

VARIATION AMONG GREEN ASH OF DIFFERING GEOGRAPHIC ORIGINS OUTPLANTED IN KANSAS

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Abstract. Green ash trees from 18 provenances were planted in a seed-source test in 1971 near Manhattan, Kansas, in the central part of the Great Plains Region. Most seed sources were from north of the planting site. After 20 years, growth measurements revealed that the tallest trees were from more southerly sources and/or those near the plantation site. Trees from moderate distances north (150 miles) of the planting site also showed adequate growth. Height and dbh age-age correlations were highly significant and increased when compared to age measurements of earlier intervals.

Throughout the Great Plains, green ash (*Fraxinus pennsylvanica*) is planted in shelterbelts and farmstead woodlots, as well as in urban settings. Its natural range extends throughout the eastern United States from eastern Texas to eastern Montana and south central Canada. Adaptation to such an extensive geographic range implies the presence of much genetic variation, which can be exploited for genetic improvement of the species (5,8). For example, Abrams et al. (1) reported that South Dakota seedlings had higher net photosynthesis and leaf conductance than New York seedlings. Seedlings from a xeric South Dakota location generally had smaller and thicker leaves, while seedlings from a mesic New York seed source had thinner and larger leaves. Van Deusen and Cunningham (6) found that trees of northern sources shed their leaves before those of southern sources in a North Dakota plantation. In 4 Western Gulf region plantations, Hendrix and Lowe (2) observed substantial variations in growth and wood specific gravity among 12-year-old green ash from different provenances. In a Mississippi plantation, Wells (7) demonstrated that 5- and 10-year-old trees from southern sources grew faster than those from northern sources.

High within-stand variation also was noted. Ying and Bagley (8) reported that age-4 green ash trees from Kansas and Oklahoma provenances suffered

mortality from winter damage in a North Dakota plantation, Kansas-source trees survived well yet had the poorest height growth in South Dakota, and Oklahoma trees had the poorest growth in central Nebraska. However, no differences were noted among green ash from 43 provenances in resistance to the ash borer, *Podosesia syringae*, according to Santamour and Steiner (3).

The purpose of this paper is to report the results of a 20-year Kansas study of green ash from various provenances.

Methods and Materials

Seedlings of 1-0 stock from 18 provenances were planted in a plantation at Tuttle Creek Experimental Area near Manhattan, Kansas (39.2°N and 96.5°W) in 1971 (Figure 1 and Table 1), where annual precipitation is about 30 in. The planting site is on a Eudora silty clay loam, which is a deep

Table 1. Provenances of green ash planted near Manhattan, KS, in 1971.

Source #	State	County	Lat. (°N)	Long. (°W)	Elev. (ft)
1-ND1	ND	Dunn	46 45'	103 00'	1343
2-ND2	ND	Morton	46 30'	101 30'	1644
3-ND3	ND	Ramsey	47 45'	98 45'	1465
4-ND4	ND	Barns	46 45'	97 45'	1221
5-ND5	ND	Morton	46 45'	101 00'	1644
6-ND6	ND	Burleigh	46 45'	100 45'	1674
7-SD1	SD	Ziebach	44 45'	102 00'	2755
8-SD2	SD	Perkins	45 30'	103 00'	2430
9-SD3	SD	Dewey	45 15'	101 00'	2031
10-SD4	SD	Potter	44 45'	100 00'	2082
11-SD5	SD	Spink	44 45'	98 45'	1300
12-SD6	SD	Hamlin	44 30'	97 00'	2265
14-NE1	NE	Cedar	42 30'	97 30'	1382
16-NE2	NE	Seward	40 30'	97 15'	1442
17-NE3	NE	Cass	41 00'	96 15'	1272
18-NE4	NE	Lancaster	40 30'	96 45'	1189
20-KS1	KS	Butler	37 30'	96 45'	1285
22-OK1	OK	Choctaw	34 45'	95 20'	785

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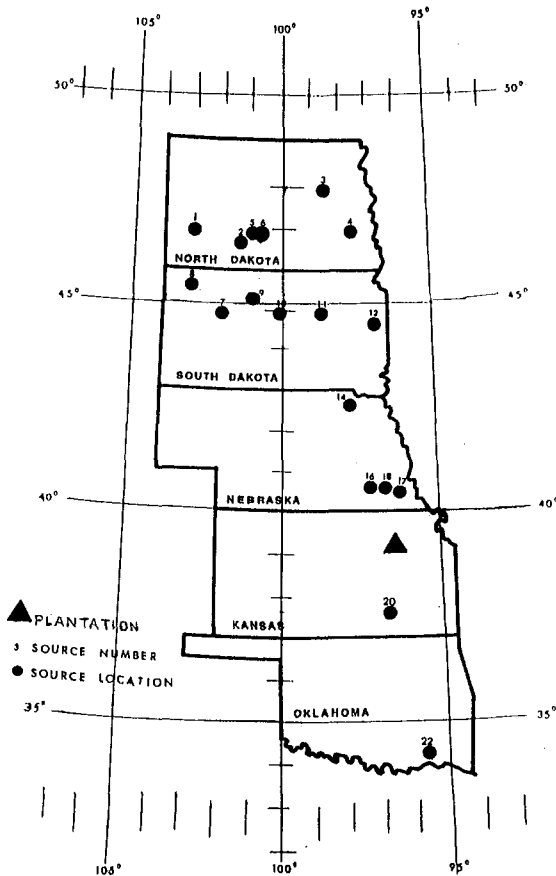


Figure 1. Green ash provenance locations of trees planted in 1971 near Manhattan, KS.

alluvial soil. The area was cultivated the first 5 years and neither fertilized nor irrigated. Each provenance was represented by a 4-tree linear plot in 3 blocks in a randomized complete block arrangement of treatments. This was predominantly a test of northern provenances (Table 1).

Total height, dbh (trunk diameter at 4-1/2 ft above ground), and survival were measured in 1975, 1982, 1987, and 1990 with a fiberglass telescopic pole and a metal diameter tape. Spring flushing of leaves (number of days after April 15 when the full crown had leaves of 1 in diameter) was recorded in 1993. Stem quality (9-ft butt log) was rated as straight, fork, crook, or sweep. Data were analyzed by analysis of variance using the SAS General Linear Model procedure (4) on an individual tree basis. Duncan's multiple range test

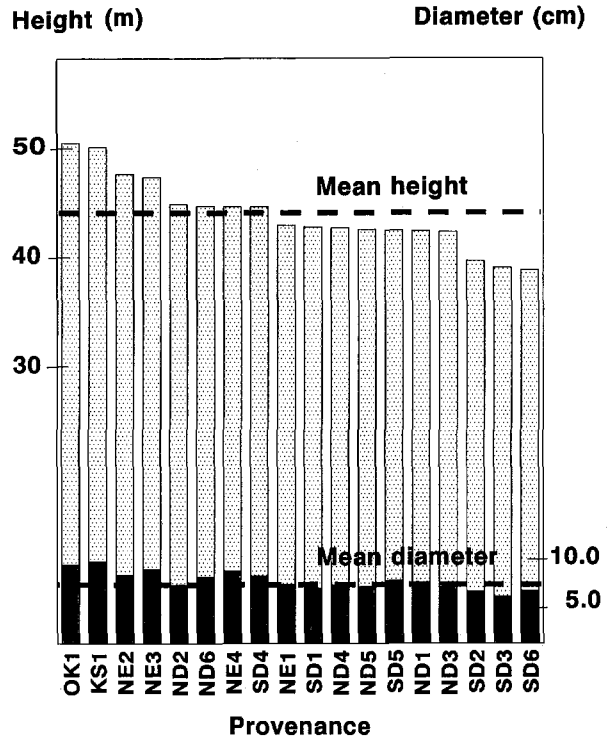


Figure 2. Twenty-year height and diameter measurements for green ash provenances.

was applied to means of provenance survival, height, and dbh. In addition, correlation analyses and stepwise regression analyses were applied to height and dbh with latitude, longitude, elevation, and provenance climatological data as independent variables. A chi-square test was applied to individual frequencies of log form to determine response probabilities across all provenances.

Results

Survival. Overall survival in this study was 97%. Trees of 14 provenances had 100% survival after 20 years. The lowest survival (83%) was for trees from South Dakota (SD6) and North Dakota (ND1).

Height and dbh. Trees from provenances as far as 550 miles north of our Kansas plantation grew well. Overall mean tree height at 20 years was 44.2 ft, with an average dbh of 7.4 in (Figure 2). Average tree height differed significantly (1% level) among provenances. Trees from Oklahoma, the most southerly geographic origin represented in this study, averaged 14.5% taller and 25.6%

larger in diameter than the overall plantation means. Trees from Kansas, Oklahoma, and 2 provenances from southeastern Nebraska (NE2 and NE3) grew significantly taller than trees from 3 northwestern South Dakota sources (SD2, SD3, SD6). Mean diameter ranged from 5.5 in South Dakota (SD3) to 9.7 in Kansas (KS1). The trees from Kansas and Oklahoma provenances have been among the tallest, and most South Dakota sources have been the shortest since age 5.

Stem quality. The chi-square test for stem quality revealed no significant difference among provenances. Of the 3 trunk (sawlog) quality categories, trees with a straight bole comprised 42%; those with forks, 24%; those with crooks, 15%; and those with sweep, 19%. However, when seed sources were grouped by tallest, middle, and shortest third rankings of total height, a significant stem quality difference was indicated, with the greatest percentage of trees with straight boles in the shortest category.

1993 spring flushing. All trees began their 1993 spring growth within 15 to 26 days after April 15. Sources differed significantly at the 1% level. The first trees to begin growth were from some South Dakota (SD1 and SD6) and North Dakota (ND2 and ND3) sources, flushing within 2 days of each other. The last trees to begin spring growth were from the southern Kansas source. Some significant correlations occurred between flushing and some geographic and climatic parameters, but they were low in value (Table 2).

Correlations and regression analysis. The greatest age-age correlations for height were among the most recent measurements (Table 3). Apparently, selection of trees at age 5 ($r = 0.37^{**}$) for good growth at age 20 may be less reliable than selection at age 12 ($r = 0.94^{**}$). The tallest onethird at age 5 were the tallest at age 20, while the others showed mixed rankings. The pattern for age-age correlations in dbh was similar to that for height (Table 3). Correlations of 1990 height and dbh with geographic and climatic traits of the provenances were significant but relatively low (Table 2). Stepwise regressions using all traits resulted in significant but low values. All 10 traits accounted for only 17.9% of the variation in tree height at 20 years.

Table 2. Correlations of growth measurements with geographic and climatic traits of the provenances for green ash.

	1990 height	1990 dbh	1990 survival	1993 spring flushing	1993 stem quality
Latitude	-.35**	-.42**	.27**	-.16	-.05
Longitude	-.27**	-.38**	-.22**	-.03	.10
Elevation	-.30**	-.34**	-.08	-.10	-.01
Mean annual temp.	.36**	.41**	-.23	.14*	-.01
Mean annual precip.	.35**	.41**	-.38**	.06	-.07
Mean #frost-free days	.37**	.45**	-.21**	.14*	-.02
Mean Jan. temp.	.35**	.39**	-.27**	.14*	.04
Mean Jan. precip.	.30**	.30**	-.53**	.04	-.09
Mean July temp.	.32**	.39**	-.11	.14	-.02
Mean July precip.	.31**	.37**	-.23**	.09	-.04
Spring flushing	-.07	-.02	.10	—	.12

*Significant at 0.05% level.

**Significant at 0.01% level.

Table 3. Correlations of height and dbh at 4 different time intervals for green ash.

	Height			Dbh			
	Yrs of Measurement			Yrs of Measurement			
Height	'82	'87	'90	'75	'82	'87	'90
1975 (5 yr)	.46	.38	.37	.82	.47	.46	.46
1982 (12 yr)		.83	.80		.73	.71	.70
1987 (17 yr)			.94			.70	.69
1990 (20 yr)							.69
Dbh							
1975 (5 yr)					.61	.59	.58
1982 (12 yr)						.93	.92
1987 (17 yr)							.99
1990 (20 yr)							

All significant at 0.01% level.

Discussion

Green ash from various Great Plains states survives and grows well in Kansas. This species seems to be well adapted to all portions of its range, from the Northeast (5) to the Gulf Coast (2), as well as the Great Plains (8).

Although the fastest growing trees came from provenances south of or near the planting site, trees originating from areas of moderate distances (150 miles) north of the plantation also provided adequate growth. However, we should emphasize that this plantation contains much greater representation of trees from northern provenances than from southerly areas and thus is not a good evalu-

ation of southern provenances (Figure 1). Similarly, the negative correlation between provenance longitude and height indicates that planting trees from areas of appreciable distances west of the planting site should be avoided; this is substantiated by the positive correlation between height and mean annual precipitation. Similar results were obtained by Wells (7) in an earlier study of green ash in Mississippi. However, the geographic and environmental variables that are useful for predicting seed-source performance at sites targeted for artificial regeneration were not identified clearly.

The stem quality of the trees revealed no significant differences among provenances; no regional characteristic could be determined.

The spring flushing data indicated that trees from South and North Dakota and Nebraska emerged earliest, followed by those from South Dakota, Kansas, and Oklahoma, with no geographic pattern observed.

Conclusions

Trees from southern sources were taller than those from northern sources, even though the number of southern sources was limited in this test. Thus, the generally accepted concept of clinal variation in which fastest growth occurs from southerly sources is supported by this research, although trees from long distances south of the planting site may not be as frost hardy as trees of local origin. These results indicate that green ash selections from Kansas, Nebraska, and Oklahoma will provide acceptable results for artificial regeneration efforts in Kansas; thus, trees from those sources should be selected for superior growth in Kansas for use in windbreaks and urban settings.

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Résumé. Des frênes de Pennsylvanie en provenance de 18 endroits différents ont été plantés dans un jardin commun d'essai en 1971 près de Manhattan au Kansas. La plupart des semences provenaient de sources situées au nord du site de plantation. Après 20 ans, les mesures de croissance prises ont révélé que les arbres les plus grands provenaient des sources de prélèvement des semences les septentrionales et/ou les plus près du site de plantation. Les arbres provenant de régions situées au nord, mais à des distances modérées, du site de plantation ont aussi donné une bonne croissance.

Zusammenfassung. 1971 wurden in der Nähe von Manhattan, Kansas, Eschen aus 18 verschiedenen Herkünften in einem Test in gewöhnlicher Gartenerde gepflanzt. Das meiste Saatgut kam aus Quellen, die nördlich des Teststandorts liegen. Nach 20 Jahren ergaben die Wachstumsmessungen, daß die größten Bäume aus mehr südlich gelegenen Herkünften und/oder aus der Nähe des Teststandorts stammten. Die Bäume aus nördlichen Gebieten mit einer mittleren Entfernung von ca. 150 Meilen vom Standort zeigten ebenfalls einen adäquaten Höhenzuwachs.