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Geographic Variation in Green Ash in the Southern Coastal Plain of the United States

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Abstract

A progeny-provenance test of green ash near Stoneville, Mississippi, is described. Nine seed sources (provenances) from the southern coastal plain were selected. Both latitude- and nonlatitude-related differences in 10 year height was demonstrated. Trees from a southern Mississippi seed source were about 3 feet taller than those from comparable latitude in Louisiana.

There was also evidence of considerable within-seed source variation in height. Statistically significant differences in height were noted among half-sib families from over one-half of the seed sources.

At 5 years, progeny of a putative pumpkin ash had markedly straighter stems than any of the other progenies in the test but at 10 years stems of all progenies had straightened to the point where differences were no longer discernible.

Key words: Progeny test, hardwoods, *Fraxinus profunda*, *Fraxinus pennsylvanica*.

Zusammenfassung

Es wird über die Ergebnisse aus einem Provenienzversuch mit 9 Herkünften von *Fraxinus pennsylvanica* Marsh., in der Nähe von Stoneville, Mississippi, berichtet, wobei das Saatgut von jeweils 10 Einzelbäumen geerntet worden war. 3 Herkünfte stammen aus der Küstenebene von North und South Carolina und 6 Herkünfte aus dem Mississippi-Tal vom südlichen Illinois bis zum südlichen Louisiana. Im Alter zehn war die Nachkommenschaft von einer Herkunft vom südlichen Mississippi 3 Fuß höher als Herkünfte aus vergleichbarer geographischer Breite in Louisiana. Offenbar gab es eine beträchtliche Variation in der Baumhöhe innerhalb der Herkünfte. Statistisch signifikante Unterschiede in der Baumhöhe wurden bei Halbgeschwisterfamilien von über der Hälfte der Herkünfte festgestellt.

5 Jahre alte Bäume einer Nachkommenschaft von einer mutmaßlichen *Fraxinus profunda* hatten deutlich geradere Stämme als einige andere Nachkommenschaften des Versuchs, aber bei den 10 Jahre alten Stämmen aller Nachkommenschaften, die sich bis zu diesem Alter gestreckt hatten, waren solche Unterschiede nicht mehr sichtbar.

Introduction

Green ash (*Fraxinus pennsylvanica* Marsh.) is a wide ranging species distributed from the Atlantic coast to the plains states and from Canada to the Gulf of Mexico. It is one of a small group of bottomland hardwood species that has been selected for culture in intensively managed plantations in the southeastern United States (Malac and Heeren 1979). Such use makes it a candidate for genetic

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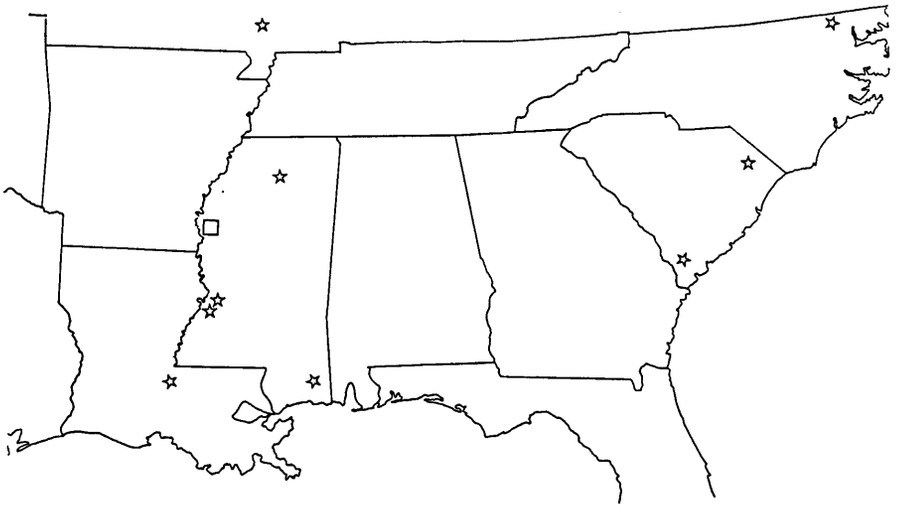


Figure 1. — Location of nine green ash seed sources (☆) and the planting site at which they were tested (□).

improvement and in fact improvement programs are being conducted in two areas of the southeast; east Texas, and the coastal plain of Virginia and North Carolina (Texas Forest Service 1978, Hardwood Research Cooperative 1978).

Wright (1944) recognized three ecotypes of green ash in the eastern part of its range; the northern, intermediate latitude, and southern coastal plain ecotypes. They were differentiated mainly on the basis of growth rate, cold hardiness, and timing of leaf fall at the end of the growing season. Meuli and Shirley (1937) also recognized three ecotypes along a north-south transect in the plains states from North Dakota to Oklahoma but because they had studied different traits and sampled different areas, comparison with Wright's test was not possible (Wright 1944).

Provenance tests established in the 1960s and 70s have resampled all the major parts of the range; the plains states (Ying and Bagley 1976), Quebec-Manitoba and as far south and west as North Carolina and Arkansas (Carter 1983, Steiner 1983), and the southwestern portion of the range (Texas Forest Service 1978). The present test was carried out in the southern Coastal Plain.

Materials and Methods

Seed was collected in either 1967, 1968, 1969, or 1971 from three areas in the coastal plain of North and South Carolina, and six areas down the Mississippi River Valley from southern Illinois to southern Louisiana and Mississippi *(Fig. 1)*. Seed was collected from 10 trees in each area (a nested design) and parent identity maintained throughout the study. Selection criteria for individual trees undemanding a wide range of phenotypes was accepted. Areas were generally less than a mile in width or breadth and it was specified that individual trees be separated by at least 200 yards to minimize relatedness. Seed was stored at about 2^0 C and stratified in moist sand for 90 days before sowing to minimize differences due to variation in germination speed. Stock was grown for 1 year in a nursery on the Harrison Experimental Forest in southern Mississippi and planted in bare-root condition. A combination of seed and stock shortages reduced the total number of $^1/_2$-sib families available for planting to 78. The planting reported on here was established in February, 1973 on the Delta Experimental Forest, Stoneville, Mississippi. The planting area was a recently cleared forest site with Sharkey clay soil. Site index varied from 75 to 95 (Broadfoot 1976) around a poorly drained central area. Blocks were arranged on the contour around this depression. Seven blocks (replications) of 78 half-sib families, representing the nine seed collection areas, were planted. A compact-family-block design was used (Wright 1976) with four-tree, half-sib family, row-plots grouped to represent a particular seed collection area. A half-sib family consisted of seedlings from a single female parent tree. Spacing was 8 × 8 feet. The planting was cultivated several times a year for the first 3 years to minimize weed competition and growth rate was rapid from the start on the fertile, alluvial soil. Mortality has been negligible and competition became intense at about 8 years with an accompanying drastic reduction in growth rate. Height was measured at years 3, 5, and 10, and form was scored at 5 years by devising 5 form classes (1 = best, 3 = average, 5 = poorest). After the 10th growing season, the planting was thinned by removing every other row on the diagonal.

Table 1. — Height and form at 5 years and height at 10 years of green ash from nine seed sources planted at the Delta Experimental Forest, Stoneville, Mississippi. Significant differences in height among the families within a seed source are indicated by a "Δ".

Seed source	Height at:		Form at 5 yrs
	5 yrs	10 yrs	
	----------feet----------		---grade[2]---
09 southern MS	20.8a[1]	34.2a	Δ3.4ab
08 south LA	Δ18.5 b	Δ31.9 b	Δ3.4ab
06 southwest MS	Δ18.6 b	Δ31.7 bc	3.6 bc
10 southwest MS	Δ18.0 bcd	Δ30.5 bcd	Δ3.6 bc
13 north MS	Δ17.6 cd	Δ30.4 bcd	Δ3.5 b
16 south IL	Δ17.2 de	29.4 cd	3.4ab
04 southeast SC	18.1 bc	32.1ab	Δ3.2a
03 northeast SC	18.3 bc	31.5 bc	3.5 b
01 northeast NC	Δ16.4 e	Δ28.8 d	3.8 c

[1]) Means opposite the same letter do not differ significantly at the 0.05 percent level.
[2]) 1 = best form, 5 = worst.

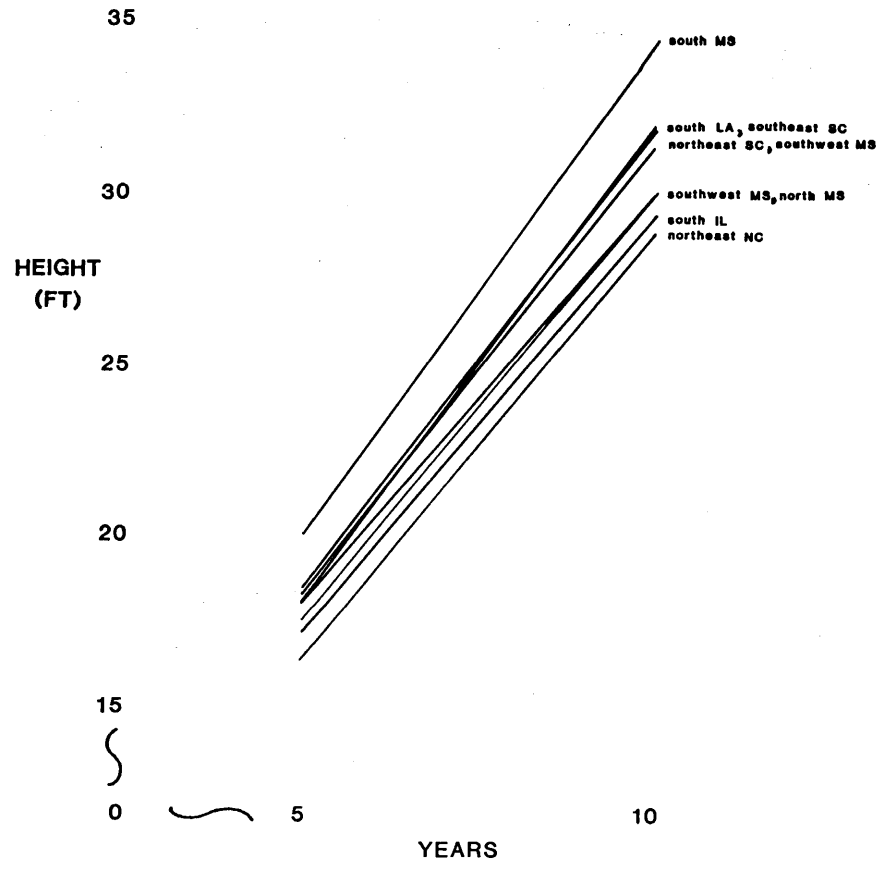


Figure 2. — Height (feet) over age for green ash from 9 seed sources planted in west-central Mississippi.

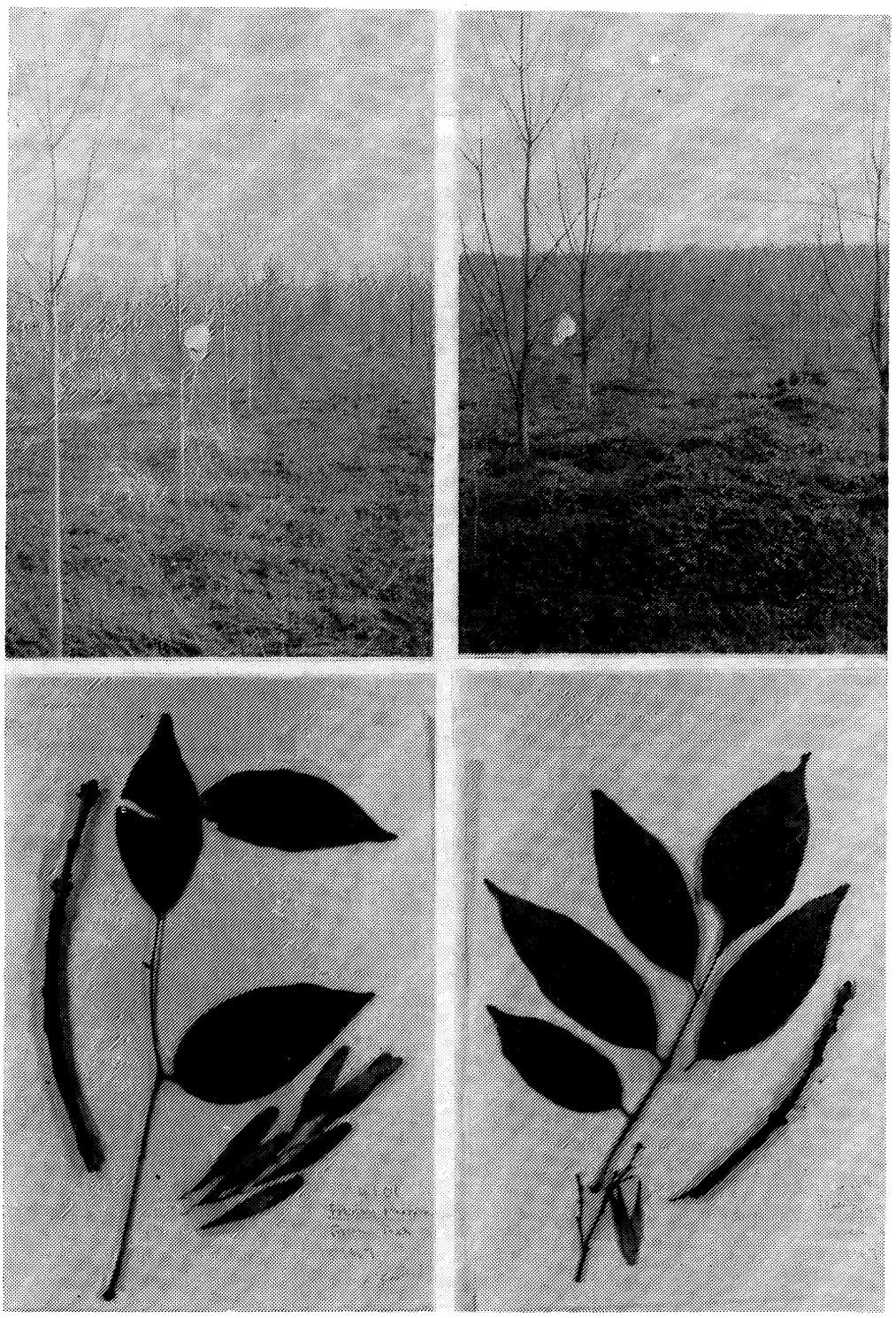
Plantings were also established in several other localities (southern Illinois, northeastern Arkansas, east-central Mississippi, south Mississippi, and North and South Carolina) but in every case growth was very slow and even with post-planting weed control they did not yield usable data. Choice of site was probably the crucial factor although less than ideal weed control probably also contributed to some of the failures. The combination of high fertility and intensive cultivation on the Delta Experimental Forest were probably the most important factors that made this planting a success.

ANOVA was first used to determine if there were differences among half-sib families within each of the seed sources represented in the planting. Degrees of freedom for analysis of data from a typical single seed source were: blocks = 6, families = 9, error = 54. The experimen-

Table 2. — Height at 10 years (feet) of half-sib families of green ash from nine seed collection areas in the southeastern U.S.

SEED COLLECTION AREA																	
northeast NC		northeast SC		southeast SC		southwest MS (06)		south LA		south MS		southwest MS (10)		north MS		south IL	
fam.	ht. [1]	fam.	ht.	fam.	ht.	fam.	ht.	fam.	ht.	fam.	ht.	fam.	ht.	fam.	ht.	fam.	ht.
1	30.5a	5	32.4a	6	34.0a	4	34.1a	3	33.4a	7	35.4a	9	33.4a	2	32.1a	7	30.6a
4	30.0a	4	32.4a	2	33.0a	10	34.0a	10	32.8a	6	35.2a	2	32.2a	7	31.3ab	10	30.2a
5	29.9a	6	32.0a	3	33.0a	1	31.9ab	8	32.6a	10	35.2a	10	31.8ab	6	31.2ab	1	30.1a
9	29.8a	2	31.7a	9	32.6a	3	31.6 b	2	32.3a	8	32.2a	1	30.2abc	8	31.2ab	6	29.6a
10	29.6a	8	31.5a	5	32.5a	9	31.2 b	9	31.6ab	2	34.7a	3	30.1abc	10	30.2ab	5	29.6a
8	29.1ab	7	31.4a	4	31.6a	7	31.1 b	6	31.5ab	9	34.0a	4	28.1 bc	9	29.9abc	8	29.5a
7	28.5abc	1	30.9a	8	31.6a	5	31.0 b	5	31.3ab	4	33.0a	6	27.6 c	3	29.7 bc	3	29.2a
2	27.6abc	9	30.7a	7	30.6a	2	30.7 b	4	31.2ab					4	27.8 c	9	28.8a
6	26.7 bc	10	30.4a	1	29.9a	8	30.0 b	1	30.1 b							2	28.7a
3	25.8 c															4	27.7a
Mean	28.8		31.5		32.1		31.7		31.9		34.2		30.5		30.4		29.4

[1]) Means opposite the same letter do not differ significantly at the 5 percent level of significance.



A B

Figure 3. — A. Foliage, twig, seeds, and progeny of putative pumpkin ash. B. Specimens and progeny typical of the other parent trees in the study.

tal unit was the mean of a 4-tree family plot. Sums of squares and degrees of freedom for family and error terms, from individual seed sources were then pooled to form overall terms relating to all nine seeds sources. Family and seed collection area means were compared by Duncan's Multiple Range Test at the 0.05 percent level. Seed source means, which were based on (up to) 40-tree plots, are necessarily more precise than family means within seed sources which were based on 4-tree plots.

Results and Discussion

Height at both 5 and 10 years was correlated with latitude of seed origin in that the northern trees were slowest growing, the southern trees grew fastest, and trees of in-

termediate latitude were growing at an intermediate rate *(Table 1)*. However, the performance of the southern Mississippi trees demonstrates major non-latitude related variation *(Fig. 2)*. The southern Mississippi trees were 2.2 feet taller than the southern Louisiana trees at both 5 and 10 years. No satisfactory explanation for this difference in growth rate is evident.

Variation in growth rate among trees within seed collection areas is also quite large. Statistically significant differences in height were noted within six of the nine seed sources at 5 years and five at 10 years *(Table 2)*. In addition, ANOVA of data from all seed sources combined indicated that the amount of individual tree variation in height at 5 and 10 years is significantly greater in some seed collection areas than in others. Altogether, this is evidence of considerably greater within-stand variation in growth rate than was the case in a similarly designed test of sycamore (Wells and Toliver, in press). In the sycamore test, only 1/3 of the seed sources showed significant variation within and the combined analysis with data from all seed sources showed a non-significant within-stand effect.

Other investigators have concluded that individual-tree variation is particularly large in green ash (Ying and Bagley 1976, Texas Forest Service 1978), and Steiner (1983) has reported a zone of particularly fast growth rate extending from west-central Illinois to eastern Nebraska. None have reported the large stand-to-stand nonlatitude related variation in growth rate exemplified here by the south Mississippi and Louisiana seed sources. This effect indicates that selection for fast growth rate would be most efficient if many stands were sampled at random within the chosen geographic area. Little emphasis should be placed on the phenotypes of the individual trees in these stands except perhaps some eugenic standards should be set. Once superior stands have been identified by progeny testing intensive selection for individual trees within these stands would be appropriate. This reasoning is based on only tenth year data, of course, but the nonlatitude related variation is quite strong and shows no signs of weakening between 5 and 10 years *(Fig. 2)*.

The progeny of one tree selected in southwest Mississippi (area 06) were of particular interest. The seed of this tree were much larger than average *(Fig.2)* and the 5-year-old progeny were straight, with light grey bark in contrast to all other progeny which were crooked with darker colored bark *(Fig. 3)*. At 5 years, this variation in straightness appeared to be an opportunity for sizeable genetic gain through selection but at 10 years it was observed that all the other families showed marked improvement in stem form to the point where the progeny of the large-seeded parent were indistinguishable. Natural stem straightening with age is characteristic of green ash (Schlesinger 1972) so it would seem superfluous to select for straightness in 5-year-old trees. The large-seeded parent may have been the variant referred to as pumpkin ash *(F. profunda* [Bush] Bush) as it is known to have large seed but all other characteristics of this particular parent tree seemed typical of green ash. The taxonomic status of pumpkin ash as a matter of controversy as some taxonomists consider the variation observed here to be within the limits of typical green ash (J. R. Watson, personal communication).

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Some Results of Inbreeding Depression in Serbian Spruce (Picea omorika (Panč.) Purk.)

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Summary

Results of a 24 year old inbreeding study of Serbian spruce *(Picea omorika)* are reported. Eleven selfs and 10 outcrosses were tested in five field trials located in northern West Germany. Height and d.b.h. were measured at age 4, 6, 9, 12, 15, and age 15, 24, respectively. At age of 15 years the average height of the selfs was 480 cm compared to a height of 660 cm for the outcrosses. The selfs had a diameter of 3.2 cm (age 15) and 6.9 cm (age 24) compared to 4.9 cm (age 15) and 9.9 cm (age 24) for the outcrosses. Variation of the metric traits was greater in selfed than in outbred progenies. In general, inbreeding depression was unexpected high.