NATURAL VARIATION IN SEED CHARACTERISTICS AND SEED YIELD OF BLACK WALNUT IN THE TENNESSEE VALLEY

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Estimates of seed orchard yields are needed early in breeding programs so that orchard areas adequate to meet expected demands for seed may be established. This is especially true for large-seeded hardwoods that begin bearing large crops late in life. Thus data on seed yield and seed characteristics of black walnut (*Juglans nigra* L.) are needed in current breeding efforts.

In the 1940's, the Tennessee Valley Authority conducted a project to develop black walnut trees having high quality seed in terms of kernel production. Seed yield data from typical open-grown trees throughout the Tennessee Valley were collected annually from 1940 through 1947. Six-year data, with emphasis on kernel characteristics, were published by Zarger (1946). Additional data are presented here with emphasis on their use in breeding programs aimed at improving timber quality.

METHODS

Seed yield and quality data for eight consecutive years from 115 open-grown trees were analyzed. These trees were located from western North Carolina and Virginia to west Tennessee; eastern and western portions of the Tennessee Valley were equally represented in the sample. DBH of the trees ranged from 6 to 26 inches at the end of the sample period, at which time they were from 14 to 71 years old.

Each year all fruit was collected from each bearing tree and weighed in the field. When yield per tree was less than 100 pounds of unhusked seed, the entire crop was husked and the cleaned seed was weighed after air-drying for one month. Larger crops were sampled to obtain estimates of total yield of air dried seed. Individual seed weight, percent filled seed, and kernel weight were estimated from a random sample of 20 seed per crop per tree.

In addition to DBH, which was recorded annually for all trees, crown radius, age, and height were measured on 94 trees in 1947.

A linear multiple regression analysis of mean annual seed yield on 1947 DBH, age, height, and crown radius showed that yield was positively related to tree size. An analysis of covariance with DBH as the independent variable

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was therefore computed to evaluate tree-to-tree variation in yield. The dependent variable was mean yield of individual trees for two four-year periods, 1940-43 and 1944-47. Use of four-year averages as units of analysis was necessary to reduce variance related to alternate bearing. A hierarchical sampling design with two physiographic regions (eastern and western portions of the Tennessee Valley), five areas per region, and six trees randomly selected per area was used to evaluate geographical effects.

Tree-to-tree variation in seed characteristics was evaluated using data from four randomly-selected crops per tree. For filled seed weight and percent filled seed (arcsin transformations), an analysis of covariance was computed with yield as the independent variable. Simple analyses of variance were computed for kernel weight and arcsin transformations of kernel weight as a percent of filled seed weight. Simple correlation coefficients were calculated for relationships among several tree and seed characteristics.

RESULTS

Tree-to-tree variation in mean annual seed production is illustrated in Figure 1 for two DBH classes: 10-15 inches (55 trees) and 15+ inches (37 trees). Twenty-three trees under 10 inches DBH each produced (with one exception) less than 20 pounds (about 500 seed) per year.

While mean annual seed yield data give an accurate picture of long-term production, they give poor estimates for a tree in any given year because of walnut's inconsistent bearing pattern. Forty percent of the trees exhibited distinct alternate year bearing and seven percent consistently produced seed two out of three or one out of three years. The remaining 53 percent of the trees had no pattern. Alternate bearing trees were found in all geographical areas.

The multiple regression of average seed yield (pounds per tree) over tree-size parameters produced the following equation: yield = -50.685 + 4.763298 crown radius + 0.656074 DBH + 0.032171 height - 0.387097 age. Forty-two percent of the variation in yield was accounted for by the four independent variables; crown radius and DBH were most important in accounting for variation in seed yield. Coefficients for simple correlations between yield and tree size parameters are given below:

	Yield
DBH	.52
Age	.17
Crown Radius	.63
Height	.37

Table 1

Analyses of Variance in Black Walnut Seed Yield

and Seed Characteristics

Source of Variation	Crop Weight df	Crop Weight Percent of Total Variance	Percent Filled Seed df	Percent Filled Seed Percent of Total Variance	Filled Seed Weight df	Filled Seed Weight Percent of Total Variance
Trees	114	59	92	50	92	60
Samples/Trees	114	41	278	50	278	40

Source of Variation	Kernel Weight df	Kernel Weight Percent of Total Variance	Percent Kernel Weight df	Percent Kernel Weight Percent of Total Variance
Trees	36	76	36	69
Samples/Trees	111	24	111	31

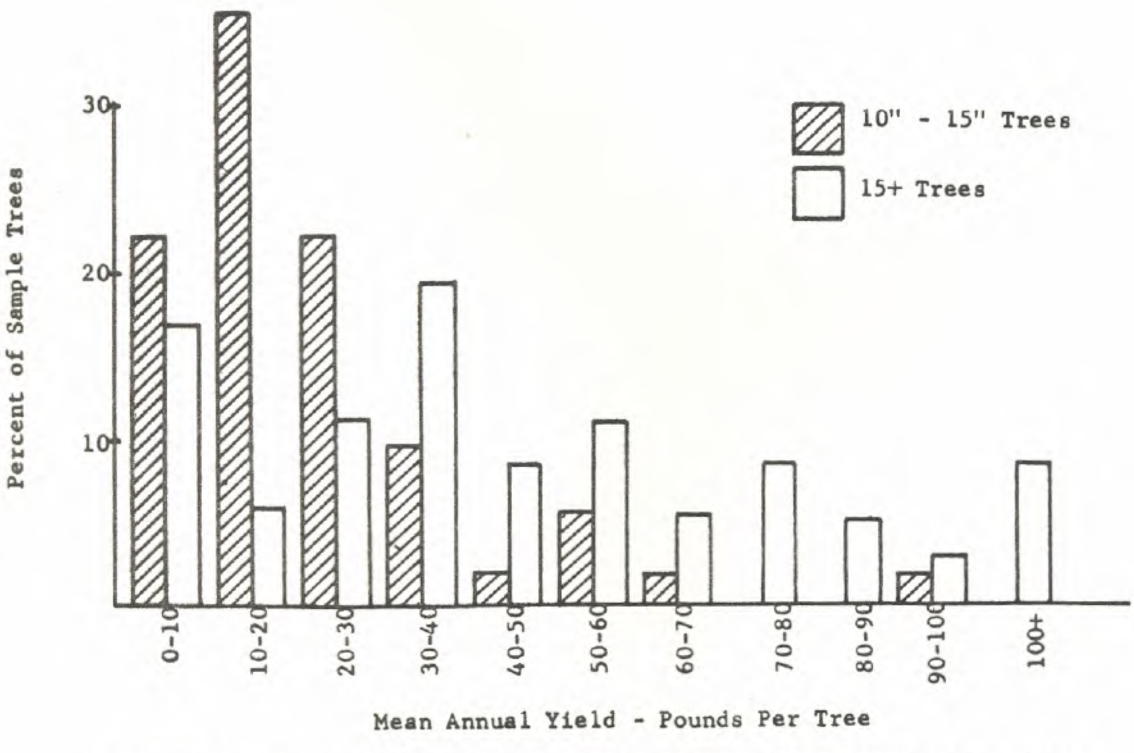


Figure 1. Natural variation in yield of air-dried black walnut seed in the Tennessee Valley.

Evaluation of yield variation by physiographic regions, areas within regions, and trees within areas indicated that regions and areas were not significant sources of variance. After adjustment for tree size, differences among trees within areas accounted for 65 percent of the yield variance. Since tree-to-tree differences were the only significant source of variance in the hierarchical analysis, a covariance analysis was used to evaluate individual tree variation in the entire sample (Table 1). In this analysis, 59 percent of the crop weight variance was associated with trees.

Filled-seed percent for individual trees varied from seven to 100 (Figure 2) and was not strongly correlated with yield (r= .17). The distribution was skewed to the right with 31 percent of the trees having over 90 percent filled seed. Fifty percent of the variance was associated with individual tree differences (Table 1).

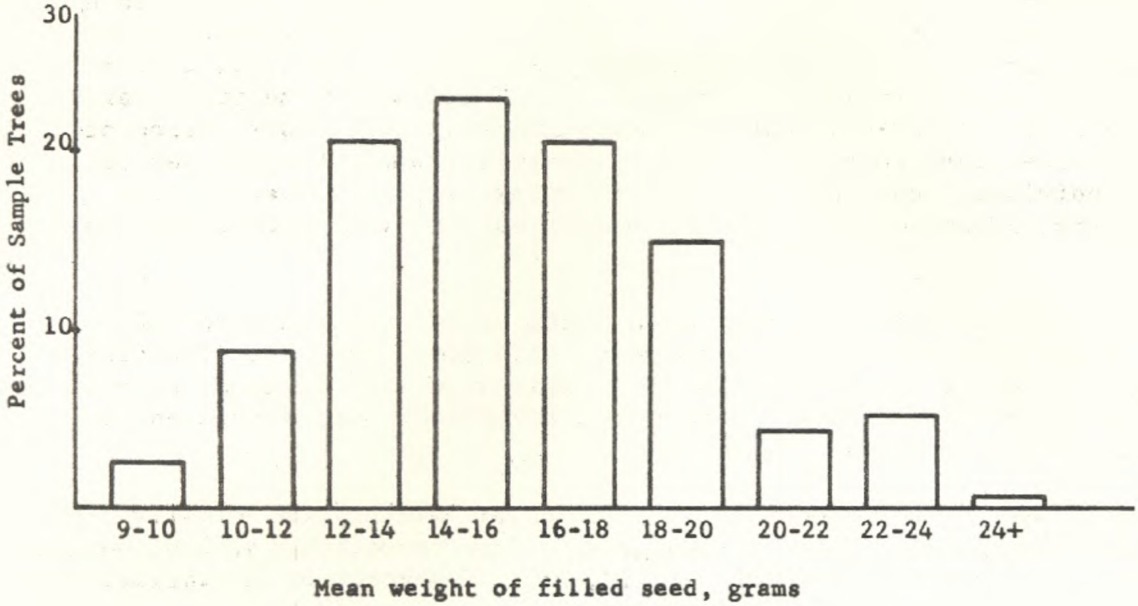
Average weight of filled seed (Figure 2) was distributed normally from 9.0 to 24.2 grams with a mean of 16.5 grams. The correlation of crop weight with seed weight had a coefficient of .17, and 60 percent of the variation in seed weight was due to differences among trees.

Mean kernel weight of individual trees (Figure 3), which ranged from 1.7 to 6.4 grams, was strongly correlated with filled seed weight (r = .84) and moderately with kernel weight expressed as a percent of seed weight (r = .62). Distribution of kernel weight was skewed slightly to the left but the distribution of kernel weight as percent of seed weight was approximately normal. Individual tree differences accounted for 76 percent of the variation in kernel weight and 69 percent of the variation in kernel percent (Table 1).

CONCLUSIONS

This study indicates that seed yields and seed characteristics of individual black walnut trees vary widely in the Tennessee Valley and that much of this variation is attributable to individual tree differences unrelated to tree size or geographic location. This variation pattern, which is also evident in oaks (Downs and McQuilkin, 1944; Christisen, 1955; Ried and Goodrum, 1957), suggests that seed yield may be under fairly strong genetic control and thus subject to effective field selection.

Some direct evidence for effective field selection for seed size was found by Urger (1945) who tested (as grafted clones) 90 trees located throughout the walnut range and selected for high kernel weight and/or percent. Means for this group of 90 clones shown in relation to random sample means of the present study are as follows:



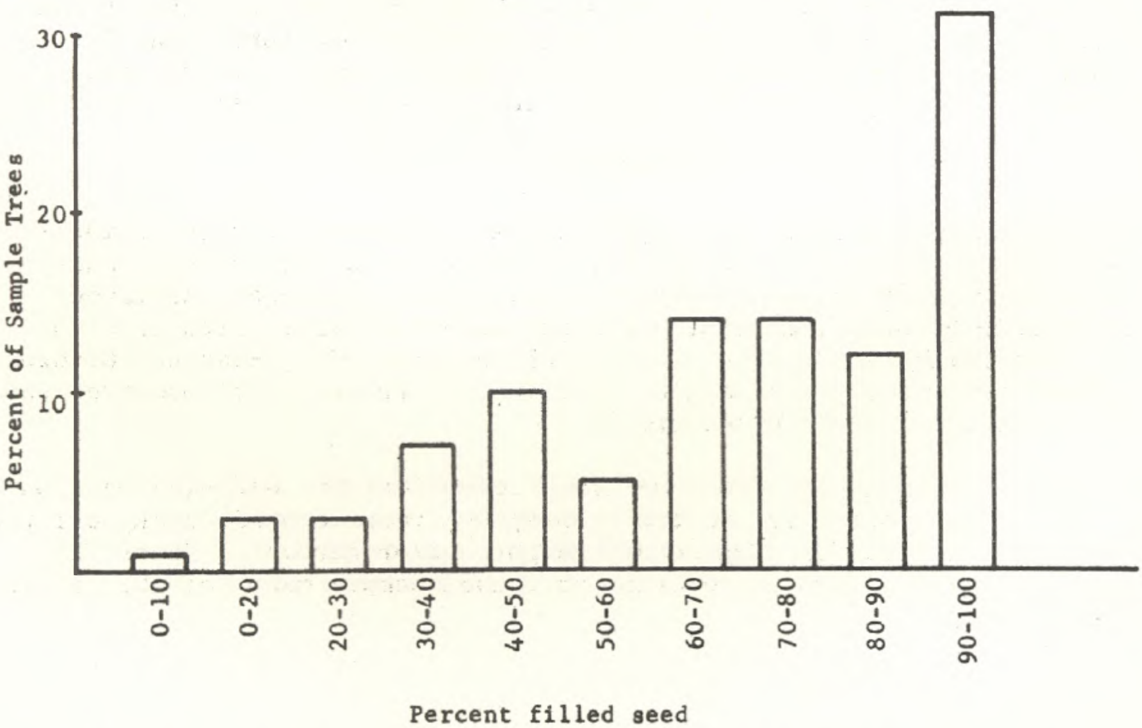


Figure 2.--Natural variation in seed weight and percent filled seed of black walnut in the Tennessee Valley.

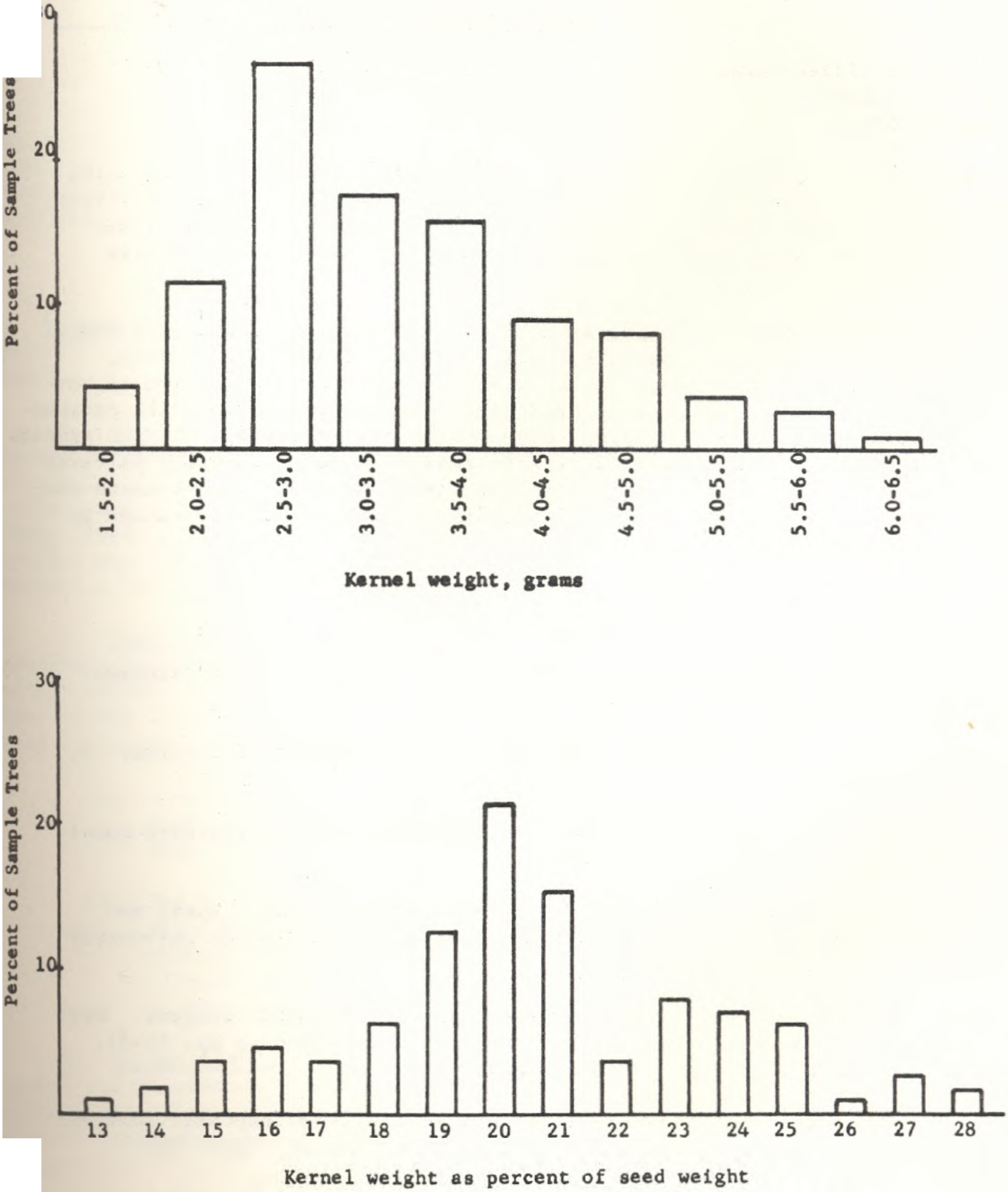


Figure 3.--Natural variation in kernel weight and percent kernel of black walnut seed in the Tennessee Valley.

	Random Sample	Ninety Selected Clones	Selection Differential, Percent
Weight of filled seed, g	16.5	19.6	19
Kernel weight, g	3.3	5.1	55
Kernel percent	20.0	27.0	35

Chase (1947) found that large black walnut seed, especially those with large kernels, produce larger seedlings than small seed; and Williams (1965) noted that large seedlings survive and grow better than small ones. Thus selection for seed size should result in gains for survival and juvenile growth.

Since seed yield varies considerably among trees, seed production should be considered when selecting phenotypically superior trees for orchards. Little benefit will accrue from initial selection for growth and form if the selections are inherentlypoor seed producers. Conversely, trees with extremely high fecundity may produce progeny which bear large seed crops at the expense of wood production. An awareness of the inconsistent yearly bearing patterns of individual trees is also essential in-both field selection and orchard management. Even ramets of the same clone Within an orchard show variation in this bearing pattern (Taft, 1966).

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