GENETIC VARIATION OF SIX-YEAR-OLD OPEN-POLLINATED PROGENY OF SWEET PECAN TREES

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Abstract.--Open-pollinated progenies from the 10 best phenotypes within each of 4 localized stands of pecan were grown in plantations at two different locations. Five years after outplanting, the trees on a well-drained upland site were significantly taller and had 30% greater survival than the progenies on a moderately-drained bottomland site. Family-within-stand variation was found to be significant for height and survival but there was no variation among stands nor were there genotype-by-environment interactions ($p < .05$). Individual tree heritability for height was .17 and family heritability was 0.48. By selecting the best four families realized gain was 29% for height and 5% for survival. Phenotypic selection of the best trees was found to be of no value when the selected progeny were compared to progeny of unselected trees within the stands.

Additional keywords: Carya illinoensis, genetic gains, half-sib families, heritability, phenotypic selection.

Sweet pecan (Carya illinoensis (Wangenh.) K. Koch) is well known for its sweet nut meat and high quality wood. Although successful genetic selection for nut quality and production has been attained for many years in the South, little attention has been given to genetic improvement for wood production. In the mid-1950's, demand for high quality pecan logs increased (Adams and Thielges 1974) and this plus the clearing of much of the bottomland hardwood sites where pecan naturally occurs has led to a decrease in supply.

Pecan is most commonly found and grows best on well-drained, loamy soils along river-front ridges and flats (Fowells 1965). The existence of many acres of sweet pecan orchards throughout the South indicates that the species can be grown under intensive culture and on a wide variety of sites. Pecan can be important to landowners as they can establish plantations of trees at relatively close spacings to produce high-quality veneer logs and perhaps take advantage of the income of annual nut crops. Thus, it appears to be a good species for planting and the selection of genotypes capable of rapid growth and good form is important.

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This study was initiated to investigate the source and degree of genetic variation among stands and half-sib families of sweet pecan. It was also designed to determine the efficiency of moderate phenotypic selection of individual trees or stands and selection by progeny testing (Adams 1976).

METHODS

Four relatively pure stands (groups) of pecan trees were located within mixed bottomland hardwood forest on Raccourci Island near the Mississippi River in south-central Louisiana. These stands were approximately two acres size and from 0.5 to 5 miles apart. Within each of these stands the ten best parent trees were selected based on their superior phenotypic appearance relative to neighboring trees. Selection of the best trees was based on apparent vigorous growth, position of the crown (dominant or codominant), straightness of bole, absence of limbs for at least 10-15 meters of the bole length and a full, live crown for at least one-third of the total height of the tree (Adams 1976).

Open-pollinated seed were collected from each selected tree and kept separated. In addition, seed were collected and composited from other unselected pecan trees within each stand. These four composited collections were used as check seed-lots against the selected trees from within their respective stands (Adams 1976).

The seed were stratified and planted in a nursery in the Spring of 1974. The resulting 1-0 half-sib seedlings were planted in the Spring of 1975 at two locations. One test was planted on Bass Pecan Company property near Lumberton, Mississippi. The soil at this site is a mature, loamy, well-drained soil previously occupied by longleaf pine (Pinus palustris Mill.). The second test was planted on an old field located near Baton Rouge, Louisiana. The soil is a relatively young, heavy clay, moderately-drained alluvial soil of the Mississippi River flood plain.

Both plantations were laid out in a randomized block design, each consisting of four replications. Included at random within each replication were 40 half-sib families (4 stands, 10 families per stand) and the 4 composited seed-lots, with each represented by single row plots of 5 seedlings. The seedlings were planted on a 3 m x 3 m spacing.

After 5 years of growth in the field, height of the half-sib trees was measured and survival was calculated. The Statistical Analysis System (SAS) procedure GLM (General Linear Model) as described by Ray et al. (1982) was used to perform the analysis of variance. SAS procedure VARCOMP was used to compute the variance components to estimate heritability.

RESULTS AND DISCUSSION

Plantation Performance

Mean height and survival of the trees in the five-year-old planta n were 97 cm and 79%, respectively. Height and survival were significantly superior at the Lumberton, Mississippi, site (Table 1). Climatic condition at both plantations were very similar. However, the two sites were quite different in terms of soil fertility, soil structure, and soil texture with the Baton Rouge site appearing to be the more favorable according to soils analyses (Sparks 1977).

Table 1. Overall means of height and survival of six-year-old half-sib pecan trees grown at two locations.[1]

Location	Height (cm)	Survival (%)
Lumberton, MS	113	95
Baton Rouge, LA	76	65

[1]Means of both variables are significantly different ($p < 0.05$).

The superior performance of the seedlings located on the Lumberton upland site over the Baton Rouge bottomland site is thought to be the resul of at least two factors. Soil at the Lumberton site was classified as a well-drained loam to sandy-loam soil, whereas the Baton Rouge soil was classified as a moderately-drained, silty-clay-loam to clay soil. Root systems of the trees at Lumberton probably grew and developed more rapidly and extensively, thus promoting early growth. Also, while not measured, weed competition appeared to be more intense at the Baton Rouge site even though both plantations were mowed or disked 2-3 times per year for the first three years (Sparks and Toliver 1978).

The superior growth and survival of the trees at the Lumberton site was evident when the trees were two years old. At that time, it was though that eventually the trees would better utilize the more fertile bottomland site at Baton Rouge and equal or surpass those at Lumberton (Sparks 1977, Sparks and Toliver 1978). However, the differences increased with 3 years of additional growth. At age 2 years, there was a difference of 11 cm (41% taller) in height and 14% in survival (Sparks and Toliver 1978). At age 6 years, these differences were 37 cm (49% taller) in height and 30% in survival. Thus, the Lumberton site was the better site and the growth and survival differences between the two sites had increased.

Genetic Variation

Among the potential sources of genetic variation, only differences among the selected half-sib families within stands were found to be significant for height and survival (Table 2). No significant differences were found among stands, implying that the four subpopu]ations were not genetically different for height growth or survival. Therefore, more gentle diversity exists among individual trees within the stands than among groups of trees or stands within the forest. This is not surprising when one considers the closeness of the stands to each other and the fact that pecan is wind pollinated. Single tree differences are common among forest trees and the location of Raccourci Island along the Mississippi River could enhance such genetic diversity. Seed could be carried great distances down-river by water. Thus, it is possible for some parent trees on the Island to be from different genetic populations but the population as a whole should be fairly homogeneous.

Table 2. Analysis of variance for height and survival after the fifth season of growth for half-sib families of pecan grown at two locations.

Source of Variation	df(ht)	MS(ht)	df(surv)	MS(surv)
Locations	1	345685.55*	1	25.10*
Reps(Locations)	6	31782.59*	6	2.37**
Stands	3	3111.84	3	0.12
Locations x Stands	3	5723.58	3	0.09
Families (Stands)	35	5546.59**	35	0.26**
Locations x Families (Stands)	30	2057.26	30	0.17
Error	1040	2024.82	1341	0.13

*p < 0.05; **p < 0.01

Neither the location by stand nor location by family -within-stand interactions were found to be significant. Thus, a genotype-by-environment interaction was not evident and it is assumed that the family performances are relatively the same at both plantations.

Phenotypic Selection versus Genetic Selection

One objective of this study was to determine if collection of seed from good phenotypes within a stand would result in a gain in growth and quality of the progeny. In all four stands, the mean height of the progen of the selected trees was less than the mean height of the progeny from the seed collected from the unselected trees (Table 3). Mean survival was also greater except in stand 1. The overall mean height of the unselected progeny was 108 cm versus 97 cm for the selects (a significant difference) and survival was 81% vs. 79%, respectively. Thus, phenotypic selection was not successful and seed could easily be collected and composited from any grcup of pecan trees on the Island without loss of growth or survival.

Table 3. Means of height and survival for six-year-old pecan trees grown on two sites.

Progeny from:	Ht(cm)	Survival(%)
All trees (selected and unselected	98	79
All selects	97	79
All unselected	108 **	81
Stand 1 (selects)	97	80
(unselected)	110	70
Stand 2 (selects)	93	77
(unselected)	108	85
Stand 3 (selects)	91	77
(unselected)	103	88
Stand 4 (selects)	104	80
(unselected)	113	82

**Significantly different ($p < .01$).

On the other hand, genetic selection through progeny testing has potential for substantial gain. Heritability estimates for height were 0.48 for family heritability and 0.17 for single tree. heritability based on the half-sib progeny of the selected trees. If these heritabilities hold and the range in heights as shown in Table 4 is maintained or increased, then gain in height could be achieved.

If one were to select the best 4 families (top 10%) based on height, then families 2-1, 4-8, 1-3, and 4-4 would be chosen (Table 4). Realized gain over the population means would be 28 cm (29%) in height and 5% in survival at age six years. Even a lower intensity of selection such as the best 10 (top 25%) would yield a gain of 18 cm (18%) in height and 1% in survival. Thus, selection through progeny testing should be successful in improving height growth and survival of pecan.

Table 4. Means of height and survival of 6-year-old half-sib families of pecan.

Stand-Family	Ht(cm)	Survival(%)	Stand-Family	Ht(cm)	Survival(%)
1-1	104	86	2-1	130	82
1-2	83	88	2-2	73	80
1-3	125	85	2-3	86	55
1-4	80	68	2-4	84	80
1-5	102	85	2-5	79	82
1-6	55	35	2-6	108	75
1-7	90	80	2-7	77	65
1-8	103	75	2-8	78	77
1-9	97	92	2-9	---	---
1-10	89	84	2-10	113	82
Stand 1 mean	97	80	Stand 2 mean	93	77
1-U	110	70	2-U	108	85
3-1	80	78	4-1	100	92
3-2	99	92	4-2	94	92
3-3	97	85	4-3	99	68
3-4	70	72	4-4	123	78
3-5	84	53	4-5	87	72
3-6	74	50	4-6	84	82
3-7	85	85	4-7	109	83
3-8	104	74	4-8	127	70
3-9	101	70	4-9	116	88
3-10	95	85	4-10	101	80
Stand 3 mean	91	77	Stand 4 mean	104	80
3-U	103	88	4-U	113	82

U: Unselected composited check.

CONCLUSIONS

After six years of growth, half-sib families of pecan trees grew bet on a well-drained upland site than on a moderately-drained bottomland sit Heavy weed competition on the bottomland site probably contributed to the poorer survival and growth of the trees.

Collection of seed from the best phenotypes within a stand did not result in a gain in height or survival over seedlings grown from seed collect from the unselected trees in a stand.

Family-within-stand variation in height and diameter was highly significant and considerable gain can be made by selecting the best families. No significant differences were found among stands and there was no evidence of genotype-by-environment interactions.

Based on data of six-year-old progeny of trees selected from a localizes population of pecan, progeny testing must be performed in order to obtain improvement in height and survival of pecan trees.

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