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Geographic Variation in Specific Gravity and Fiber Length of Green Ash (Fraxinus pennsylvanica Marsh.) in East Texas

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Abstract

Specific gravity and fiber length were evaluated in three, ten-year-old green ash genetic tests in East Texas which contained 42 open-pollinated families representing seven East Texas provenances. Fiber length was significantly affected by family within provenance and the plantation × provenance interaction. No consistent geographic pattern of variation was discernible for this interaction. Specific gravity was significantly affected by plantation, provenance, family within provenance, and the plantation × family within provenance interaction. Family heritability estimates for specific gravity and fiber length were 0.80 and 0.73, respectively. Coefficients of genetic prediction between fiber length and growth parameters were small; those between specific gravity and growth parameters were near 0. Based on these data, a tree improvement program could be expected to produce moderate gains in specific gravity. Among family variation in fiber length was too small to warrant attempts at genetic improvement.

Key words: Progeny testing, heritability, provenance, genotype × environment interaction.

Introduction

Green ash (*Fraxinus pennsylvanica* MARSH.) is a widely distributed North American species whose range encompasses the eastern half of the United States and southern Canada. Uses for its wood include handles, cabinetry, furniture and cooperage (VINES, 1960). Green ash is also used to produce paper (BARKER, 1974), although it makes a weaker pulp than American sycamore (*Platanus occidentalis* L.) or sweetgum (*Liquidambar styraciflua* L.).

Geographic variation in green ash has been investigated in Mississippi by WELLS (1986). At age 10 he found differences in height growth attributable to latitude of provenance, provenances within the same latitude, and individual trees within a provenance. Variation was great enough to suggest significant potential for genetic improvement. HENDRIX (1986) found similar results from four genetic tests in Texas, Arkansas, Mississippi and Louisiana. Both provenance and family within provenance differences existed for growth rate and specific gravity. Heritability values for growth parameters were intermediate (0.56), while heritability for specific gravity was high (0.89).

Fiber length and specific gravity affect the economics of making paper and the quality of the product (CLARK, 1978). The fineness of the fiber and its length determines paper smoothness and strength. If high wood density results from thick-walled fibers, paper quality suffers; however, the yield of pulp from a given volume of wood increases as specific gravity increases (CLARK, 1978).

The potential for genetic improvement of fiber length and specific gravity has been demonstrated for few hardwood species. Significant genetic variation in specific gravity was documented for American sycamore (NEBGEN and LOWE, 1982), based on data from three genetic tests in southeast Texas and southeast Louisiana. Genetic differences in fiber length have been found in genetic tests of white ash (*Fraxinus americana* L.) (ARMSTRONG and FUNK, 1980), and hybrid *Populus* clones (MURPHEY *et al.*, 1979).

In an earlier paper, STAUDER and LOWE (1983) reported data on height, diameter and volume from three green ash genetic tests in eastern Texas. The present study is a continuation of that work, examining specific gravity and fiber length data from the same plantations.

The objectives of this study were to determine the effects of provenance, family within provenance, and plantation location on fiber length and specific gravity of green ash; to estimate the narrow sense heritability for specific gravity and fiber length in East Texas; and to estimate the degree of correlation among these traits and growth parameters.

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Materials and Methods

The three plantations in Burleson, Montgomery, and Harrison Counties, Texas, were described by STAUDER and LOWE (1983). The Burleson County plantation is situated on a Ships clay soil (very fine, mixed, thermic Udic Chromustert)[3]) in the Brazos River bottom. The site was previously in annual crop production. The Montgomery and Harrison County sites were forested prior to being cleared for the experimental green ash plantings. Soils on the Harrison County site are fine-loamy, thermic, Aeric Fluvaquents of the Nahatche and Mantache series (USDA, 1974) whereas those on the Montgomery County site are Sorter silt loams (coarse loamy, siliceous, thermic Typic Ochraqualf) (USDA, 1972).

[3]) HARRIS, B. L.: **Personal communication. Extension Soil** Specialist, Texas Agric. Extension Service, College Station, TX., 1987.

Open-pollinated seed from 58 green ash ortets were collected in 1968 and 1970 from 15 counties in Texas representing seven geographic areas. These geographic areas were defined by STAUDER and LOWE (1983); the longitudinal divisions were based on rainfall patterns. Seedlings were produced at the Texas Forest Service Indian Mound Nursery near Alto, Texas, during 1971, and the three genetic tests were planted during early spring 1972.

The Burleson County test contained 26 families and four complete blocks; the plantings in Montgomery and Harrison Counties contained 50 families and six complete blocks. Families were represented by one four-tree row plot in each block. Eight families in each of the larger tests were omitted from the analyses because they occurred in one test only.

All planting sites were disked before planting and annually for three years after planting to control competing

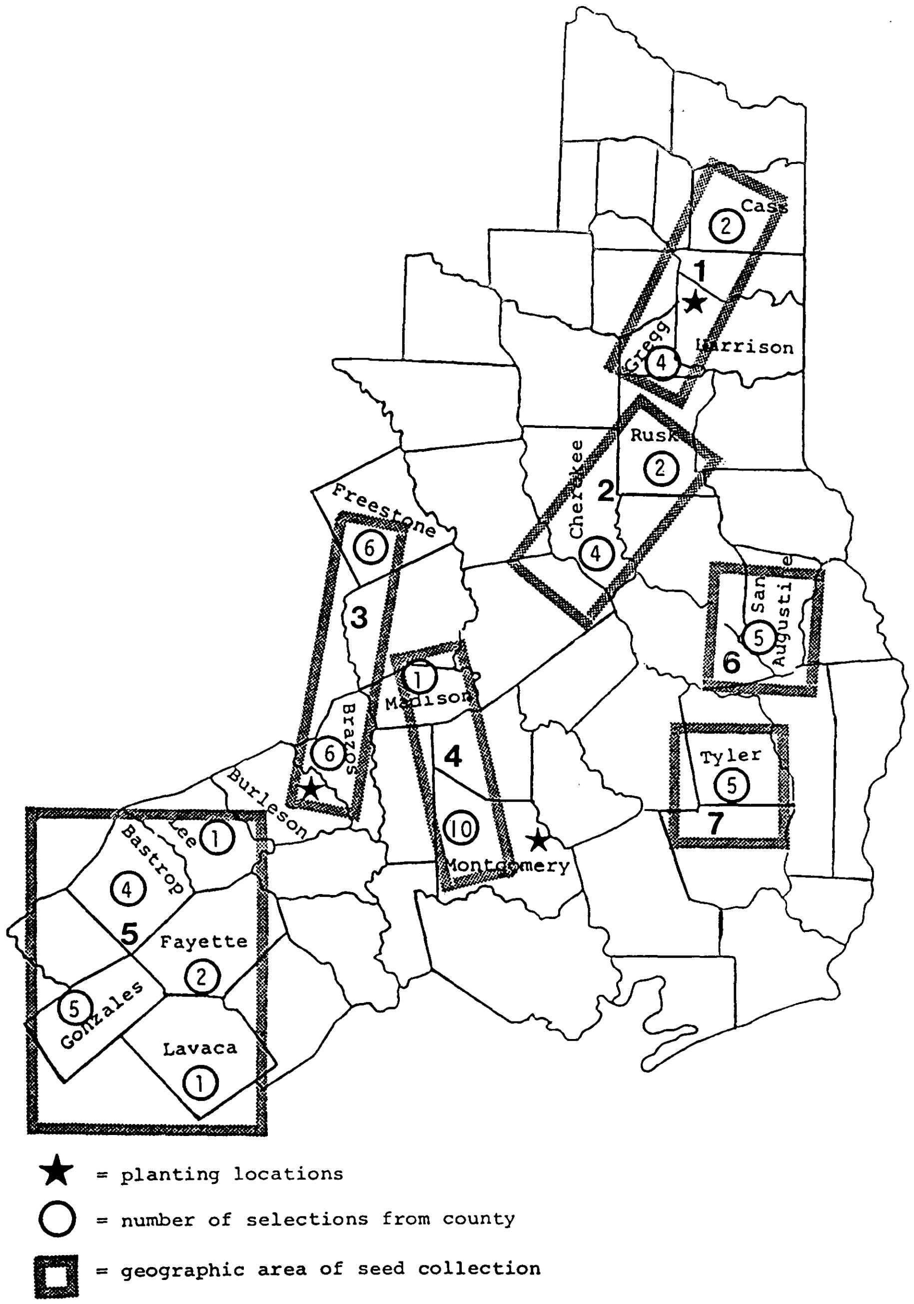

Figure 1. — **Geographic regions, numbers of families collected, and green ash genetic test locations in East Texas (From STAUDER and LOWE, 1983).**

vegetation. The test in Harrison County was fertilized with 345 kg/ha of 16-20-0 at age one, and the test in Montgomery County was fertilized with 13-13-13 at the rate of 470 kg/ha at two years after planting.

Tree height and DBH were determined at age 10 in all three plantations. Height was measured with a Suunto clinometer to the nearest 0.5 m; diameter was measured to the nearest 0.1 cm with calipers at 1.4 m from the ground. Planted tree volume in dm^3, based on a conic form, was calculated by

$$\text{Volume } (dm^3) = 0.02618D^2H \quad (1)$$

where D = dbh in cm and H = total height in m.

In 1982, bark to bark 5 mm diameter cores were extracted with an increment bore from all trees in each test at 1.4 m from the ground. Cores were collected from the same direction in all trees within a test; knots, crooks, and other areas of tension wood were avoided when possible. Samples were frozen in plastic bags until analysis. The maximum moisture method was used to determine specific gravity on each core (SMITH, 1954).

Wood from the last two growth rings (years 9 and 10) was used in fiber length determination. Rings were cut from both ends of the cores and divided into slivers. Samples were chemically macerated in a 1:1 solution of glacial acetic acid and hydrogen peroxide at 60^0 C for 48 hours (FRANKLIN, 1946). After maceration, the fibers were washed with distilled water and stained with basic fuchsin (ECHOLS, 1958). Samples were mounted on microscope slides in sodium silicate solution. Fifty fibers from each tree were measured with an ampliscope (ECHOLS, 1959).

Specific gravity and fiber length data from the three plantations were combined with height, diameter and volume data and subjected to analysis of variance. Plantation, block, and family were treated as random effects, while provenance was considered a fixed effect (*Table 1*). In cases where there was no valid F statistic, the Satterthwaite pseudo-F statistic was used (HICKS, 1973). Duncan's multiple range test was applied to plantation means of specific gravity and fiber length. All tests of significance were done at the five percent level.

Narrow sense heritability (h^2) values, based on open-pollinated families, and coefficients of genetic prediction (CGP) (BARADAT, 1976) were calculated for height, diameter volume, specific gravity, and fiber length. Heritability figures for height, diameter, and volume of these three plantations were published by STAUDER and LOWE (1983) and will not be discussed in the present article.

Results and Discussion

Fiber Length

Family means for fiber length ranged from 0.98 mm to 1.14 mm, with an overall mean of 1.05 mm. Family within provenance accounted for a significant portion of the variation in the fiber length (*Table 1*). No significant effects on fiber length could be attributed to provenance or plantation, though the plantation × provenance interaction was significant.

These results were similar to those reported for sweetgum by JOHNSON and MCELWEE (1967). In their study, they found no broad geographic effects on fiber length, while trees in stands within geographic regions showed significant differences in fiber length. Although genetic and environmental effects were confounded in their study, it suggested that sweetgum fiber length varied on a local scale rather than a broad geographic scale. Our data indicated a similar case for green ash.

Table 1. — Analysis of variance and expected mean squares for fiber length and specific gravity of green ash from three ten-year-old open-pollinated genetic tests planted in East Texas.

Source of Variation	dF	Fiber Length MS	Fiber Length F	Sp. Gravity MS	Sp. Gravity F	Expected Mean Squares
P1/	2	.0925	0.48	.0673	58.93**	$\sigma^2_e + 2\sigma^2_{P*F(Pr)} + 13\sigma^2_{B(P)} + 69\sigma^2_P$
B(P)	13	.1920	66.69**2/	.0009	2.49**	$\sigma^2_e + 28\sigma^2_{B(P)}$
Pr	6	.0224	1.17	.0086	2.48*	$\sigma^2_e + 5\sigma^2_{B(P)*Pr} + 5\sigma^2_{P*F(Pr)} + 11\sigma^2_{F(Pr)} + 23\sigma^2_{P*Pr} + 62\sigma^2_{Pr}$
F(Pr)	35	.0109	3.66**	.0030	5.01**	$\sigma^2_e + 6\sigma^2_{P*F(Pr)} + 13\sigma^2_{F(Pr)}$
P*Pr	10	.0112	3.24**	.0011	1.54	$\sigma^2_e + 5\sigma^2_{B(P)*Pr} + 5\sigma^2_{P*F(Pr)} + 29\sigma^2_{P*Pr}$
P*F(Pr)	56	.0030	1.03	.0006	1.65**	$\sigma^2_e + 5\sigma^2_{P*F(Pr)}$
B(P)*Pr	72	.0034	1.17	.0005	1.24	$\sigma^2_e + 6\sigma^2_{B(P)*Pr}$
B(P)*F(Pr)	407	.0029		.0004		σ^2_e

1) P = plantation, B = block, Pr = provenance, F = family
2) ** Significant at the 1 percent level, * Significant at the 5 percent level

The significant plantation × provenance interaction indicated that provenances responded differently in different planting locations (*Figure 2*). Trees from region 6 (San Augustine County) consistently produced long fibers in all three plantations; however, no other consistent

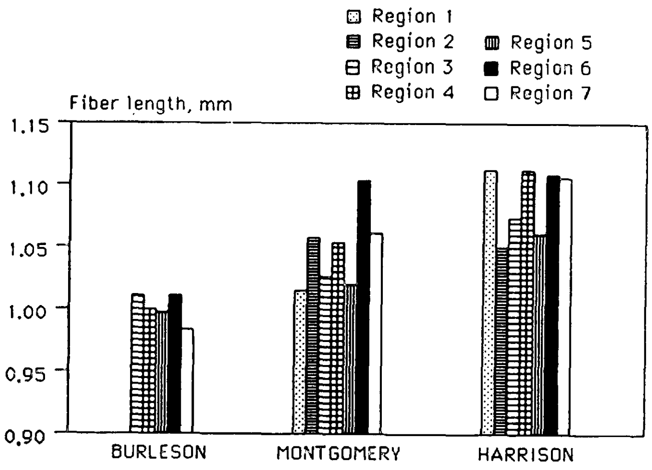

Figure 2. — Provenance means of fiber length for three green ash genetic tests in East Texas. Regions 1 and 2 were not represented in the Burleson County test.

Table 2. — Provenance means of green ash specific gravity in three genetic tests planted in East Texas.

Provenance	Counties	Specific Gravity (gm/cc)
1	Gregg, Cass	0.549 bc[1]
2	Cherokee, Rusk	0.536 d
3	Freestone, Brazos	0.566 a
4	Madison, Montgomery	0.553 b
5	Lee, Bastrop, Fayette, Gonzales, Lavaca	0.547 bc
6	San Augustine	0.566 a
7	Tyler	0.542 cd

[1]) Means followed by the same letter are not significantly different at the 95 percent level, according to DUNCAN's multiple range test.

pattern of variation related to distance or direction of seed source movement could be detected.

Specific Gravity

Provenance means for specific gravity ranged from 0.536 to 0.566; however, no geographic pattern was evident. The significant effect of provenance (*Table 1*) was in agreement with HENDRIX (1986) from green ash provenances in Texas, Arkansas and Louisiana. The significant effect of plantation on specific gravity was expected because the three tests were on very different sites, and HENDRIX (1986) reported similar results in four green ash genetic tests. Specific gravity ranged from 0.527 for the Montgomery County test to 0.575 for the Harrison County planting. The Burleson County planting had an average specific gravity of 0.569. The range of specific gravity means was greatest for family means (0.078), indicating a potential for improving specific gravity in green ash breeding programs. Selection pressure for improving specific gravity should be placed at the family level instead of the provenance level. The family variance component was substantially larger than the provenance variation component (0.134 vs. 0.007) and accounted for 85 percent of the total genetic variation.

Because the plantation × family within provenance interaction was significant, SPEARMAN rank correlation coefficients were calculated for families between plantings. Rank correlation between the Montgomery and Harrison County plantings was high (0.72, alpha = 0.0001) while that between the Montgomery and Burleson County plantings was moderate (0.60, alpha = 0.001). The smallest degree of correlation was between the Burleson and Harrison County plantings where the SPEARMAN coefficient was 0.37 with alpha = 0.06. These two sites were the most disparate in terms of climatic and edaphic factors, so a lower correlation was expected. STAUDER and LOWE (1983) reported that the family volume rankings at age 10 were similar between the Harrison and Montgomery sites, and the Burleson County site was quite different from the other sites. The plantation × family within provenance interaction would probably not be important in a breeding program because families which produced high specific gravity wood in all three plantations could be identified. The development of separate breeding populations would not be justified because of the significant rank correlation among the plantings.

Heritabilities and Coefficients of Genetic Prediction

Family heritability for specific gravity in the present study was high (*Table 3*), indicating a genetic improvement program to identify sources of high or low specific gravity would be effective. Coefficients of genetic prediction between specific gravity and growth parameters indicated that specific gravity was essentially independent of growth rate. Therefore, specific gravity could be included in a breeding program without affecting volume

Table 3. — Family heritability[1]) (diagonals) and coefficients of genetic prediction for height, diameter, volume, specific gravity, and fiber length of open-pollinated green ash families in three genetic tests planted in East Texas.

Trait	Height	Dia.	Volume	Specific Gravity	Fiber Length
Height	0.72 (0.23)	0.61	0.62	-0.03	0.39
Diameter		0.55 (0.25)	0.57	-0.05	0.28
Volume			0.55 (0.25)	-0.03	0.28
Spec. grav.				0.80 (0.23)	0.33
Fiber len.					0.73 (0.24)

[1]) Numbers in parentheses are standard errors for heritability values.

improvement (*Table 3*). This was in partial contrast to HENDRIX (1986). He reported a weak negative relationship between specific gravity and diameter (CGP = −0.28), but essentially no relationship between specific gravity and height or volume.

Fiber length was highly heritable, with a family heritability of 0.73 (*Table 3*). Family means across plantations ranged from 0.98 mm to 1.14 mm, while within plantation family means ranged from 0.94 mm to 1.17 mm. Coefficients of genetic prediction between fiber length and growth parameters ranged from 0.28 to 0.39. Based on these data, selection for volume growth in a breeding program would not have negative impact on fiber length. However, because the range in fiber length among family means was so small (0.16 mm,or 15 percent of the overall mean), and because other commercial bottomland hardwoods produce longer fibers than green ash (FOSTER and Thor, 1979; EZELL and STEWART, 1981), it is doubtful that a breeding program to select for longer fibers in green ash would be useful.

Conclusions

Genetic and environmental factors influenced fiber length in green ash. However, it appeared that local genetic variation was more important than geographic variation. No discernible pattern of geographic variation could be identified.

Fiber length was a highly heritable characteristic which was moderately related to growth rate in green ash. It should be possible to select for volume improvement without reducing fiber length. However, selection for fiber length would not be useful, since the range among family means was small.

Specific gravity of green ash was affected by plantation, provenance and family within provenance. A significant plantation × family within provenance interaction existed for specific gravity; however, families with high specific gravity at all test locations could be identified.

Specific gravity was highly heritable and unrelated to growth parameters. Selection of high or low specific gravity families could be made without significant loss of volume gains in a breeding program.

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The Xylem Resin Terpene Composition of Pinus greggii Engelm. and Pinus pringlei Shaw

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Summary

Stem-xylem oleoresin was collected from natural stands of one provenance (33 trees) of *Pinus greggii* ENGELM., and one provenance (26 trees) of *P. pringlei* SHAW, in Mexico. The samples were analysed for monoterpene and sesquiterpene composition by gas-liquid chromatography using OV1 and CW20M capillary columns. Frequency distributions and mean terpene values and ranges, as percentages of total terpenes present in the samples, for seven major terpenes, were used to identify distinctive terpene profiles in each species. Little intra-specific variation was encountered in *P. greggii*, which typically contained high levels of limonene and β-phellandrene. However, substantial variation was observed in *P. pringlei*. It was