of phenotypic differentiation as soon as the seeds germinate and the seedlings begin to grow. Shoot growth is very sensitive to these environmental influences.

Height measurements taken in our sugar maple (Acer saccharum Marsh.) provenance progenies at the end of the second growing season showed that there was wide variability within sources, and even within mother-tree progenies*. Results showed neither any statistical difference between sources nor any recognizable pattern of geographical variation. Nevertheless, there were noticeable source-related differences in vigor. There was outstanding height growth of some seedlings in the central New York progenies, generally rapid growth with more forking and more slender stems in Tennessee trees, and high total shoot production but much more branchiness among trees from southern Illinois. Trees from Ohio sources were quite vigorous.

The maples are now growing in replicated field tests at Wooster in north central Ohio and at Carpenter in southeastern Ohio. Height measurements taken on every tree in the Wooster plantation at the end of the seventh growing season (1960) indicate highly significant differences between sources. There was also significant site stratification associated with blocks, but no interaction between sources and blocks. Therefore the interaction was not tested in the 1962 analysis, which was based on plot means and which gave results very similar to those of the 1960 analysis (Table 1). A 1962 analysis of the Carpenter plantation, also based on plot means, showed that highly significant differences between sources existed in this field test as well as in the Wooster test (Table 2).

Present provenance relationships are illustrated in Figure 1, which shows heights

*Kriebel, H. B. 1957. Patterns of genetic variation in sugar maple. Ohio Agr. Exp. Sta. Bul. 791, 56 pp.

of the most vigorous 18 sources in each plantation. The differences in rank between adjacent sources are probably not significant, although in both tests the seed source component of variance is highly significant. An exception is the southern Illinois provenance at Carpenter, which shows outstanding vigor. This will be discussed below. With this exception, the comparatively slight gradation of means at both Wooster and Carpenter makes the differences in 2-year and 9-year rankings more apparent than real.

Present mean height in our "seedling-source" test at Wooster is shown in Figure 2 for comparison. These trees were brought from native habitats to Wooster and planted in the spring of 1954 as small trees averaging about 3 feet in height. Ohio trees were replanted and are omitted from the ranking, as are bushy southern trees of the floridanum type. The source localities are different in some cases from those in the seed source tests, but the general pattern is one of high vigor among trees from the Central States, Lake States, and Northeast, and low vigor among trees from the southern Appalachians. Because the trees were all about the same size but not all the same age when planted, some low-vigor specimens were included which may be selfs and may distort the picture slightly. For this reason Figure 2 also includes a ranking of sources by tallest tree.

This "seedling-source" test was not established for comparative growth analysis, and because of varying tree age it does not provide a definitive test of geographical variation in growth rate. Its greater value is for analysis of phenotypic traits not closely correlated with tree age or vigor. However, it does provide useful supplementary data on relative vigor for comparison with results obtained in the seed-source experiment at Wooster.

Correlation analyses were run on data from the 2-year measurements in randomized, replicated nursery plots and on the 9-year measurements at Wooster and Carpenter. Nineteen provenances were included which are common to both outplantings and sufficiently free of mortality for analysis. Figure 3 illustrates the results of analysis of the Carpenter test. The correlation of 0.481 is significant at the 5 percent level, although it would not be considered a close relationship. Mean 9-year height growth is not very impressive, mostly ranging from 2 to 3 feet.

The seed source at the top of Figure 3 is obviously an outlier. This is the southern Illinois provenance previously mentioned. These trees are much more closely related to sugar maples of Georgia, Florida, and Mississippi origin than to sugar maples originating 200 miles to the north in central Illinois. Trees of these extreme southern origins were planted in separate plots, rather than in the main tests, because of early results of the previously-established seedling-source test. The latter included both northern and southern sources, but it soon became evident that the vigorous southern trees would become bushy and eventually be overtopped by the single- stemmed northern trees. These southern trees are not included in this report. They are still far ahead of the rest in height growth at Carpenter, although this is no longer the case at Wooster.

The southern Illinois trees have a greater tendancy toward apical dominance, however, than the Georgia, Florida, and Mississippi trees. Some have fairly good form and it is too early to say that they will be overtaken in height growth by northern types. If their vigor continues, they will be a promising genotype for southern Ohio, because they are very resistant to heat and drought and so far have been entirely winter-hardy.

Nevertheless, the Southern Illinois seed source is an outlier in this analysis, although its ommission from correlation analysis only slightly improves the correlation coefficient. The calculated regression line is shown to indicate the trend. The dashed line includes the outlier, the solid line excludes it.

The relationship of second-year height to ninth-year height at Wooster is shown in Figure 4. The correlation of 0.784 is highly significant, although it would probably be a little lower if all 30 provenances in the Wooster test were included. Those not among the 19 used for correlation analysis are shown with circles rather than solid dots. The calculated regression line is shown to indicate the trend. Mean 1962 heights are nearly all in the range of 6 to 12 feet, in contrast to the 2 to 3 foot range at Carpenter. There is no outlier. In fact, the southern Illinois mean is quite close to the regression line, indicating that trees of some other sources are keeping up with the southern Illinois stock or surpassing it in height.

Considering trees of the 19 provenances common to Wooster and Carpenter, the correlation between the performance of the various genotypes at the two localities is fairly close (Figure 5). Elimination of the outlier increases the correlation and reduces the chances of a nonsignificant relationship from 5 in 100 to 1 in 100, with a slight modification of the regression line.

The nine-year trends in height growth are shown in Figure 6 for trees of four different origins. 1957 was the first growing season in the Wooster plantation, 1958 the first in the Carpenter test following a year in a transplant nursery. The spread between the top and bottom lines of each graph includes nearly all the seed-source means not shown. Southern Illinois trees are no longer taller than local trees at Wooster, as they were prior to 1957, and may continue to lose rank if the present trend continues. At Carpenter, however, there is presently no indication of this falling-off and it is conceivable that there may be a greater adaptability of these southern Illinois trees to the soil and climate of southeastern Ohio than there is for northern Ohio trees. Tennessee trees are presently slightly ahead of northern Ohio trees at Carpenter, but not at Wooster. This could turn out later to be a meaningful effect of outplanting locality, although it is too early to draw any conclusions.

The apparent temporary reduction in height growth at Carpenter between 1956 and 1960 was the result of dieback and some mortality during the first year after planting. Another factor was defoliation by insects, which affected the taller trees more than the shorter ones. The southern plantation is really only beginning to put on height growth, and long-range trends are not yet well defined.

SUMMARY

Thus, although there is a significant correlation between second year and ninth year height, our assumption that the second-year evaluation of vigor would not be very reliable seems to have been correct. The ten best sources in 1954 at Wooster now include five in the upper third, three in the middle third, and two in the lower third. Of the 19 seed sources at Carpenter which can be evaluated, both the tallest and shortest at 2 years are now intermediate and equal in mean height. Any nursery roguing by source on the basis of vigor would have been inadvisable at two years.

At present there is no single outstanding seed source identifiable in the Wooster test. At Carpenter, there is one outstanding source, but it is possible that it may

lose its position in time. In both areas, local seed sources are among the best, although trees from sources as far west as Illinois and as far east as New York and Pennsylvania are also among the most vigorous.

We must not forget that height growth is only one factor in the total appraisal. Other factors may be equally or more important. Tree form, drought resistance, and length of growing season, for example, are very important and can be estimated with considerable accuracy at a very early age. It is not difficult to include height measurements with measurements of these other more highly heritable attributes. We intend to continue these studies of growth trends of sugar maple in relation to provenance and plantation locality. In time we expect to obtain an estimate of the minimum age at which a reliable appraisal of relative growth rate is possible in relation to provenance and possibly also in relation to female parentage.

Table 1.--Analysis of variance of tree height in provenance test L-15 at Wooster, Ohio. Top: fall, 1960. Bottom: fall, 1962.

Year	Component	Some of Squares	df	MS	F
1960	Total	109165.84	405		
	Sources	23264.55	30	775.49	3.184**
	Blocks	10703.60	5	2140.72	8.790**
	Sources x Blocks	36532.69	150	243.55	
	Error[1]	38665.00	220	175.75	
1962	Total	1378.2207	179		
	Sources	359.0166	29	12.3799	2.191**
	Blocks	199.8285	5	39.9657	7.072**
	Error	819.3756	145	5.6509	

[1]Sampling error (tree-to-tree variation). The interaction is used as the experimental error to test variation of sources.

Table 2.--Analysis of variance of tree height in provenance test SE-1 at Carpenter, Ohio. Fall, 1962.

Year	Component	Some of Squares	df	MS	F
1962	Total	1378.2207	113		
	Sources	359.0166	18	2.5460	4.243**
	Blocks	199.8285	5	.9096	
	Error	819.3756	90	.6000	

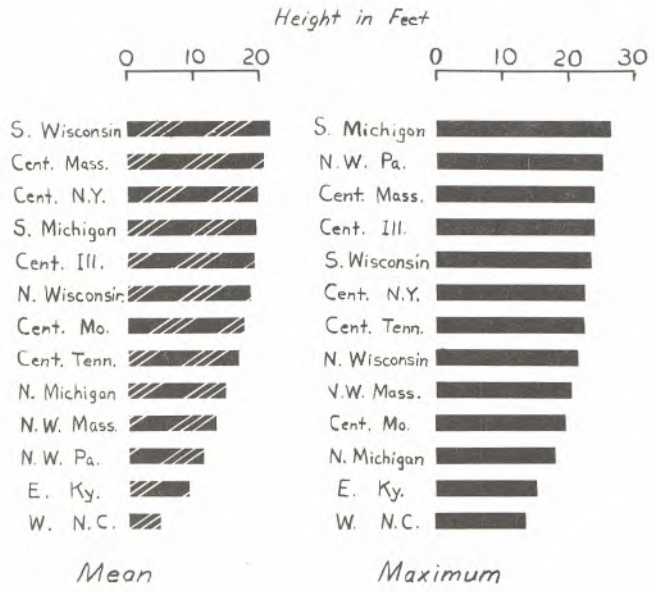

Figure 2.--Ranking of 13 provenances by mean height and by maximum height, in the "seedling-source" plantation.

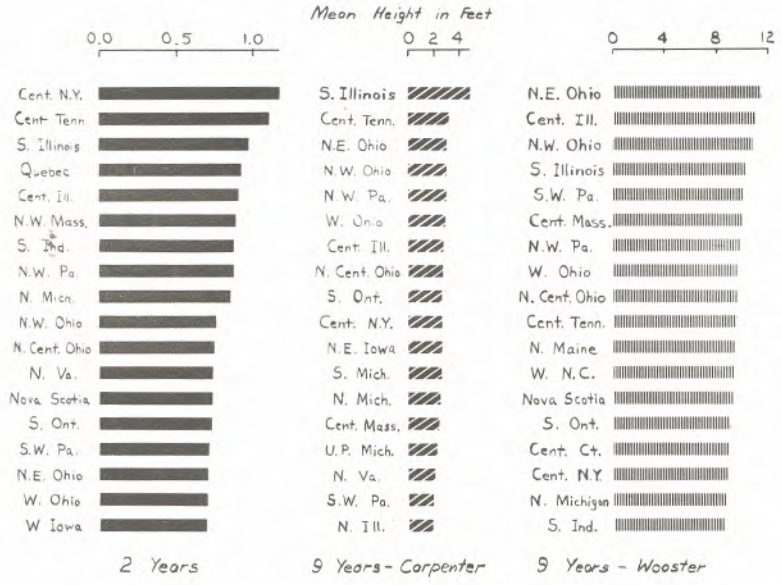

Figure 1.--Ranking of 18 provenances by vigor in the nursery and in two experimental plots.

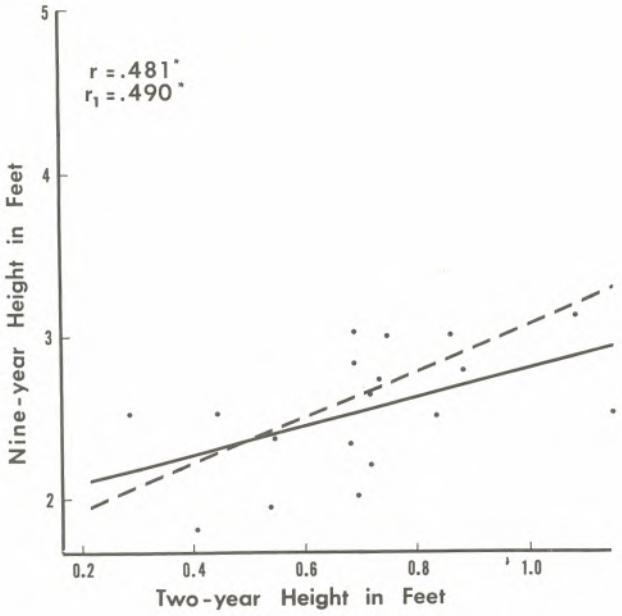

Figure 3.--Relationship between two-year height and nine-year height at Carpenter. Correlation coefficient r is based on all provenances; r_1 excludes outlier. Dashed regression line ($\hat{Y} = 1.64 + .2799X$) includes outlier; solid regression line ($\hat{Y} = 1.94 + 1.693X$) excludes outlier.

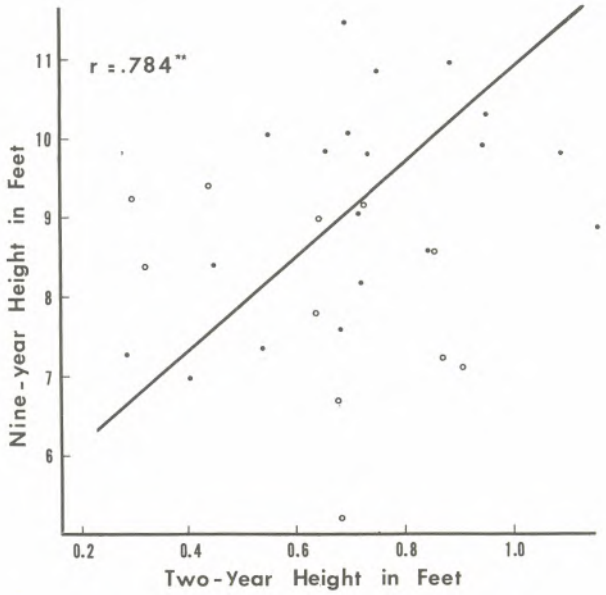

Figure 4.--Relationship between two-year height and nine-year height at Wooster. Regression equation: $\hat{Y} = 4.87 + 1.1899X$. Provenances common to Wooster and Carpenter plantations are indicated by solid dots.

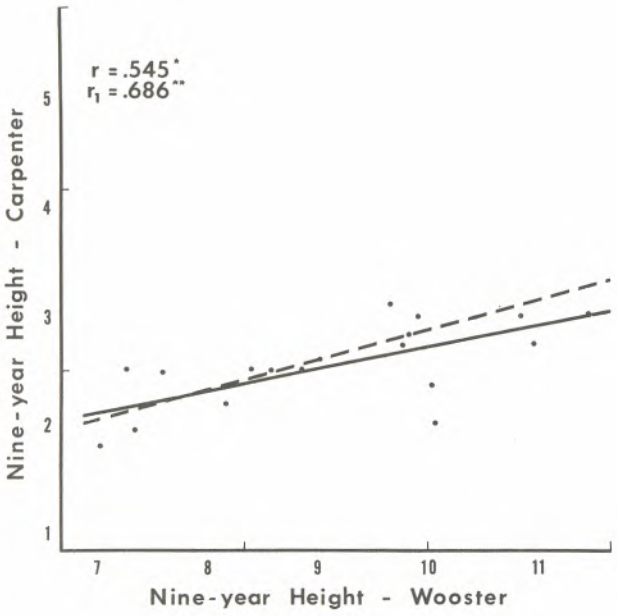

Figure 5.--Relationship between nine-year mean height at Carpenter and nine-year mean height at Wooster. 19 provenances. Correlation coefficient r is based on all provenances; r_1 excludes outlier. Dashed regression line includes outlier; solid regression line excludes outlier.

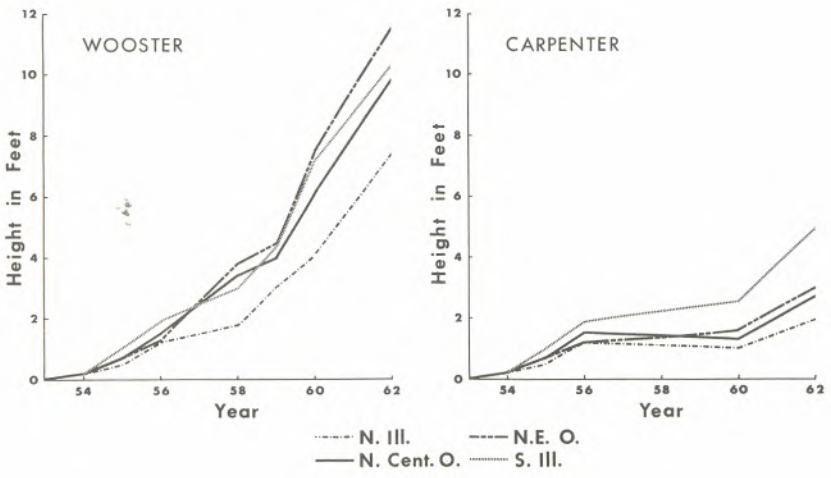

Figure 6.--Nine-year height growth trends of trees of four provenances at Wooster in north-central Ohio and Carpenter in southeastern Ohio.