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GENETIC VARIATION AND HERITABILITY ESTIMATES IN BLACK WALNUT CLONES AT DIFFERENT AGES

W. F. Beineke
Department of Forestry and Natural Resources
Purdue University, West Lafayette, Indiana 47907

H. E. Stelzer
Proctor and Gamble Company
Perry, Florida 32347
and

G. A. Fisher
415 Emerson Street
Seymour, Indiana 47274

ABSTRACT: Results from the Purdue University black walnut (*Juglans nigra* L.) genetic improvement project demonstrated highly significant clonal difference in diameter and stem form at ages 4, 6, 10 and 15 and height at ages 10 and 15. Broad sense heritabilities at age 15 for height, diameter, and stem form were 01.31, 0.52 and 0.50, respectively. Positive correlations were found between height and stem form and diameter and stem form.

Additional key words. vegetative propagation, genetic improvement, *Juglans nigra* L.

INTRODUCTION

Indiana grows over one half of the high quality black walnut veneer logs and manufactures over three fourths of the walnut veneer in the prime walnut growing area of the central and southern Lake States (Blyth and Smith 1986). High prices paid for veneer quality trees have stimulated landowners to plant black walnut and landowners have urged that tree improvement programs be initiated. In response, the improvement strategy chosen for Purdue University's program was to 1) select superior phenotypes from wild populations, 2) establish clone banks through grafting, 3) establish open-pollinated progeny tests, 4) based on data collected from the progeny tests, determine clones to propagate and place in the Indiana Division of Forestry seed orchards, and 5) determine clones to be patented and propagated by grafting (Beineke 1989).

Although black walnut is usually propagated by seed, exceptional individuals can be propagated by grafting, thus by-passing the long-term sexual reproduction and progeny testing by seedlings (Beineke 1982). A commercial venture utilizing vegetative propagules is now in existence (Beineke 1989).

Information about genetic variation, heritabilities, and correlations between characters is necessary before an improvement strategy can be critically evaluated (Mohn and Randall 1971). Therefore, the objective of this study was to analyze genetic variation, calculate broadsense heritabilities for height, diameter, and form, correlations

between those traits, and to determine if analyses at very young ages remained valid (Beineke 1974; Bey, Hawker and Roth 1971; McKeand 1978).

MATERIALS AND METHODS

The original selections were made from Indiana and southern Michigan forests, yards, and parks and were based on outstanding timber quality, straightness, and rapid growth rate. These selections were grafted into clone banks established in 1972 at Purdue University's Martell Forest, nine miles west of West Lafayette, Indiana. The clone banks were located on well-drained Genesee sandy loam soils and received the usual cultural practices for black walnut plantations including weed control, fertilization and pruning. Rootstocks were selected from a random assortment of one-year-old seedlings, and at least ten grafts were made from each selection (Beineke 1984b). Successful grafts were outplanted the spring following grafting in a completely randomized design at a 12 x 12 ft spacing.

Height to the nearest 0.05m and diameter at 1.37m (dbh) to the nearest 0.10cm have been measured annnually. Stem form was evaluated by incorporating sweep, and the number of crooks and forks into a subjective scale from 1 to 5 according to the following criteria: 1—a perfectly straight tree, no crooks, forks, or deviations of the central stem; 2—a few minor crooks that will probably straighten in time with further growth of the tree; 3—an average tree, some crook, perhaps a minor fork, some defect will probably remain in the log at harvest age; 4—poor form, crooks, sweep, and forks prominent, low quality log, and; 5—extreme crook, sweep, and forks, unlikely to produce a usable log. All form ratings each year were done by the senior author.

Analysis of variance, on an individual tree basis, provided the clone and error variance components as estimated from the mean squares for all variables, and hence the heritability estimates following the approach of Becker (1984). At least two live ramets of each clone were required for an ortet to be included in the analysis. broadsense heritabilities were calculated using the formula:

$$h^2 = \sigma^2_c/(\sigma^2_c + \sigma^2_e)$$

where σ^2_c = variance due to differences among clones

σ^2_e = variance due to error

Pearson correlation coefficients for each trait with all other traits were calculated.

RESULTS AND DISCUSSION

Analysis of variance revealed significant clonal differences at the 1% level in height at ages 10 and 15 and in diameter and stem form at all ages indicating that genetic differences were present (Table 1).

Broadsense heritability estimates are reasonably high with the exception of height at ages 4 and 6 (Table 1). Generally, heritabilities increased as age increased; however, heritability for height appears to have stablized between ages 10 and 15 with values of 0.35 and 0.31 respectively, while diameter heritability increased from 0.44 to 0.52 between age 10 and 15 and form heritability increased from 0.42 to 0.50 during that time (Table 1). Fewer ortets and ramets were available as the study aged because of morality, thinning (spacing problems), roguing (removal due to interior form) and damage (deleted due to wind breakage, tractor damage, or canker infection). This may

Table 1. Numbers of ortets and ramets, variances, significance levels and heritabilities of height, diameter, and stem form at different ages of black walnut selections grafted in 1972.

Trait	Age	No. Ortets	No. Ramets	Mean	Range of Clone Means	Clone Variance	Error Variance	F Ratio	h^2
Height	4	36	124	3.48	2.76- 4.18	0.14	1.00	1.49^{NS}	.12
(m)	6	32	97	4.91	3.87- 5.75	0.24	1.54	1.46^{NS}	.13
	10	28	82	8.60	6.40- 9.81	1.56	2.87	2.59**	.35
	15	25	71	12.41	9.54-14.97	4.25	9.41	2.28**	.31
Diameter	4	36	124	3.15	2.03- 3.39	0.06	0.17	2.27**	.27
(dbh-cm)	6	32	97	5.64	3.89- 7.37	0.19	0.43	2.31**	.30
	10	28	82	11.30	7.49-14.22	0.86	1.13	3.22**	.44
	15	25	71	16.76	11.68-21.59	1.92	1.75	4.10**	.52
Stem	4[a]								
Form	6	32	97	3.39	2.33- 5.00	0.42	0.81	2.58**	.34
(1-5)[b]	10	28	82	3.09	1.33- 5.00	0.47	0.65	3.12**	.42
	15	25	71	2.63	1.33- 5.00	0.54	0.53	3.91**	.50

[a] Form not recorded at age 4. [b] Stem form rated from 1 = good to 5 = poor stem form. [NS] Not significant. **Significant at $\alpha = 0.01$ level.

have produced some of the improvement in heritability estimates over time. Since this was a selected population, at least for form, heritability estimates provide limited application to similar populations. Genetic variation and heritability estimates indicate that clonal components of variance were adequate at ages 10 and 15 to provide for effective selection for height, diameter and form. Since Rink and Clausen (1988) found heritabilities in the range of from .18 to .23 for height at age 13 in black walnut seedlings, the clonal heritabilities that we calculated indicate that clonal propagation by grafting is a viable alternative to seedling production. Similar heritabilities were found in clonal and seedling progenies in conifers (Franklin 1979) and cottonwood (Foster 1985); Mohn and Randal 1971).

Significant positive correlations at age 15 at the 5% level were found between height and form ($r = .39$), but correlations between diameter and form ($r = .34$) were not significant. While weak, correlations are positive indicating that faster growth indicates better form. Height is significantly correlated with diameter at age 15 ($r = .84$). Since height is becoming increasingly difficult to measure with accuracy, diameter could suffice as the only growth parameter measured.

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