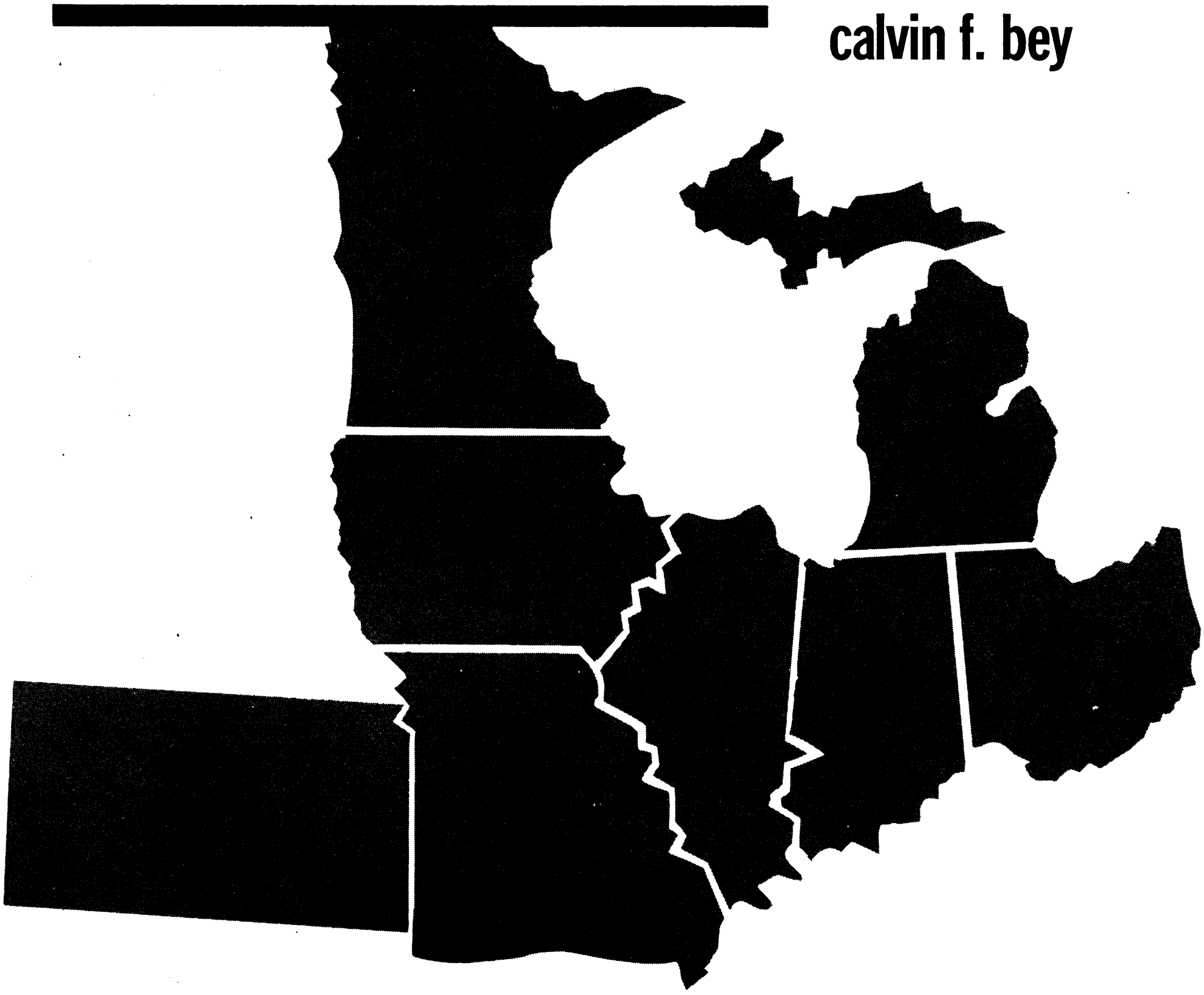
USDA Forest Service
Research Paper NC- 91
1973

GROWTH OF BLACK WALNUT TREES IN EIGHT MIDWESTERN STATES—A PROVENANCE TEST

calvin f. bey



NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

THE AUTHOR, a Principal Plant Geneticist, is headquartered at the Station's Forestry Sciences Laboratory in Carbondale, Illinois. The Laboratory is maintained in cooperation with Southern Illinois University.

CONTENTS

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service — U.S. Department of Agriculture
Folwell Avenue
St. Paul, Minnesota 55101
(Maintained in cooperation with the University of Minnesota)

Manuscript approved for publication May 16, 1973

GROWTH OF BLACK WALNUT TREES IN EIGHT MID-WESTERN STATES — A PROVENANCE TEST

Calvin F. Bey

Black walnut (*Juglans nigra* L.) is native to a large geographic area in the eastern United States. Within the natural range, climate varies from wet to dry, with hot to cool summers and mild to severe winters. As expected, a lot of genetic variation in black walnut exists over this wide range (Bey 1970, Bey *et al.* 1971). We have shown that the geographic variation (among stands) is greater than local variation (among trees within stands) (Bey *et al.* 1972a).

In planning tree improvement and reforestation projects, maximum gain will be made only if we take advantage of the natural variation of the species. Ideally, nurserymen want to provide the "best" seedlings, from the "best" parent trees, from the "best" geographic area. In this study, we have observed how trees from widely separated geographic areas survive and grow at eight locations in the midwestern United States. Results of this early test can be used as an interim guide for geographic selection in black walnut tree improvement and reforestation projects.

METHODS

In 1967, 1-year-old black walnut seedlings from 15 to 25 geographic sources were planted at each of eight locations in midwestern United States (table 1). Each source consisted of seedlings grown from seed collected from an average of six parent trees generally located within the same stand. Although most of the sources were represented in two or more plantings, no two plantations contained trees from all of the same sources. Each planting consisted of a randomized complete block design with six replicates of four-tree plots.

Weeds were controlled in all plantations for at least the first 3 years. Some corrective pruning was done to develop straight central stems, but the amount and type varied among plantations. Site quality was originally considered to be good to very good for walnut.

In the fall of 1971 (6 years from seed), data were collected on survival, height, and diameter at 12 inches

Table 1. – *Location of plantation, number of sources, and cooperating agencies for eight black walnut seed source plantations*

State	County	Latitude °N	Longitude °W	No. sources	Cooperating agency[1/]
Illinois	Alexander	37.3	89.3	20	Shawnee N.F.
Missouri	Pulaski	37.8	92.2	15	Clark N.F.
Indiana	Lawrence	38.7	86.6	15	Wayne-Hoosier N.F.
Kansas	Pottawatomie	39.2	96.5	15	Kansas State Univ.
Ohio	Wayne	40.8	81.9	25	OARDC
Iowa	Johnson	41.8	91.7	25	U.S. Army Corps of Engineers
Michigan	Kalamazoo	42.3	85.4	20	Michigan State Univ.
Minnesota	Winona	44.2	92.0	15	Minnesota Div. of Forestry

1/ The author greatly appreciates the help of all cooperators in establishing these studies and collecting data.

above ground for all trees. Because each plantation at least partially represented a different population, only comparisons of trees from sources within plantations were made.

RESULTS

Survival

Survival ranged from 41 percent for trees in the Minnesota plantation to 87 percent for the Missouri plantation (table 2). About 10 percent of the seedlings died during the first growing season. The loss was concentrated in a few sources and was presumably associated with root rot, which was observed when the seedlings were planted. The biggest loss (17 percent) occurred during the first winter and second growing season. For the next 3 years (1969-1971), only 5 percent of the trees died. From the survival standpoint, the first winter is probably the most severe.

In the Indiana plantation, survival was unexpectedly low. The area was flooded briefly in the spring during the first 2 years and some mortality may be attributed to the flooding.

Except for the Ohio and Minnesota plantations, survival of trees was not related to the latitude of the source. Wright (1954) also reported no correlation between survival and origin of source. In the Ohio plantation, the trend was for generally higher survival from the southern sources (fig. 1). Thirty percent of the variation in survival was accounted for by the latitude of the seed source.

In the Minnesota plantation, there was a strong continuous trend with latitude, with higher survival in trees from the northern sources (fig. 1). Trees from sources within 250 miles south of the planting site had

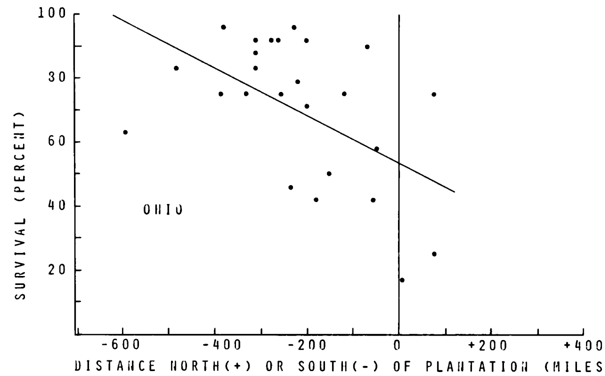


Figure 1. – *In the Ohio test, trees from southern sources generally survived better than trees from northern sources.*

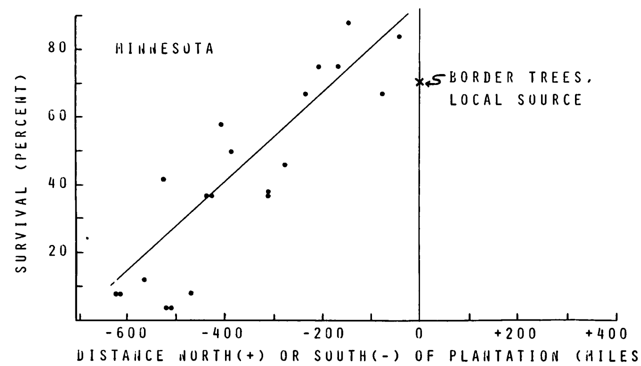


Figure 2. – *In the Minnesota test, trees from the northern sources generally survived better than trees from the southern sources.*

76 percent survival while trees from sources 250 to 650 miles south had only 29 percent survival. Seventy-one percent of the Minnesota-source border trees survived. Seventy-nine percent of the variation associated with survival can be accounted for by latitude of seed

Table 2. – *Average survival, growth, correlation coefficient (for height and diameter), and gain by selection for each plantation*

State	Survival by year: 1967	1968	1969	1970	1971	Diameter at 12 inches above ground	Height	Height (ft.) divided by diameter (in.)	Correlation coefficient between ht. and dia.	Average gain in height by selecting tallest sources: Tallest 40 percent	Tallest 20 percent
	Percent	Percent	Percent	Percent	Percent	Inches	Feet			Percent	Percent
Illinois	94	88	85	85	85	2.0	8.1	4.1	0.93	14.8	21.0
Missouri	92	--	88	87	87	1.4	5.9	4.2	.74	9.4	13.4
Indiana	86	64	61	61	61	2.7	11.6	4.2	.95	10.5	13.9
Kansas	88	77	--	--	75	3.5	12.0	3.4	.52	5.4	7.2
Ohio	--	83	79	71	70	1.8	8.1	4.6	.79	7.8	10.3
Iowa	92	--	--	76	76	1.8	6.6	3.6	1.00	12.4	18.1
Michigan	90	85	--	--	82	1.1	5.4	4.8	.92	12.3	18.4
Minnesota	92	50	--	41	41	1.6	6.8	4.4	.78	9.3	14.6

source. In a Nebraska test, Emerson (1906) also showed that the trees of southern provenances suffered more cold injury than those of northern provenances.

Although we did not run a combined analysis (all sources at all locations) for survival, there were obvious interactions that had practical significance. For example, trees from one North Carolina source had 92 percent survival in Missouri and 8 percent survival in Minnesota. In contrast, trees from one Iowa source had good survival in both plantations: 96 percent in Missouri and 75 percent in Minnesota. These and other examples demonstrate the need for conducting provenance tests at many locations.

Growth Differences Among Plantations

Average tree height and diameter varied from 12.0 feet and 3.5 inches for the Kansas plantation to 5.4 feet and 1.1 inches for the Michigan plantation (table 2). Although the Kansas and Michigan plantations have only six sources in common, the distribution of sources (north and south of the planting site) was similar for both plantations. The growth differences between these two plantations (and others) probably reflect site productivity differences. In addition to the site factors, differences among plantations may also be due to the particular sources included at each plantation. The Kansas plantation is on a well-drained alluvial soil below Tuttle Creek dam. It is obviously an excellent site for walnut. Trees from one Mississippi source grew, on the average, 0.9 inch in diameter per year. The Michigan plantation is on a level hilltop with a sandy loam soil. Although the site might be described as a typical upland in southern Michigan, it is not considered a good site for walnut.

From our original estimation of site productivity, we anticipated that trees in the Illinois, Missouri, and Indiana plantations would grow at about equal rates. Such has not been the case. Trees in the Illinois and Missouri plantations grew less than expected. The Illinois plantation is on a well-drained silt loam soil. Late summer leaf yellowing and early leaf drop on trees in the Illinois plantation in 1970 suggest the site may be droughty and therefore less than ideal for maximum growth. Although the soils at the Missouri and Indiana sites were considered to be similar (slightly heavy for walnut), trees in the Indiana plantation are about twice as large as those in Missouri. Climatic conditions and cultural treatments, although not identical in both plantations, probably are not responsible for the major growth differences. Although soil texture is similar, other soil properties are presumably different and responsible for the growth differences. A fertilizer experiment in an adjacent plantation in Missouri suggests that the soil is deficient in nitrogen and phosphorus.[1]

Growth Differences Among Trees From Various Sources

At all locations tested, trees from sources as far as 200 miles south of the planting site generally grew as large or larger than trees from local or northerly sources. The data suggest that seed can be safely moved 200 miles north of the collection area. At some locations, seed may be safely moved as far as 400 miles north of the collection area. Trees from seed collected north of the planting site will usually be smaller than trees of local origin.

Growth of trees from particular sources was dependent on the source and plantation location. For example, trees from one Texas source were tallest (25 percent above plantation mean) in Illinois and shortest (26 percent below plantation mean) in Iowa. In contrast, trees from one Tennessee source were 7 percent below the plantation mean in Illinois and 3 percent above the plantation mean in Iowa. Again, this genotype x location interaction demonstrates the need for conducting provenance tests at many locations.

Illinois, Missouri, and Indiana

Trees from sources south of the planting site were generally taller and larger in diameter than trees from local and northern sources (figs. 3-6). On the average,

---

[1] *Phares, Robert E. 1972. Fertilization of young black walnut plantations with nitrogen, phosphorus, and lime. File report for study CH-433 dated June 8, 1972.*

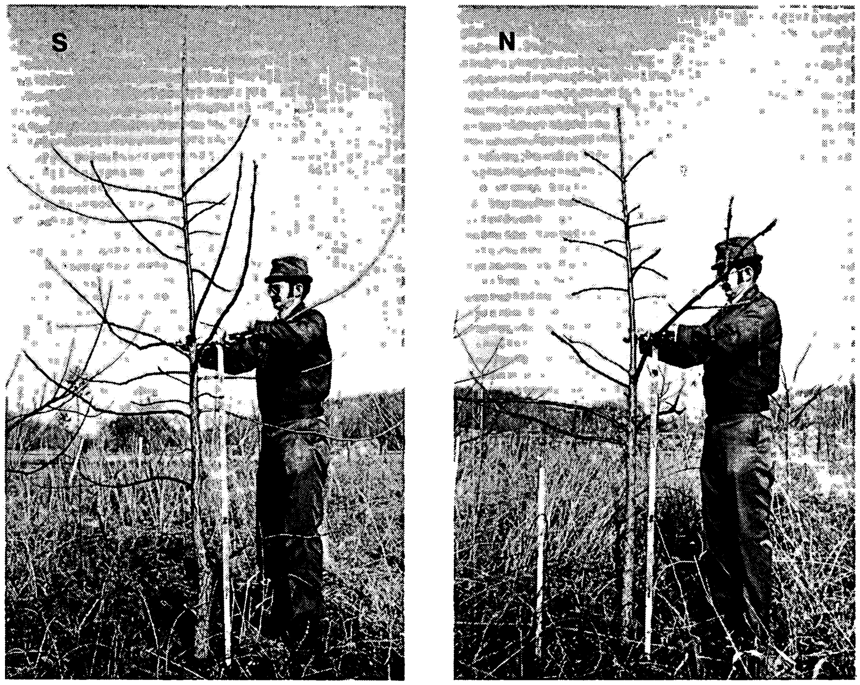


Figure 4. – *In an Illinois provenance test, trees from sources 300 miles south (S) were generally 20 percent larger than those 300 miles north (N) of the planting site.*

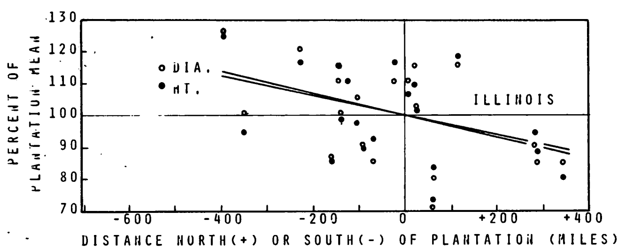


Figure 3. – *In Illinois, trees from sources south of the planting site were generally larger than trees from local and northern sources.*

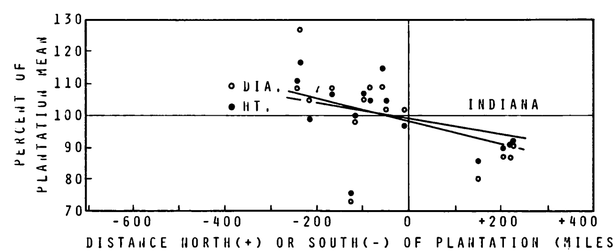


Figure 6. – *In Indiana, trees from sources south of the planting site were generally larger than trees from local and northern sources.*

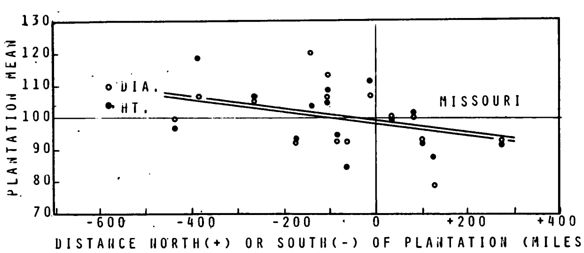


Figure 5. – *In Missouri, trees from sources south of the planting site were generally larger than trees from local and northern sources.*

trees grown from seed collected 300 miles south of the planting site were 10 percent taller and larger in diameter than trees of local origin. In the Indiana and Missouri plantations, height and diameter were average or below for trees from eight of the nine sources located north of the planting site.

There is no apparent explanation for the exceptionally poor growth of trees from one source in the Indiana plantation. The source (Kentucky 2001) is located 125 miles south of the plantation and is 25 percent below the mean. Trees from this source grew about average in Michigan and 10 percent below average in Missouri. The danger of drawing conclusions based on too few trees is illustrated by this oddball example.

Kansas and Ohio

Trees from local sources grew about as much as those from sources farther north and south of the plantation (figs. 7 and 8). Straight-line regressions for height and diameter over latitude were not significant. Nothing in the data suggests that it would be unwise to collect seed from 200 to 300 miles south of the plantations. However, in the Ohio plantation, trees from three of the four sources located more than 350 miles south of the planting site had less than average growth. Seed collection for Ohio should probably be limited to not more than 300 miles south of the planting site.

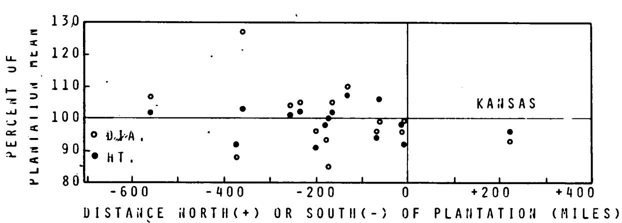


Figure 7. – *In Kansas, tree size was not associated with latitude of seed source.*

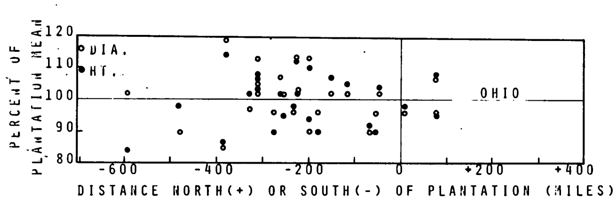


Figure 8. – *In Ohio, tree size was not associated with latitude of seed source.*

Iowa

There is a definite limit on how far walnut trees can be safely moved northward (fig. 9). Trees from northern sources were generally larger than trees from southern sources. The evidence is strong that movement of seed into Iowa from the south should be limited to areas within 200 miles of the planting site. Within a zone 200 miles north and south of the planting site, there was no apparent trend in size of trees from various sources. The sources with the tallest trees generally also had the highest survival. The correlation coefficient between height and survival was 0.61.

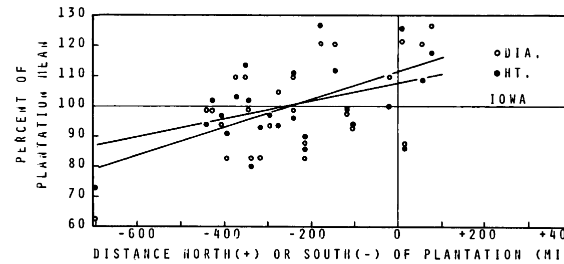


Figure 9. – *In Iowa, trees from northern sources were generally larger than trees from southern sources.*

Michigan

Trees from sources south of the planting site were generally larger than those from local and northern sources (fig. 10).[2] Trees from sources 300 to 500 miles south of the planting site (especially Virginia, West Virginia, Kentucky, Tennessee, and North Carolina) grew about 15 percent larger than those from local sources and had 93 percent survival. Although the results are not consistent with results from Ohio, Iowa, and Minnesota, the black walnut trend seems to parallel that of white pine grown in southern Michigan (Wright 1970). Persons planning to plant walnut farther north than the lower half of Lower Michigan and in the Upper Peninsula should probably use seed from not more than 200 miles south of the planting site. This

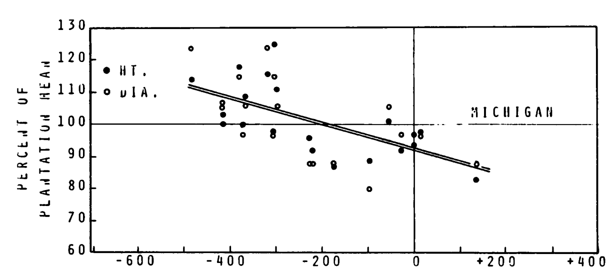


Figure 10. – *In a southern Michigan plantation, trees from sources 300 to 500 miles south of the planting site grew about 15 percent larger than those from local sources.*

---

[2] *One source from Indiana (1708) was badly infected with root rot at the time of planting and was not included in the analysis.*

would be in line with results from other black walnut provenance tests in Iowa and Minnesota.

Minnesota

Trees from northern sources generally grew larger than those from southern sources (fig. 11). In this test, border trees of Minnesota origin were measured for comparison purposes. Trees from all sources within 300 miles south of the planting site survived about as well as and grew larger than border trees of Minnesota origin. For trees from the 15 sources in the Minnesota test, the coefficient between height and survival was 0.54 and significant. Although the trend in growth and survival is distinctly continuous from north to south, it appears that we can safely move seed into Minnesota from areas up to 200 miles south.

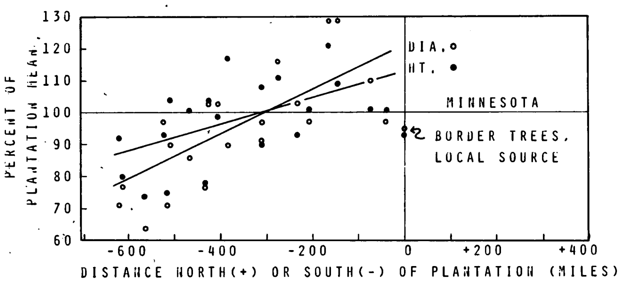


Figure 11. – *In Minnesota, trees from northern sources were generally larger than trees from southern sources.*

Height-Diameter Ratio

The average height-diameter ratio, an expression of the stockiness of a tree, differed among plantations. Trees in the Kansas and Iowa plantations were consistently stockier (3.38 and 3.63) than trees in the other plantations. Trees in the Michigan plantation were the least stocky; they had the highest ratio (4.81). Values for the remaining five plantations varied from 4.12 to 4.56.

Within each plantation, a correlation coefficient was computed between height-diameter ratio and latitude of the source. The correlation coefficient was positive for the Indiana (+ 0.52) and Ohio (+ 0.99) plantations, indicating that in these tests the southern sources were the most stocky. The correlation coefficients were negative for the Iowa (− 0.47) and Minnesota (− 0.46) plantations, and nonsignificant for the other plantations. The negative correlations for the Iowa and Minnesota plantations indicate that the northern sources were the most stocky.

Selection

Perhaps the best character for evaluating the value of sources at this early age is height. Although merchantable volume and quality will undoubtedly provide a better estimate of value at a later date, height is an estimate of potential size and indirectly reflects winter dieback and susceptibility to late spring frosts. Trees that have their tops killed back by severe winters and/or late spring frosts will be shorter than those not affected. Trees with multiple tops (poor form), from whatever the cause, are not likely to be as tall as trees with single central stems.

Selecting for height generally also means selecting for diameter. Based on source means, the correlation coefficients between height and diameter for each plantation averaged 0.83 and varied from 0.52 for the Kansas plantation to 1.00 for the Iowa plantation. There was no apparent relationship between the correlation coefficient and either the geographic location of the plantation or the size of trees in the plantation.

Although provenance tests are designed primarily to show regional or geographic variation patterns, the value of using fast-growing seed sources can also be demonstrated from these tests. If each plantation now under study were thinned to leave only the trees in the tallest 40 percent of the sources, the average height for all plantations would increase 10 percent (table 2). By selecting the tallest 20 percent of the sources the average height would increase about 15 percent. Plantations with the greatest variation offer the greatest opportunity for improvement through source selection. Additional gains could also be made by selecting the tallest trees within the tallest sources and perhaps the tallest trees in some of the shorter sources (Bey *et al.* 1972b).

DISCUSSION

This report is intended as an interim guide for those concerned with tree improvement and planting of black walnut in the Midwest. Although the experiment will not define the best geographic sources for all areas where walnut is grown, it is adequate to rule out some geographic origins for specific areas. Thus it reduces the size of the geographic area to be considered in future provenance and progeny tests.

In the six plantations where straight-line regressions for height and diameter over latitude were significant, latitude accounted for an average of 25 and 32 percent of the observed variation for height and diameter. The unaccounted for variation is attributed to genetic aspects related to longitude, altitude, and locale, and the variation due to the test environment. The amount of variation appears to be about the same for sources from the various latitudes in each plantation. This suggests that there is an approximately equal opportunity within any defined area for genetic gain for height and diameter growth through additional selection. Progeny testing, with roguing and conversion to seedling seed orchards, has been recommended; such orchards should be established within the geographic constraints shown in this report (Funk 1966, Bey *et al.* 1972b).

Recommendations are based on results from 6-year-old trees and are valid to the extent that 6-year-old performance represents future performance. The reader is cautioned against applying the results from any single plantation to an entire State. Results from a single or several adjacent States may be more appropriate. For example, for northern Illinois the results from Iowa are likely to be more meaningful than the results from southern Illinois. Although source names and numbers are not presented in this paper, the author would be glad to furnish additional details for those interested.

LITERATURE CITED

Bey, Calvin F. 1970. Geographic variation for seed and seedling characters in black walnut. USDA For. Serv. Res. Note NC-101, 4 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Bey, Calvin F., Norman L. Hawker, and Paul L. Roth. 1972a. Variations in growth and form in young plantation black walnut trees. South. For. Tree Improv. Conf. Proc. 11:120-127, illus.

Bey, Calvin F., Allan S. Mickelson, and Melvin Gerardo. 1972b. Black walnut seedling seed orchard development — a case history. Northeast. Area Nurserymen's Conf. Proc., p. 48-56, illus.

Bey, Calvin F., John R. Toliver, and Paul L. Roth. 1971. Early growth of black walnut trees from twenty seed sources. USDA For. Serv. Res. Note NC-105, 4 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Emerson, R. A. 1906. The relation of early maturity to hardiness in trees. Nebr. Agric. Exp. Stn. Annu. Rep. 19: 101-110.

Funk, David T. 1966. Seed orchards. *In* Black walnut culture. North Cent. For. Exp. Stn., St. Paul, Minn. p. 62-65.

Wright, Jonathan W. 1954. Preliminary report on a study of races in black walnut. J. For. 52: 673-675.

Wright, Jonathan W. 1970. Genetics of eastern white pine (*Pinus strobus* L.). USDA For. Serv. Res. Pap. WO-9, 16 p. Washington, D. C.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1973–762-072