# DEVELOPMENT AND USE OF JUVENILE - MATURE CORRELATIONS IN A BLACK WALNUT TREE IMPROVEMENT PROGRAM

Fan H. Kung[1/]

Abstract. -- Cross section discs were cut at predetermined intervals from 19 black walnut trees. Growth rings on each disc were measured. Diameter, height and volume at various ages were determined by stem analysis. Character used for early selection should have the high juvenile - mature correlations. The earliest age for selection should maximize the product of the juvenile mature correlation and the selection differential at that age.

## INTRODUCTION

Agricultural geneticists can evaluate progeny performance and make their selection decision at the end of an organism's life cycle or at its maturity, because the materials they work with have a relatively short life span. On the other hand, the forest geneticist faces a dilemma; either he makes an early selection with unknown certainty, or makes a late selection further compounding the interest rate on his initial investment. However, if a juvenile - mature correlation is found, reliable selection in a test plantation can be made at an early age.

Most of the juvenile - mature correlations in forest trees were derived from observations throughout the testing period (Callaham and Duffield 1962, Steinhoff 1970, Squillace and Gansel 1972, La farge 1972). In this study, instead of waiting 30 years for black walnut trees to reach maturity, stem analysis was used to study the past growth history of the trees. Data retrieved from the stem analysis then were used to compute the juvenile - mature correlation.

## METHOD

Nineteen black walnut trees in a native mixed hardwood forest in southern Illinois were sampled. Trees were cut at 6 inches and cross section discs of 1-inch thickness were cut at intervals of 1 , 2, 3, 4, 5, and 6 feet above the stump and every two feet thereafter. The top surface of each disc was sanded to facilitate viewing.

Diameter of each annual ring (the sum of the longest and the shortest radius) was measured to 1/20 of an inch. Smalian's formula was used to compute the cubic-foot volume at each age.

---

[1/] Assistant Professor, Department of Forestry. Southern Illinois University. Carbondale, Illinois 62901.

## RESULTS AND DISCUSSION

### Age-Age Correlations

The age-age correlations calculated from individual tree volumes at various ages are presented in Figure 1. The closer the two ages, the higher is the correlation. As a rule of thumb, when the juvenile age is half of the mature age, the correlation for volume is about .9, and when the juvenile age is near one-third of the matural age, the correlation is about 7.

The age-age correlations calculated from diameter inside back at 4.5 feet above ground, and calculated from total height were not significantly different from those calculated from volume, probably due to the limited sample size.

### Which type of early measurement should be used for mature - volume selection?

The early trait used in indirect selection for mature volume should have a high correlation and should be measured easily and precisely. Accurate height and diameter measurements are easier to obtain than volume measurement and are therefore to be preferred. From age 1 through 3, total height of the seedling should be used for selecting volume, because their correlation coefficients are highest among other early traits (Table 1). From age 4 through 11, diameter inside bark at 3.5 feet above ground could be used. However, others may want to use diameter inside bark at 4.5 feet or simply dbh because of the ease of measurement. From age 12 and throughout the later years volume has the highest correlation coefficients, therefore volume should be given priority over height or diameter measurements.

Table 1. -- Correlation coefficients between various early measurements and cubic foot volume at age 30

| Juvenile Years | Vol. | Ht. | Diameter inside bark at | | | |
|---|---|---|---|---|---|---|
| | | | 1.5' | 2.5' | 3.5' | 4.5' |
| | Correlation Coef. | | | | | |
| 1 | .03 | $\boxed{.47}$ | .15 | .03 | .22 | - |
| 2 | .26 | $\boxed{.60}$ | .40 | .36 | .39 | .32 |
| 3 | .30 | $\boxed{.67}$ | .49 | .52 | .46 | .33 |
| 4 | .39 | .61 | .56 | .63 | $\boxed{.65}$ | .52 |
| 5 | .46 | .66 | .63 | .67 | $\boxed{.70}$ | .64 |
| 6 | .48 | .62 | .67 | .71 | $\boxed{.72}$ | .68 |
| 7 | .52 | .66 | .66 | .71 | $\boxed{.72}$ | .69 |
| 8 | .57 | .64 | .67 | .71 | $\boxed{.72}$ | .70 |
| 9 | .62 | .63 | .68 | .71 | $\boxed{.71}$ | .70 |
| 10 | .66 | .66 | .67 | .71 | $\boxed{.71}$ | .70 |
| 11 | .70 | .67 | .67 | .71 | $\boxed{.71}$ | .70 |
| 12 | $\boxed{.74}$ | .68 | .67 | .71 | .72 | .72 |
| 13 | $\boxed{.79}$ | .68 | .68 | .72 | .72 | .73 |
| 14 | $\boxed{.82}$ | .68 | .67 | .72 | .72 | .73 |
| 15 | $\boxed{.85}$ | .68 | .68 | .72 | .72 | .74 |

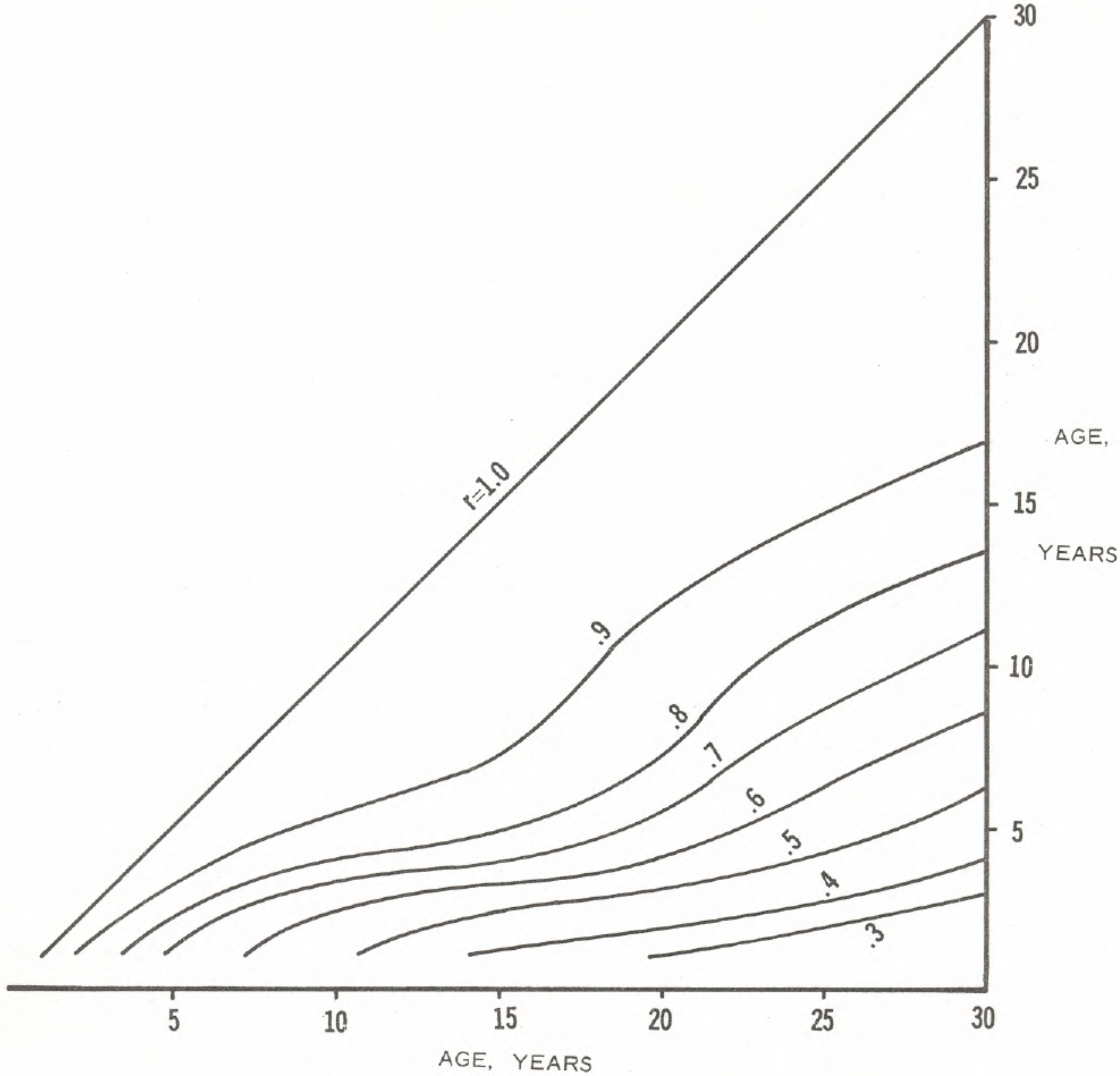


Fig. 1. INDIVIDUAL AGE–AGE CORRELATIONS ON CUBIC FEET VOLUME.

How high a juvenile - mature correlation is high enough for early mass selection?

The correlation between height at early ages and volume at age 30 reaches a plateau at age 3 (Table 1). Therefore, if one chooses height of the saplings as his only criterion for volume selection, he would not obtain any gain by waiting. On the other hand, if the correlation increased throughout the early ages as in the case of volume correlation, how high is high enough?

In an established test plantation, the spacing between trees was fixed. Once the final number of seed trees is determined, the selection differential will be the same at various ages. Therefore, the highest correlation will give the maximum selection gain. On the other hand, if the test plantation is yet to be established, the designer still has the freedom to choose the spacing. Then both correlation and selection differential at various ages must be considered simutaneously. The philosophy here is that if we want to select trees at age X, we should plant the trees at the optimal spacing for trees at age X. Let us assume that the spacing and number of trees per acre in Table 2 are optimal values for black walnut trees, and further that 50 seed trees or selections per acre are desired. One can calculate the percentage of trees saved (column 5= column 4/column 3), and then find out the selection differential between the selected group and the original population in units of standard deviation. Values in column 6 were taken from table of accurate values for selection intensities by Namkoong and Snyder (1969) • It can be easily seen that selection differentials are higher for the earlier ages.

Table 2. -- Gain of volume selection at early ages over age 20

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|
| Age | Spacing | Total trees per acre | Trees to be selected | % of trees to be selected | Selection differential | J-M corr. coef. | Exp'd diff. | Gain |
| yr. | sq. ft. | Number | Number | % | st. dev. | | st. dev. | st. dev. |
| 1 | 2x2 | 10890 | 50 | .46 | 2.92 | .29 | .85 | -.01 |
| 2 | 3x3 | 4840 | 50 | 1.03 | 2.65 | .41 | 1.09 | .23 |
| 3 | 4x4 | 2722 | 50 | 1.84 | 2.45 | .49 | 1.20 | .34 |
| 4 | 5x5 | 1742 | 50 | 2.87 | 2.28 | .61 | 1.39 | .53 |
| 5 | 6x6 | 1210 | 50 | 4.13 | 2.14 | .69 | 1.48 | .62 |
| 6 | 7x7 | 889 | 50 | 5.62 | 2.01 | .74 | 1.49 | .63 |
| 7 | 8x8 | 681 | 50 | 7.34 | 1.90 | .78 | 1.48 | .62 |
| 8 | 9x9 | 538 | 50 | 9.29 | 1.79 | .81 | 1.44 | .58 |
| 9 | 10x10 | 436 | 50 | 11.47 | 1.69 | .84 | 1.42 | .56 |
| 10 | 11x11 | 360 | 50 | 13.88 | 1.59 | .86 | 1.37 | .51 |
| 20 | 20x20 | 109 | 50 | 45.87 | .86 | 1.00 | .86 | .00 |

The expected selection differential at the mature age can be estimated by the product of the selection differential at the early age and the juvenile mature correlation coefficient. For example, the expected selection differentials for age 20 (colume 8) are obtained by multiplying the selection differentials (column 6) by the correlations (column 7). The gains of early selection over late selection (column 9) are obtained by subrracting the expected selection differential at age 20 (= .86) from the expected selection differentials at various juvenile ages (column 8). The result shows that early volume selections are favored, except in age 1 when the juvenile - mature correlation is low.

For mass selection of black walnut tree by early volume, 6 years seems to be a desirable testing period. However, if column 7 of table 2 is substituted by values in table 1, one can compute the gain of various indirect selections (by juvenile trait) over direct selection (by volume at age 30). It was found that total height at age 3 offered the highest gain among all age - trait combinations. Here again, the product of the juvenile - mature correlation and the selection differential at the juvenile age determines the best criterion and the best age for selection.

It may be desirable to leave more than 50 trees per acre at age 3 because of possible subsequent mortality. A multiple stage selection then can be applied. If one has predetermined to thin a seed orchard at ages 3, 8, and 15, he should plant the trees at 4' x 4' spacing in the beginning. At age 3, the plantation should be thinned to 538 tallest tree per acre. At age 8, the plantation should be thinned to 170 trees per acre, using d.i.b. at 3.5 ft. for selection standard. At the final stage, when the trees are 15 years old, they are selected by volume.

Of course during the multiple-stage-selection one can manipulate the ages for selection as well as the traits for selections to maximize the total selection gain. The total selection gain is defined as the sum of products of the selection differential from one stage to the next and the correlation coefficient from one stage to the next stage.

## Practicality of the proposed procedure

Because the correlations were derived from single trees, the proposed procedure could be used with phenotypic selection of individuals in a seed orchard. Since the trees in this study were sampled from a wild stand, the juvenile - mature correlation estimate may be conservative when it is applied to a test plantation.

The use of stem analysis to retireve past growth history and to construct age-age correlation may be worthwhile for planning a provenance test-seed orchard. For example, 20 trees each from 20 provenances are cut and measured. Data from 400 trees can be used to compute individual juvenile-mature correlations. Selection in the seed orchard is based on individual tree performance. On the other hand data from 20 trees within provenance can be used to compute individual within provenance juvenile-mature correlation. This information may be useful for selecting individual sapling within the provenance. Finally, the provenance means are computed from 20 trees. Those 20 provenance means are used to calculate provenance juvenile-mature correlation. Then in the plantation, the mean values of juvenile performance of each provenance are considered for provenance selection.

Mature trees with known family origin are seldom available. Therefore, the stem analysis may not be practical in finding age-age correlation of family means. In this case, one can not help it but wait for the data to come in.

After he has collected the mean values of the family performance in juvenile stage as well as at the end of the rotation, then he can compute the family juvenile - mature correlation.

The family juvenile - mature correlation obtained through record keeping during the first generation test period would be a valuable asset in planning a family selection in the second generation short term progeny testing or progeny testing-seed orchard scheme. For a short term progeny test in which the test plantation is disposed of at the end of the testing period, the juvenile - mature correlation should be at the peak or high enough for the return of the investment. For the progeny testing-seed orchard, the correlation and the selection differential at each age should be considered jointly.

The simultaneous consideration of the juvenile - mature correlation and the selection differential offers maximum selection gain as well as the maximum genetic gain per unit of area, for the mature trait. If one is interested in maximum gain per unit of area per dollar spent on planting and thinning, he can divide the gain at each age by the cost, then find the criteria that would maximize the quotient. Usually the selection age would be delayed for a few years so that fewer trees need to be planted and thinned. Further, if one is interested in maximum genetic gain per unit of area per dollar per year, he should divide the above quotients by the juvenile age and find out the maximum return.

In the practical tree breeding program, one must consider the flowering age as well as the selection age. The breeding should be done at the later one. In black walnut, trees may be selected at age 3 by total height; but breeding can be done only when trees have reached sexual maturity (age 13). On the other hand, some pines may have flower at age one (Mergen and Cutting, 1957) but the actual breeding work should be carried out at the age with the maximum gain.

## LITERATURE CITED


Callaham, R. T. and J. W. Duffield. 1962. Heights of selected ponderosa pine seedlings during 20 years. Forest Genetics Workshop Proc. 1962 pp. 10-13. (So. Forest Tree Improvement Com. Pub. 22 Macon GA.)

Johnson, H. 1964. Forest tree breeding by selection. Silvae Genetica. 13: 41-49.

La Farge, T. 1972. Relationship among 3rd., 5th., and 15th. year measurements in a loblolly pine stand variation study in Georgia. Paper presented at the IUFRO Meeting of Working Party on Progeny Testing. Oct. 25-27, 1972 at Macon, GA.

Mergen, F. and S. G. Cutting. 1957. Male flowers on one-year-old mugo pine seedling. Forest Science 3: 355-356.

Namkoong, G. and E. B. Snyder. 1969. Accurate values for selection intensities. Silvae Genetica 18: 172-173.

Squillace A. E. and C. R. Gansel. 1972. Juvenile - mature tree correlations in slash pine. Paper presented at the IUFRO Meeting of Working Party on Progeny Testing, Oct. 25-27, 1972 at Macon, GA.

Steinhoff, R. J. 1970. Northern Idaho ponderosa pine and racial variation study -- 50-year results. USDA Forest Service Research Note INT--118 4 pp.