VARIATIONS IN GROWTH AND FORM IN YOUNG PLANTATION BLACK WALNUT TREES

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Action programs and research for genetic improvement of black walnut (*Juglans nigra* L.) have been started in many areas in the Eastern United States. As new information becomes available, additional walnut improvement programs will undoubtedly be started.

We believe that improvement programs should be aimed primarily at producing straight, rapid growing trees. In plantations there is little, if any, problem in selecting the largest trees, but selecting for stem straightness is more difficult. Since straightness, branching habit, and apical dominance are generally considered interrelated, we decided to examine the intercorrelations among these and other characters. We have conducted a preliminary plantation survey and established a progeny test.

In the plantation survey we found: (1) No correlation exists between the number of branches on 1-year-old wood 1 year and 1-year-old wood the next. (2) Number of branches developing on 1-year-old wood was not significantly correlated with the amount of current year's terminal growth. (3) A negative correlation was found between branch angle of branches on 1-year-old wood of succeeding years. (4) Branch angle measured from the zenith increases as branches become older.

PROGENY TESTING

Method

In an attempt to evaluate the genetic aspect of growth and form in walnut, we started a study in 1966 using seed from 17 parent trees from six widely separated geographic sources (table 1). The field planting consists of 308 trees in a completely randomized hierarchal design. The 308 trees were derived from 154 nuts. Genetically identical pairs were derived by longitudinally splitting the hypocotyl and epicotyl of germinating seeds (Bey, 1967) (fig. 1). Each seedling was grown in a pot for 1 year, transplanted into the nursery for 1 year, and then transplanted to the field in 1968. The

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Table 1.--Location and average value by family and source for eleven characters

Source Location	Family no.	Height 1970	Diameter 1970	Length of branches below current year's terminal 1969	Length of branches below current year's terminal 1970	No. branches below current year's terminal 1970	No. lateral buds on current year's terminal 1969	No. lateral buds on current year's terminal 1970	Leaf flush-days after April 1, 1970	Leaf fall-days after Aug. 1, 1970	Index of crook 1969	Index of crook 1970
		cm	mm	cm	cm							
Winona Co.,	102	102.2	21.2	8.5	71.2	3.2	26.0	21.8	22.7	43.5	11.8	13.1
Minnesota	103	107.5	21.9	17.4	140.4	4.4	21.8	18.5	25.7	34.7	4.9	20.2
	108	97.4	18.7	7.0	94.2	3.5	20.5	18.7	29.4	36.5	10.5	18.4
Source 1 ave.		101.9	20.2	11.3	111.4	3.8	21.4	18.8	27.4	36.3	8.3	17.2
Delaware Co.,	206	97.2	20.7	2.5	43.1	2.7	21.7	21.2	24.3	33.5	3.8	15.6
Iowa	210	100.0	20.1	17.4	157.2	4.1	21.6	17.3	31.6	31.8	5.1	21.5
	212	107.1	21.6	17.8	212.0	7.4	22.4	20.3	26.8	44.6	7.1	12.4
Source 2 ave.		103.5	21.0	15.4	170.2	5.7	22.1	19.5	27.9	39.1	6.0	16.5
Marion Co.,	302	147.0	26.3	67.3	309.7	10.7	32.2	22.3	26.0	36.3	8.7	14.2
Missouri	305	123.9	26.5	37.8	294.9	7.4	28.5	21.3	29.7	47.8	10.5	18.1
	310	113.8	21.6	7.6	80.6	1.8	25.4	24.0	29.7	47.1	3.9	9.0
Source 3 ave.		125.8	25.1	35.7	240.7	6.5	28.4	22.2	29.0	45.3	8.4	13.8
Dent Co.,	401	132.4	26.5	62.4	248.5	7.4	31.8	23.3	30.6	50.1	13.3	18.0
Missouri	407	135.7	26.2	32.4	269.8	7.9	31.1	22.3	27.2	49.6	10.9	23.5
	410	128.0	24.6	17.6	157.7	5.3	29.4	26.9	28.2	53.4	9.8	14.9
Source 4 ave.		131.5	25.7	38.1	217.9	6.7	30.7	24.5	28.9	51.3	11.4	18.8
Stone Co.,	502	152.9	27.4	40.4	298.9	7.2	35.3	25.7	24.8	54.1	14.5	16.9
Arkansas	504	136.8	26.7	49.7	233.0	4.9	30.3	24.4	22.2	56.1	16.4	21.0
	506	142.0	28.2	41.7	292.8	6.6	31.6	24.0	24.0	55.8	21.1	26.7
Source 5 ave.		143.9	27.4	43.9	275.2	6.2	32.4	24.7	23.7	55.3	17.4	21.5
Walker Co.,	602	156.2	30.7	86.0	401.3	7.9	41.9	25.9	19.5	74.1	28.1	30.3
Texas	604	150.8	33.3	71.0	452.8	8.0	32.0	24.0	19.0	82.1	28.2	30.8
Source 6 ave.		154.2	31.7	81.7	420.6	7.9	39.1	25.2	19.4	77.1	28.1	30.5

seedlings were smaller than most 1-year-old transplant stock. The field was sprayed with simazine (2.5 lb./acre) and atrazine (2.5 lb./acre) each year to control weeds. The trees were "correctively pruned" (lateral branches removed that were competing with the terminal for a dominant position) during the growing season of the first two years--1968 and 1969.

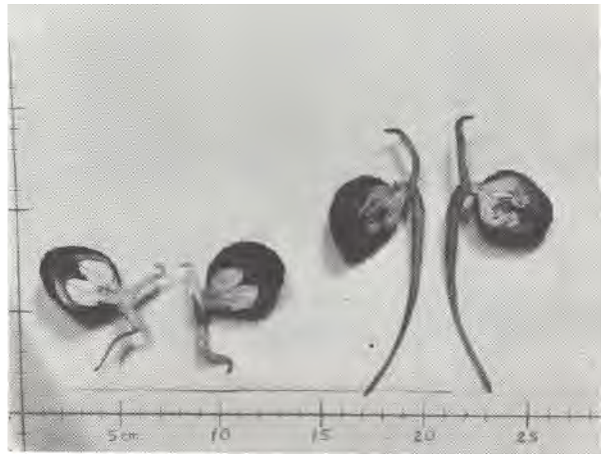

Figure 1.--Genetically identical pairs were derived by splitting germinating seeds.

At the end of the 1968 and 1969 growing seasons, as well as during and after the 1970 growing season, we made a detailed study of the following growth and form characters.

1. Diameter at 15 cm above ground and total height were measured to the nearest millimeter and centimeter, respectively.
2. Length of branches below current year's terminal was measured to the nearest cm in 1969 and 1970.
3. The number of branches below the current year's terminal were counted **in** 1970.
4. The number of lateral buds on current year's terminal were counted in 1969 and 1970.
5. Flushing was considered to have occurred when the first leaf reached 2.5 cm in length.
6. Leaf fall was considered to have occurred when all the leaflets had fallen from all the leaves or all but one.
7. Index of crook was computed as the sum of (1) degrees lean, (2) number of crooks x 10/total height, and (3) degree of maximum crook.

"Lean" was measured from the base of the tree to the tip. Any deviation of 2.5 cm or more from bole to a straight line tangent to the bole was considered a "crook". "Maximum crook" is the value for the distance from bole to a straight line tangent to the crook in the bole x 100 divided by the length of the straight line. "Maximum crook" values were then adjusted so that on the average they contributed the same as the component for number of crooks. For 1969 and 1970, lean contributed 30 and 27 percent, respectively, to the total index of crook values.

Results

Analysis of variance revealed that after 5 years trees from southern sources were generally taller and larger in diameter, had greater branch length after 1969, developed more lateral buds on the current year's terminal, flushed earlier, and dropped their leaves later than trees from local and northern sources (table 2). Although ANOVA revealed no significant differences between sources for (1) number of branches below current year's terminal, (2) total branch length after 1970, (3) index of crook 1969, and (4) index of crook 1970, these characters are correlated with height. Using source means, the correlations (r) between height and variables (1)-(4) are .92, .84, .88, and .75, respectively. These correlation coefficients are significant at the .05 level. This would indicate that selection for fast growing sources will mean concurrent selection for trees that have more branches and more crook.

Table 2.--Mean squares for eleven characters by sources, families, pairs, and error

	Height	Diameter	Length of branches below current year's terminal		No. branches below current year's terminal	No. lateral buds on current year's terminal		Leaf flush-days after	Leaf fall-days after	Index of crook	
	1970	1970	1969	1970	1970	1969	1970	April 1, 1970	Aug. 1, 1970	1969	1970
Sources	20,379**	671**	15,097*	152,494	78	1,614**	425**	518**	6,157**	1,189	755
Families/S	996	32	4,273	59,050	55	106	74*	74**	331*	497**	325
Pairs/F	1,497	57	2,785	88,480**	33**	82**	39**	18**	171**	177*	203**
Individuals/P (error)	858	36	2,373	7,542	19	45	25	9	58	124	317

** Indicates significant difference at .01 probability level.
Indicates significant difference at .05 probability level.

The hierarchal design also permitted us to test for differences among families within sources, and among pairs within families (table 2). There were differences among families within sources for number of lateral buds on current year's terminal in 1970, leaf flush, leaf fall, and index of crook for 1969. There were differences among pairs within families for all characters except height, diameter, and length of branches below current year's terminal in 1969. The fact that few characters show differences among families suggests that trees within stands are related--perhaps coming from a common parent several generations in the past.

The phenotypic and genetic contribution due to sources, families, and pairs was computed using the following model:

	D.f.	EMS
Sources	5	$\sigma_e^2 + 2\sigma_P^2 + 18.65\sigma_F^2 + 48.23\sigma_S^2$
Families in sources	11	$\sigma_e^2 + 2\sigma_P^2 + 17.32\sigma_F^2$
Pairs in families	137	$\sigma_e^2 + 2\sigma_P^2$
Error--within pairs	154	σ_e^2

The variance coefficients were adjusted because of an unbalanced design (Sokal and Rohlf, 1969). The phenotypic variance for error was generally high (table 3). The higher the error variance, the greater the opportunity for improvement through silvicultural manipulation. Conversely, relatively low error variances, as for leaf flush and leaf fall, indicate that there is a better chance for gain through genetic manipulation°

Table 3 --Phenotypic variance due to sources, families, pairs, and error (expressed as percent of total variance)

	Height 1970	Diameter 1970	Length of branches below current year's terminal 1969	Length of branches below current year's terminal 1970	No. branches below current year's terminal 1970	No. lateral buds on current year's terminal 1969	No. lateral buds on current year's terminal 1970	Leaf flush--days after April 1, 1970	Leaf fall--days after Aug. 1, 1970	Index of crook 1969	Index of crook 1970
Sources	25	22	8	3	1	29	18	36	49	8	5
Families/S	0	0	3	0	5	2	5	13	4	10	7
Pairs/F	20	18	7	82	29	20	16	18	23	14	64
Individuals/P (error)	55	60	82	15	68	49	61	33	24	68	24

In general, the family component for genetic variance was very low, while source and pair components were high (table 4). High source components, as for the growth characters, indicate large genetic differences among stands. Low family components indicate minor genetic differences within stands. High pair components indicate large genetic differences within progeny from individual trees.

Heritability for each character was computed as the ratio of total genetic variance over total phenotypic variance (table 4). The heritability values were .40 or higher for 7 of the 11 characters. The potential for genetic gain through selection for growth, flushing, and leaf fall appear good.

Table 4.--Genetic variance due to sources, families, and pairs (expressed as percent of total genetic variance) and heritability values*

	Height	Diameter	Length of branches below current year's terminal		No. branches below current year's terminal	No. lateral buds on current year's terminal		Leaf flush-days after	Leaf fall-days after	Index of crook	
	1970	1970	1969	1970	1970	1969	1970	April 1, 1970	Aug. 1, 1970	1969	1970
Source	55	54	43	3	4	57	45	54	65	24	7
Families	0	0	17	0	15	3	13	19	5	31	9
Pairs	45	46	40	97	81	40	42	27	30	45	84
Heritability	.45	.40	.13	.85	.32	.51	.39	.67	.76	.32	.76

*Expressed as ratio of total genetic variance over total phenotypic variance.

Implications

For any specified planting zone (e.g., a state, part of a state, etc.), it is important to first define the geographic area whose seed gives the "best" performance. This study and other early tests indicate that for southern Illinois plantings, south-of-local areas are "best" for growth characters (Bey, Toliver, and Roth, 1971),

Within the "best" seed collection areas collect seed from few trees per stand but many stands. For characters such as height and diameter having low family variance, many parent trees will need to be included for family selection to be effective. Where family variance *is* relatively high, such as for leaf flush, family selection would be effective with fewer parent trees.

In roguing progeny tests (for the purpose of converting t seedling seed orchards), it appears that we should save some trees from most of the families. For example, *if* we use 12 families (those with 10 or more trees per family) from the data presented here, and select all trees taller than 162 cm (the best 20 percent of all trees), we would select some trees from all except one family (table 5).

One alternative to the minimum selection approach is to make use of the family means and variances. Normal probability paper is useful when using this procedure (Kung and Squillace, 1971) (fig. 2). When the cumulative curve of a normal distribution is plotted on normal probability paper, it becomes a straight line. The mean appears on the 50th percentile and one standard deviation above the mean will be on the 84.13 percentile. Using this procedure, and again selecting 20 percent of all trees, we would select some

Table 5.--A comparison of methods for making selections

Family number	Mean ht.	Percent of trees selected in each family: Minimum selection-- 162+ cm in height	Percent of trees selected in each family: Selection based on family means and standard deviations
	Cm	Percent	Percent
103	107.5	4	3
108	97.4	4	3
210	100.0	-	2
212	107.1	9	6
305	124.0	19	15
401	132.4	42	24
407	135.7	19	22
410	128.0	12	19
502	152.9	47	44
504	136.8	21	25
506	142.1	22	31
602	156.2	40	44

trees from all families. The percentages selected within each family by the two methods are in close agreement. In cases where phenotypic variances are proportional to genetic variances, the selection method based on means and variances makes greater use of the data and may lead to greater improvement.

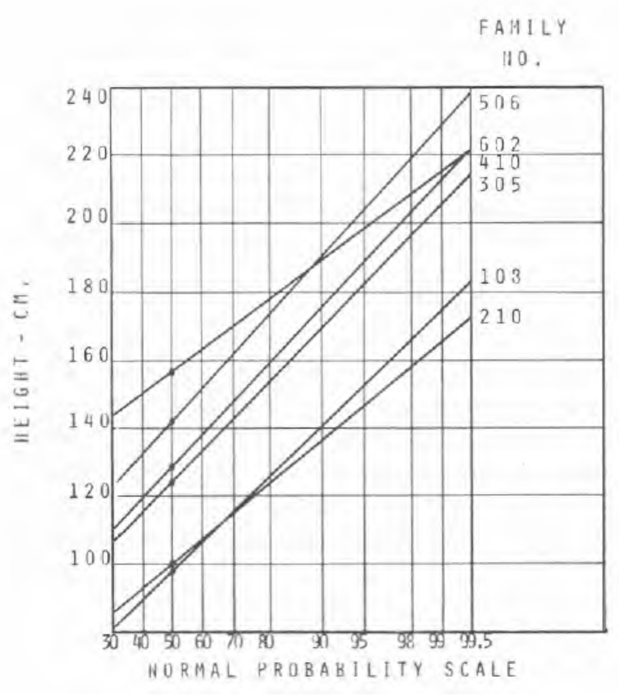

Figure 2.--Estimated cumulative frequency distribution for height of tree. One family from each source is shown.

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