

Geographic variation in *Juglans nigra* in the midwestern United States

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Summary

In 1967, 1-year-old black walnut seedlings from 15 to 25 provenances were planted at each of eight locations in Midwestern United States. During the first 10 years we evaluated survival, growth, and winter hardiness. Except for the Minnesota planting, survival was not related to the origin of the seed. In Minnesota, survival was only 25% for trees originating 300 to 600 miles south of the planting site versus 70% for northern trees. There were height growth differences related to origin of seed in all plantations except Missouri and Kansas, and diameter growth differences in all plantations. In the Kansas and Missouri plantings, the cold dry winter of 1976–1977 was hard on the trees. Although only a few percent died, crown dieback was severe in trees of the most southern origin.

Key words: Black Walnut, Provenance, Seed Source, Cold Hardiness.

Zusammenfassung

Im Jahre 1967 wurden einjährige Schwarznußsämlinge von 15–25 Herkünften an 8 Standorten im mittleren Westen der USA angepflanzt. Während der ersten 10 Jahre sind Überlebensprozent, Wachstum und Winterhärte geschätzt worden. Nur von der Minnesota-Anpflanzung wurde das Überleben zur Saatgutherkunft in Beziehung gesetzt. Dort überlebten nur 25% der Bäume von Herkünften 480–

sachte das Kronensterben der Bäume südlicher Herkünfte ernste Schäden.

Introduction

Black walnut (*Juglans nigra* L.), highly prized for its fine furniture wood, occurs naturally throughout most of the Eastern United States. It is planted throughout the natural range and has been considered a good candidate for genetic improvement. As with many species, planting success and genetic gains depend partially on rapid growth and winter hardiness traits. These traits are generally influenced by the geographic origin of the seed, and black walnut is no exception. Trees of southern origin tend to be faster growing and less cold hardy than those of northern origin (BEY 1973, WILLIAMS *et al.* 1974).

Materials and Methods

In 1967, 1-year-old black walnut seedlings from 15 to 25 provenances were planted at each of eight locations in Midwestern United States (Table 1). Each provenance or seedlot was grown from seed collected from six parent trees within a stand. Most seedlots were represented in two or more plantations, but no two plantations contained the same seedlots. Each plantation consisted of a randomized complete block design with six replicates and four-tree row plots. Weeds were controlled in all plantations for the first 3

Table 1. — Location of plantation, number of provenances, cooperating agencies, survival and growth for eight black walnut plantations.

State and County	Lat. ON	Long. OW	Provenances No.	Cooperating agency ¹	Ave. Survival Percent	Survival of tallest trees ² Percent	All Provenances		Local Provenances		Tallest 20% of the Provenances	
							Height m.	Diameter cm.	Height m.	Diameter cm.	Height m.	Diameter cm.
Illinois, Alexander	37.3	89.3	20	Shawnee N.F.	84	93	5.00	6.7	4.87	6.5	6.16	8.6
Missouri, Pulaski	37.8	92.2	15	Clark N.F.	87	85	4.21	5.7	4.33	5.8	4.63	6.9
Indiana, Lawrence	38.7	86.6	15	Wayne-Hoosier N.F.	61	78	5.76	8.8	6.04	9.2	6.40	10.6
Kansas, Pottawatomie	39.2	96.5	15	Kansas State Univ.	65	76	7.83	14.2	8.17	14.9	8.40	15.4
Ohio, Wayne	40.8	81.9	25	OARDC	68	83	5.70	9.2	5.73	9.3	6.13	9.9
Iowa, Johnson	41.8	91.7	25	U.S. Army Corps of Engineers	75	89	4.82	7.1	5.24	8.2	5.58	8.8
Michigan, Kalamazoo	42.3	85.4	20	Michigan State Univ.	81	91	4.57	6.5	4.33	6.2	5.12	7.6
Minnesota, Winona	44.2	92.0	15	Minnesota Div. of Forestry	40	55	2.80	--	3.44	--	3.47	--
Average					70	81	5.09	8.3	5.27	8.6	5.74	9.7

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

² Average survival for trees of tallest 20 percent of provenances.

970 km südlich vom Pflanzort, gegenüber 70% der nördlichen Herkünfte. In Abhängigkeit von der Saatherkunft gab es bei allen Anpflanzungen in den Höhen Differenzen, mit Ausnahme von Minnesota und Kansas, und Durchmesserunterschiede. Bei den Kansas- und Missouri-Anpflanzungen war der trocken-kalte Winter 1976/77 ungünstig für die Bäume. Auch wenn nur ein geringer Teil abstarb, verur-

years. Site quality in all plantations was originally considered to be good for walnut. However, during the 10 years of field observations, some of the sites were found to be less productive than originally expected.

At the beginning of the third growing season, European black alder (*Alnus glutinosa* L.) trees, which are nitrogen fixers, were interplanted as trainers in three plantations. In Illinois and Indiana, the alder grew rapidly and had to be cut down after four growing seasons to prevent overtopping of the walnut. In Missouri, the alder grew slowly and in 1976 were about the same height as the walnut. Data have been periodically collected on survival, height, and other traits in all plantations.

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Results and Discussion

Survival

Average mortality in all plantations was 10 percent at the end of the first growing season, 23 percent at the end of the second growing season and 30 percent after the 10th year. The losses during the first 2 years were concentrated in a few provenances and were associated with transplanting shock and root rot, which was observed when the seedlings were planted. The trees have gone through a severely cold and dry winter and future mortality, due to cold, is not anticipated. During the winter of 1976—1977 average low temperatures throughout the test area were about 4°, 3°, and 8° C below normal for November, December, and January, respectively (FELCH 1976 a, 1976 b, 1977). Over all plantations, trees from the tallest 20% of the provenances had an average survival of 81%, well above the overall average of 70%. Survival of the tallest 20% ranged from 55% in Minnesota to 93% in Illinois (Table 1).

On the basis of survival data, there is apparently a great deal of cold hardiness inherent in black walnut. In every plantation, except Minnesota, trees originating 300 or more miles south of the planting site have survived as well as northern trees. Climatic factors have apparently selected for the cold hardy types in the mid-south and southern trees. It is conceivable that during the evolution of the species a few very cold winters throughout the natural

range could have provided the needed selection pressure. Or perhaps the races today are adapted to the colder climate of 1,000 or more years ago. There is, of course, a limit on how far north seed can be safely moved and the Minnesota plantation offers the best example for differentiation of provenances on the basis of survival. In Minnesota, survival was only 23% for trees originating 300 to 600 miles south of the planting site versus 70% for northern trees.

Growth Differences

Average height and diameter for all eight plantations at age 10 was 5.09 m and 8.3 cm (Table 1). On the basis of only local seed the plantation heights varied greatly from 3.44 m in Minnesota to 8.17 m in Kansas. Soil productivity, rather than climate, is likely to be primarily responsible for growth differences among plantations. Although the northern-most plantation (Minnesota) contains the shortest trees, the next shortest trees are in the Missouri test, which is far to the south and the tallest trees are in the Kansas plantation, about midway in range of latitudes for plantations represented.

There were significant height differences at the .05 probability level among provenances in all the plantations except Missouri and Kansas. Differences between provenance means needed for significance varied from 1.2 to 1.9 m (Figure 1). Diameter differences were significant in all plantations. In general, the tallest trees came from the

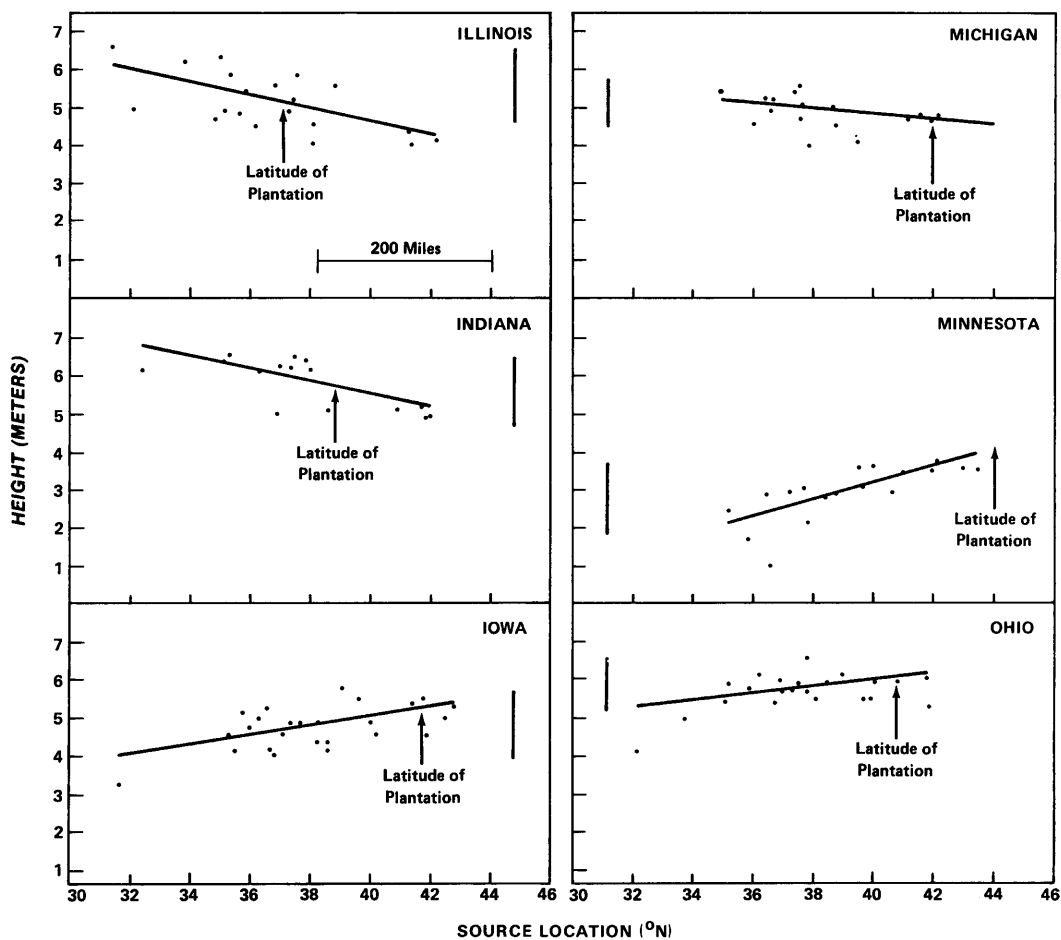


Figure 1. — In general, the tallest trees were from south of the planting location. Even in Iowa, Ohio, and Minnesota, where the danger of going too far south is apparent, the 200-mile zone immediately south of the plantation produces trees as tall as the local sources. (Line length indicates difference between provenances needed for significance at 0.05 level, based on Tukey's w-procedure (STEEL and TORRIE, 1960).)

south. In the Illinois, Indiana, and Michigan plantations, the regression for height over latitude shows that trees from the near-south and far-south are taller than northern trees. Latitude was used in the regression because it represents both day length and temperature. Although temperatures in eastern United States also vary with longitude and elevation, the predominate factor is latitude. In the Iowa, Ohio, and Minnesota plantations, the danger of going too far south for seed becomes apparent. In these plantation, the 200-mile zone immediately south of the plantation produces trees as tall as local sources, but beyond 200 miles, the growth is reduced.

In the Michigan plantation, trees from the far south were cold hardy and had good growth — somewhat of a contrast to that in the Iowa and Minnesota plantations. This is not entirely unexpected for the southern Michigan climate is definitely milder than climates of same latitude but further west.

Correlation Among Traits

For each plantation, there were significant correlations for height and diameter at ages 5 and 10 (Table 2). These correlations, based on provenance means, suggest that genetic effects for height and diameter are strong and stable and that selections made for either height or diameter at age 5 would hold well for selections made for either trait at age 10.

Data from the Illinois plantation showed a significant correlation between 2^d year leaf fall date and 10 year height and diameter (0.61**, 0.68**), and between 4th year flushing

percentage growth increase basis, the southern provenances have a lower rate than the northern provenances for the first few years. With time the growth rate increase for the two provenance groups tends to equalize or, as in the case in the Illinois plantation, the southern provenances rate of increase eventually exceeds that of the northern provenances. For the years 1974 to 1976, in Illinois, the percentage increase was 10% for the northern provenances and 17% for the southern provenances. In comparison, the values were 6 and 4% for the Indiana plantation. Cross-over of provenance growth curves has occurred, but only among closely associated curves, and the effect is minor and not considered significant at this time.

Several plantations were observed in the spring of 1977, following the extremely cold and dry winter of 1976-77. In the Illinois plantation, the average low temperature was 8° C below normal for January 1977 at Cairo, Illinois, 20 miles south of the planting. Rainfall for November through January was 92 mm, or 208 mm below normal. A few smaller branches in some of the trees of Texas and Mississippi origin died, but this only resulted in slightly thinner crowns. No trees died because of the severe winter conditions. By late spring, the crowns were full and dense. Growth was probably not reduced because of the winter damage.

In the Missouri planting, winter damage was severe on trees of Texas and Mississippi origin; almost every tree had dead branches in the crown (Figure 2, Table 3). As a result of the dieback, leaf flush was late in trees of these

Table 2. — Correlation¹ between height and diameter at ages 5 and 10 for all plantations.

	Height - age 10				Diameter - age 5				Diameter - age 10			
Height - age 5 ²	IL	IN	IA	KA	IL	IN	IA	KA	IL	IN	IA	KA
	0.86**	0.87**	0.83**	0.48 ^{NS}	0.93**	0.96**	0.91**	0.77**	0.81**	0.84**	0.83**	0.56*
	MI	MN	MO	OH	MI	MN	MO	OH	MI	MN	MO	OH
	.91**	.68**	.84**	.73**	.92**	-	.74**	.79**	.91**	-	.89**	.75**
Height - age 10	--	--	--	--	IL	IN	IA	KA	IL	IN	IA	KA
					.87**	.84**	.83**	.66**	.98**	.90**	.98**	.71**
					MI	MN	MO	OH	MI	MN	MO	OH
					.81**	-	.74**	.49*	.96**	-	.84**	.95**
Diameter - age 5 ²	--	--	--	--	--	--	--	--	IL	IN	IA	KA
									.87**	.87**	.85**	.65**
									MI	MN	MO	OH
									.87**	-	.62*	.57**

¹ * — 5 percent level; ** — 1 percent level.

² For Kansas plantation, height and diameter are for age 6.

date and 10 year height and diameter (-0.45*, -0.53*). The southern sources were first to flush in the spring and last to drop their leaves in the fall. Date of leaf flush by provenance varied from April 20 to May 1, while date of leaf fall varied from October 7 to November 4.

Growth Trends and Winter Damage

In the Illinois and Indiana plantations, where height was measured almost every year, we looked at the growth trends of provenances. In both plantations the actual height growth differences among trees from diverse provenances have increased with time. Several provenances were grouped for these growth trend comparisons. In the Illinois plantation, the height difference between the northern and southern origin trees increased from .21 meters to 1.40 meters in 10 years. In Indiana the height differences increased from .37 meters to 2.01 meters in nine years. On a yearly

provenances, just the reverse of the early flushing in previous years. In addition to the dieback and late flushing, one Texas and one Mississippi provenance had a high percentage of trees with sprouts and/or cankers that developed on the bole during the previous year. The sprouting probably developed in response to stress in the tree resulting from the cankers. The pathogen responsible for the cankers has not been indentified. Whatever the cause, the cankers very likely also weakened the trees and made them more susceptible to winter dieback.

The 1976—1977 severe winter had a pronounced effect on trees in the Kansas planting. Although only 5% of the remaining trees died, branches died back throughout the plantation (Table 4). The amount of crown that died back ranged from 6% for local trees to 42% for trees of Mississippi origin. The 1976—1977 crown dieback and tree mortality was definitely related to origin of seed. Mortality and

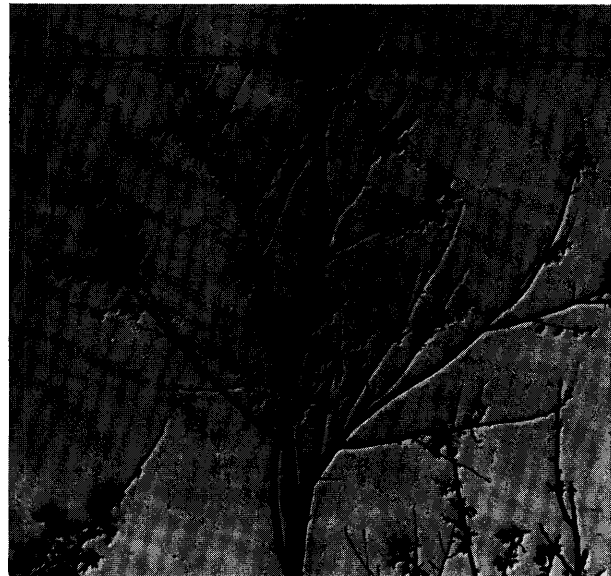


Figure 2. — Normal leaf flush of tree in Kentucky provenance (on left) and extensive winterskill and late leaf flushing in trees of Texas provenance (on right) in Missouri planting. Photos taken May 20, 1977.

Table 3. — Growth, sprouting, cankering, dieback, and leaf flush in trees in Missouri plantation.

Provenance no. and State	Lat. °N	Survival Percent	Ht. Ft.	DBH In.	Trees with	Trees with	Trees with	Leaf expansion on May 9:
					sprouting on bole in 1976	cankers on bole 5/19/77	dieback in crown	1-bud break 5-fully expanded
1802 IA	41.8	96	13.1	1.95	30	13	26	2.9
2702 MO	39.6	71	11.8	1.72	19	0	12	2.4
1707 IN	39.3	92	13.0	1.98	5	18	32	2.6
1709 IN	39.0	92	14.1	2.18	14	23	36	2.9
1902 KA	38.3	88	13.8	2.32	14	5	10	2.9
2704 MO	37.6	67	15.8	2.78	5	6	6	2.8
2001 KY	36.9	96	12.8	1.97	30	43	43	2.3
2707 MO	36.6	75	14.4	2.30	17	17	50	2.9
3804 TN	36.4	100	14.6	2.52	29	33	37	3.0
3803 TN	36.3	83	14.0	2.08	10	30	50	2.6
1101 AR	35.8	100	14.8	2.37	17	17	42	3.0
3102 NC	35.4	92	13.4	1.95	18	32	41	3.0
2602 MS	34.0	96	14.5	2.30	65	57	91	2.0
2601 MS	32.2	88	15.0	2.98	33	38	86	1.4
3902 TX	31.6	79	12.5	2.23	90	74	100	1.3

Table 4. — Percent of crown winterkilled, 1976 survival and 1977 (spring) survival for provenances in Kansas planting¹.

Provenance no. and State	Latitude °N	Longitude °W	Survival		Winter- kill ²
			1976	1977	
3903 TX	31.1	94.9	71	54	39
3601 SC	33.8	82.1	62	58	38
2602 MS	34.0	88.9	71	67	42
3105 NC	35.5	82.6	75	67	37
1101 AR	35.8	92.3	79	79	12
3804 TN	36.3	82.0	83	75	21
2707 MO	36.6	94.4	67	67	25
2003 KY	36.7	84.1	71	67	32
4103 VA	36.8	78.7	83	75	38
1904 KA	37.3	94.7	71	71	13
1708 IN	38.2	86.6	50	50	16
1902 KA	38.3	95.2	50	50	7
1704 IN	39.0	86.1	29	29	29
1903 KA	39.1	94.9	79	79	6
1803 IA	42.3	91.2	83	79	13

¹ 'Winterkill' is an estimate of amount of crown that died because of cold temperature.

² plantation is located at 39.2° N. Damage was minor in zone south to 37° N, or 150 miles south of plantation.

crown dieback was generally low among trees up to 150 miles south of the planting site and high for those from beyond 150 miles. Trees of one Arkansas provenance were an exception. They came from 235 miles to the south and had only 12% dieback. To be safe, it would be advisable to reduce the seed collection zone to about 150 miles to the south for Kansas walnut plantations.

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