PHENOTYPIC VARIATION IN HEIGHT, DIAMETER, AND VOLUME
OF EASTERN WHITE PINE TREES IN SOUTHEASTERN NEW HAMPSHIRE—SELECTION POTENTIAL

Harold W. Hocker, Jr.[1]

In a forest tree improvement program there is a need for information which shows the amount of variation occurring in different traits in a natural population of a species. Such information usually is available from breeding studies which are designed to provide measurements of variation. There may be another source of information which, though it may be lacking in its ability to predict genotypic variance, it may, nevertheless, provide an indication of the amount of variation which can be exploited in selection and breeding. Trimble and Seegrist (1970) suggest a method of selecting plus red oak for superior diameter growth rate and length of clear stem. The method is based on the analysis of distribution in natural red oak populations of trees superior in these traits and necessitates a need to set a desired upper percentile limit of the population from which the trees to be bred will be selected.

This paper is concerned with finding a method for identifying potential plus eastern white pine trees, and with determining the selection differential between plus trees and average dominant trees within a stand. The data for analysis were collected as part of a study by Husch and Lyford (1956) of soil-site relationships of eastern white pine in southeastern New Hampshire. To represent stands in the soil-site, study measurements were made of d.b.h., total height, form class (Girard), and age (at breast height) on 10-15 dominant, codominant, and intermediate white pines on 45 sample plots; in addition, all trees on each plot were measured at d.b.h. Later, on 28 additional plots total height, diameter, and age (b h) were measured on at least 10 sample trees per

[1] Assoc. Professor of Forest Resources, University of New Hampshire, Durham, N. H.

plot. Since the measurements of height, diameter, and form class of the site study results were averaged for each plot, differences among trees on the plots for these measurements were lost. To retrieve this information for this paper, the original plot data were consulted and analyzed using only the data for height, diameter, and form class for the dominant trees. The form class data were combined with that of height and diameter to provide estimates of individual tree volume using the formula included in Leak et al. (1970).[2] Form class for the trees on the last 28 plots was estimated from data presented in Barrett (1966). In all there were measurements for 302 trees on 62 sample plots.

Two separate analyses were carried out. The first analysis involved a combined regression analysis for each of height, diameter, and volume.[3] Data for each trait of each of the 302 trees was fitted to a form equation where $y = bo + b1\ (age) + b2\ (age)^2$. The difference between the observed value and the calculated value for each of the three traits was divided by the standard deviation around the mean of each trait (Table 1). The dividend which resulted produced an array of 't' values which were used to arrange the population into a frequency distribution of trees according to the different traits (Table 2).

Using a 99% limit of the population ('t' > + 2.59) it was possible to identify 14 trees which were superior in one of the three traits (bottom line, table 2). When these 14 trees were arranged into table 2, under the Combined Analysis heading, it was evident that there were only 11 trees represented, because four trees were superior in two traits each (10-5, 51-9, 71-1, 71-5).

It was noted that the ages of the plus trees were somewhat older or younger than mean age 43 years from which the standard deviation had been derived and which was used to derive the array of 't' values. It was felt that a second analysis should be carried out in which the trees were stratified by age group. This analysis was conducted. The trees were arranged into five age groups (20, 30, 40, 50, and 60 years). This analysis, it was felt, would overcome any lack in homogeneity in variances which could have affected the results of the first analysis. Again, the results of the analysis provided for an identification of potential plus trees (Table 3, Stratified Analysis, and Table 4). As with the first analysis, the difference between the measurement of each trait for each tree and the computed value for that trait was divided by the standard deviation around the mean (Table 3). Identified from this array of 't' values was a group of only 7 potential plus trees (Table 3, Stratified Analysis). As a result of this second analysis, 4 of the original trees were shown to be superior in at least one of their traits, and two additional trees were identified as potential candidates. Six trees of the original set (Combined Analysis) were not sufficiently larger than other members of their age group to show up as potential plus trees in the second analysis.

[2] Volume, cubic foot = $1.837 + .00002636\ (D^2)\ (Ht)\ (GFC)$.

[3] The regression program used is included in Barrett, J. P. 1971. Elementary Computer Programs for Statistical Analysis, Chapt. 15. Analysis of Linear Model Data. Duxbury Press, Belmont, California.

Table 1.--Means, standard deviations, and coefficients of variation for height, diameter, and volume for combined analysis--Mean age, 43 years.

Item	Height	Diameter	Volume
	Feet	Inches	Cu.ft.
Mean value	59	11.6	21.83
Standard deviation	±7	±2.3	±10.50
Coefficient of variation	12%	20%	48%

Table 2.--Frequency distribution of individual trees according to 't'.

't'[1]	Number of trees		
	Height	Diameter	Volume
≤ -2.59	4	--	--
-2.58-2.35	3	1	1
-2.34-1.97	6	1	3
-1.96-1.65	2	4	7
-1.64-1.29	8	18	11
-1.28-1.05	8	17	6
-1.04-0.85	20	23	12
-0.84-0.68	10	10	11
-0.67-+0.67	176	155	207
+0.68-0.84	19	16	9
+0.85-1.04	7	17	6
+1.05-1.28	11	14	8
+1.29-1.64	15	9	5
+1.65-1.96	4	6	2
+1.97-2.34	5	5	4
+2.35-2.58	1	3	2
≤ +2.59	3	3	8

[1] 't' = $\frac{y-\hat{y}}{s}$ where: $\hat{y}$ = bo + b1 (age) + b2 (age)^2

s = standard deviation

y = individual tree measurement trait.

Table 3.--Age, height, diameter, and volume of plus trees identified in each analysis (* denotes superiority of trait).

Plot & tree number	COMBINED ANALYSIS Age (Years)	Height (Feet)	Diameter (Inches)	Volume (Cu.ft.)	STRATIFIED ANALYSIS Age (Years)	Height (Feet)	Diameter (Inches)	Volume (Cu.ft.)
4-5	63	91	21.0	87.5*				
4-48	65	77	20.2	71.41*				
Av. Plot 4	64	84	20.6	79.46				
10-5	64	69	24.8*	80.14*			24.8*	
Av. Plot 10	63	65	15.0	35.58			15.0	
28-10	58	69	21.0*	59.59			21.0*	
Av. Plot 28	54	66	16.8	41.53			16.8	
39-1	61	84	19.5	76.77*				
39-2	59	82	20.0	71.87*				
Av. Plot 39	62	84	18.7	67.24				
51-9	63	84	23.8*	100.92*				100.92*
Av. Plot 51	61	77	15.9	48.25				48.25
56-1	23	62*	6.4	6.92		62*		
Av. Plot 56	24	56	6.0	6.00		56		
71-1	53	90*	17.1	58.03*				
71-4	55	89*	15.3	46.32				
71-5	62	88	19.0	70.50*				
Av. Plot 71	59	83	16.3	52.40				
58-3					36	72*	13.9	31.17
Av. Plot 58					38	61	10.7	17.15
61-5					48	70	17.7*	48.66*
Av. Plot 61					48	68	13.8	30.15

A major criticism of this technique for identifying plus trees is that it does not account for site quality differences, which can exist among plots on which the trees are located. This difficulty can be remedied by comparing measurements of the different traits of the candidate trees to the means of the measurements of other dominant trees on the same plot. In table 3 the means for each trait for each plot is included below the measurement of the plus tree. It is interesting to note that the difference between plot means and each of the plus tree measurements does not greatly exceed one standard deviation; although in the population, the measurement of each plus tree exceeded the 99% limit of the population for each trait.

It would appear then that dominant white pine trees which exceed trees of the same crown class and the same age growing on the same site, by at least 5-6 feet in height, 2-3 inches in diameter, or 3-20 cubic feet in volume (depending on age) are likely candidates for plus tree selection and breeding where the improvement program is designed to exploit fast growth. This does not mean that trees with a smaller selection differential cannot be selected for breeding, if they exhibit other desired traits; however, the genetic gain in a generation of breeding where fast growth is concerned, would be less than if a larger selection differential were maintained. Of course, the eventual gain per generation will depend upon the degree of genetic control which is exercised over each of the traits--height, diameter, and volume.

Table 4.--Means, standard deviations, and coefficients of variation for height, diameter, and volume at different ages.

	Mean age (Years*)				
	26	33	45	56	64
Height (feet)					
Mean	45	52	58	70	79
Standard deviation	±6	±5	±8	±8	±8
Coefficient of variation	13%	10%	14%	14%	10%
D.b.h. (inches)					
Mean	8.8	10.3	12.1	14.5	16.6
Standard deviation	±3.5	±2.1	±1.9	±2.2	±3.4
Coefficient of variation	40%	20%	16%	15%	20%
Volume (cu.ft.)					
Mean	9.50	14.23	20.85	34.64	66.02
Standard deviation	±3.24	±5.52	±7.48	±11.65	±19.92
Coefficient of variation	34%	39%	30%	34%	30%
Number of plots	12	14	13	12	11

* Mean age for each age group was not at the mid-point of the group range because of a skewed distribution of ages within several groups. Also two plots, one with a 19-year mean age and another with a 71-year mean age, were combined; in the first case with the 20-year age group, and in the second case with the 60-year age group.

LITERATURE CITED

Barrett, J. P. 1966. Shortcut sampling methods for eastern white pine. Jour. Forestry 64(9):603-605.

Husch, B., and W. H. Lyford. 1956. White pine growth and soil relationship in southeastern New Hampshire. N. H. Agric. Exp. Sta. Tech. Bull. 95. 29 pp.

Leak, W. B., P. H. Allen, J. P. Barrett, F. K. Beyer, D. L. Mader, J. C. Mawson, R. K. Wilson. 1970. Yields of eastern white pine in New England related to age, site and stocking. USDA Forest Serv. Res. Paper NE-176. 15 pp.

Trimble, G. P., Jr., and D. W. Seegrist. 1970. Distribution of diameter growth rates and clear stem lengths as a basis for selecting superior phenotypes. USDA Forest Serv. Res. Paper NE-160. 11 pp.

DISCUSSION

SCHREINER - With a tree as valuable as walnut, why isn't it economically feasible to use clones?

BEY - It is possible to graft but not necessarily cheaply. I think the biggest drawback to grafting is the difficulty in making effective selections in natural stands. Effective selection in natural stands depends on the use of comparison trees, and since trees of the same age and on the same site are so difficult to find, I don't believe we can ever count on making much gain with that approach. Also, consider the fact that we do not bore trees for age determination, lest we initiate defect through stain.

SCHREINER - Do you expect to propagate some of your best progeny trees now as clones, or will you depend entirely on seed propagation?

BEY - We are presently emphasizing improvement through seed propagation methods. We have provided clonal material from some of our better phenotypes for use in clonal seed orchards, but for the most part, the clonal material is untested. I really believe that seedling seed orchards with minimum emphasis on superior tree selection in the natural stands is the best approach to follow. The 1971 Northeastern Nurserymen's Conference Proceedings contains a paper describing the procedure for seedling seed orchard establishment.

SCHREINER - At the T.V.A. in the middle 1930's, we found that one of the best--most uniform-- varieties was the Thomas. It was rapid growing and quite uniform in height in the nursery; compared to the Stabler and some of the other varieties, the Thomas was really superior. Do you think that was an indication of selfing in the Thomas?

BEY - I couldn't say for sure. In our nursery we see very uniform growth within families. You can easily see where one family stops and the next one begins.

SCHREINER - For seedling planting stock, I would use a variety like the Thomas, but if I were a grower, I'd also select some of the very best individuals and grow them as clones.

BEY - As a grower, I would first of all be certain that my seed did not come from areas north of the planting site. And, secondly, I would be willing to pay extra for seed collected from the best trees from the best families in a seedling seed orchard-progeny test.

DORN - You indicated the early flushers are also the fastest growers, therefore, we have to compromise between frost injury and early growth rate. That doesn't mean that we don't want to move trees north just because they are subject to frost damage, does it? But it indicates that there is some limitation; did you arrive at any particular limitation?

BEY - We have a lot of data from provenance tests now to show very definitely that, at least in the southern part of the midwest, southern sources grow larger. Perhaps as we go farther north, we should be more concerned about the late frost. At this time, it appears that the gains in selecting for late flushing types are likely to be small. We are working on the problem of how to combine rapid growth and late flushing in the same tree.

VALENTINE - How did you say you estimate your heritability? Was this narrow sense heritability based on maternal half-sibs?

BEY - Yes, maternal half-sibs.

GABRIEL - We had some late frost in Vermont, and our tallest trees were killed; they were from Oklahoma. The pitfall in choosing the tallest trees for clonal stock is very obvious. When you have a severe frost, you may lose all those so-called fast-growing clones.

BEY - We recognized that, and that's why the estimates I reported are based on a population that extends only 150 miles south of the planting site. The estimates should be useful for practical tree improvement programs.

CECH - Cal, you pointed out that the tallest trees were more frost susceptible. Are they the tallest in spite of the frost?

BEY - Our results are simply on the basis of the date of flushing. I don't know that given the same stage of development whether the early flushers are more susceptible than the late flushers. We are talking about frost avoidance.

CECH - If they go through a frost and are still the tallest trees, what difference does it make if there is a little crook at a point two or three feet above the ground?

BEY - If a tree can get frosted back and still outgrow one that has not been frosted while still maintaining comparable quality, we probably shouldn't worry about the frost.

GERHOLD - I'd like to return to Ernie's question, at the risk of belaboring a point. I think his question was directed at whether clonal propagation was a suitable means of mass production of an improved variety. The reasons that you gave for not using clonal propagation related to selection and seed orchard stock, I believe, but not to mass production.

BEY - You are correct, Henry. When I answered the question of using clonal stock, I was thinking primarily about seed orchard establishment rather than mass propagation. Nut growers and hobbyists do a lot of grafting with walnut. Although some nurserymen claim 80 percent success in grafting walnut, other people have a lot of difficulty.

SCHREINER - That isn't too high for bench grafting. At the T.V.A. we had an experienced pecan grafter who used two CCC boys to select, i.e., match, stocks and scions, and he made the grafts; he got as high as 90 percent. But, where are you going to find these experienced nut-tree grafters today?

BEY - I don't know. We have done some grafting in the greenhouse and don't get 90%. We haven't worked as long and hard as the old-timers, but very few people will admit to ever having "bad years" for grafting. I doubt if the "bad year" reports get published as often as the successful endeavors.

SCHREINER - You did, in part, answer that question on mass selection when you said that you can't identify a superior genotype. If you can't do that, then you are using clonal propagation "by guess and by gosh."

BEY - I'm not completely against individual tree selection in the natural population as the first step. But, from a practical tree improvement standpoint, I don't believe in rigorous selection standards. Gain from selection in natural populations depends on the ability to make valid comparisons--and this is many times impossible with walnut. We avoid the obviously diseased or unhealthy tree. Most gains in walnut will likely come from roguing out entire families and individual trees within families in progeny test-seedling seed orchards, and not from our ability to select in natural stands.

ANONYMOUS - Was growth possibly related to seed size?

BEY - No, in this case it wasn't. Most of the time in our nursery work we have found that seed size and growth are definitely correlated. In our progeny test this year, the family with the tallest seedlings came from the smallest seed; and there was absolutely no correlation between growth and seed size. The genetic component just overrode the seed size effect in the first year.

GERHOLD - You referred to considerable uniformity within families. Do you have an explanation for that? Was this only in respect to flushing date, or also in other characteristics?

BEY - It is true for most characteristics. Walnut is basically an outcrossing species; male and female flowers are on the same tree, but they mature at different times.

FOWLER - You probably had very few trees actually involved in the crossings.

BEY - In some cases this may explain the limited within-f amily variation. It is possible that a family could be full-sibs. However, many of the parent trees in this test had many other walnut trees in the immediate area.

FOWLER - Isn't there also quite a bit of variation in flowering time between individual trees, so you may have five trees around but only two trees that are really synchronized in respect to flowering?

BEY - That's right. Although the stigma is receptive for several days, it is possible that when the first pollen mass drifts in, it gets the entire tree fertilized.

GERHOLD - In other words, a single tree may have been the predominant male parent for many of the families.

BEY - That is possible. We really don't have a good estimate on how often it occurs.

GERHOLD - But it might have given you a considerable overestimate on your heritability.

HUNT - There is a wealth of important information coming out of Carbondale. The technique of planting stratified nuts is a real breakthrough. If you delay planting your progeny test/seed orchard until most variables can be made more comparative (site preparation, soil fertility, even the development stage of the nuts) you should achieve more reliable results. For example; by planting only nuts that exhibit definite signs of germination, you can markedly improve the survival percentage and still avoid the effects of various nursery techniques, different nursery soils, and the shock of transplanting. To my knowledge, this is the first seed orchard so established, and Cal Bey deserves much of the credit for its initial success.