HEIGHT VARIATION IN A FIVE-YEAR-OLD YELLOW-POPLAR PROVENANCE/PROGENY TEST IN ILLINOIS

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Abstract.--Yellow-poplar height growth can be increased up to 10 percent by selecting the proper seed source; in southern Illinois this seed source is southwest Kentucky or Tennessee. Individual-tree selection in the progeny test will increase height growth from 3 to 7 percent, depending on whether applied with or without provenance selection. Stability analyses of height data indicated that selection of half-sib families on the basis of mean height alone should probably be avoided and that the seedling seed orchard approach would not be effective for improving yellow-poplar.

Additional keywords: Expected gains, heritability, stability analyses, Liriodendron tulipifera L.

Yellow-poplar (Liriodendron tulipifera L.) has been the subject of tree improvement research for more than 30 years (Limstrom and Finn 1956). In spite of this, little data have been published from large-scale provenance and progeny tests. In response to the need for such information and in order to expand the data base for this commercially valuable species, seed collections from north-south and east-west transects were used to establish provenance/progeny tests. The objective of this paper is to report on the distribution of variation in seedling height in a 5-year-old Illinois provenance/progeny test established approximately 50 miles outside the natural range of the species. 2/

METHODS

Seed were collected in the fall of 1976 from throughout the range of yellow-poplar; no special effort was made to select outstanding parent phenotypes, although unusually poor phenotypes were avoided. Seed were sown at the Tennessee Valley Authority nursery at Norris, TN, in the spring of 1977 and seedlings were shipped to Carbondale, IL, in spring 1978 for outplanting.

Provenances of seed used for the Illinois outplanting ranged from 35° N to 38° N latitude and 77° W to 90° W longitude (table 1). The plantation was established at the Principia College Farm, Elsah, Illinois (latitude 35° 57' N, longitude 90° 20' W), in May 1978 on a field that had been planted to corn the previous summer. The soil on this Mississippi River bluff site is" a deep Fayette silt loam. The progeny test consists of six open-pollinated families from each of nine stands in a randomized complete block design with eight blocks planted in 3-tree row plots at a spacing of 1,8 x 3.1 m. Weeds were controlled

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Table 1.--Location of yellow-poplar stands from which seeds were collected, mean stand survival, and average 5-year height

Stand number	Stand location	North latitude	West longitude	Survival (%)	Height (cm)
2-A	West Kentucky	37° 0'	87° 45'	83	329
14-B	Tennessee-Cumberland Plateau	35° 30'	90° 50'	78	323
14-A	Central Tennessee	35° 20'	87° 45'	68	316
3-A	West Tennessee	35° 50'	88° 50'	86	308
12	Piedmont, North Carolina	35° 30'	78° 30'	69	288
15	East Arkansas	35° 30'	90° 50'	78	276
11	Coast Plain, North Carolina	35° 0'	77° 0'	73	272
13	West North Carolina	35° 0'	82° 50'	53	266
1	East Illinois	37° 50'	89° 50'	77	262

by spot spraying with glyphosate and simazine in 0.9 m diameter circles prior to planting, in the spring of 1979 and again in spring 1980. A double border row of yellow-poplar seedlings was planted around the progeny test in spring 1979. Due to high mortality, two of the blocks were deleted from the analysis.

Data were analyzed by Analysis of Variance (ANOVA), Correlation, Regression, and Duncan's New Multiple Range Test techniques. A mixed model ANOVA was used in which stands were assumed to be fixed effects while families nested in stands were random; data in this model were analyzed on an individual tree basis. Variance components were used to generate heritabilities for total height from 3- and 5-year measurements. Expected gains were calculated using the multistage selection scheme of Namkoong et al. (1966).

The regression method of Eberhart and Russel (1966) was used to estimate stability parameters. Using stability analyses involves partitioning genotype x environment interactions to determine individual genotype contribution to the interaction. In this case, such an analysis was used to partition a family x block interaction. The analysis involved regressing family block mean 5-year height over an environmental index developed for each block; in this study the environmental index is defined as the difference between mean height of all families in a given block and the mean height of all families in all blocks.

RESULTS AND DISCUSSION

Five years after outplanting mean survival in family plots averaged 74 percent. The low survival may have been a result of poor control of competing vegetation. Survival was significantly positively correlated with 5-year height (r = 0.16), although less than 3 percent of survival variation could be accounted for by height variation.

Analysis of variance of 5-year height measurements indicated statistical significance for all treatment effects except the interaction of blocks and stands (table 2). Significance of the stand and family-within-stand effects implied that selection at both levels will result in some gain. However, the variance component for families-within-stands was low and no variance component could be generated for stands because it was considered a "fixed effect" (table 2). The narrow-sense heritability of height at age 5 was 0.23, approximately the same magnitude typically obtained for open-pollinated American sycamore (*Platanus occidentalis* L.) at this age (Ferguson et al. 1977). Furthermore, the heritability had increased from the 0.18 obtained at age 3 (data on file). Therefore, it would be interesting to evaluate expected gains from this progeny test if it were to be converted to a seedling seed orchard.

Table 2.--Analysis of variance, variance components for random effects, and heritability for 5-year total height measurements

Source of variation	d.f.	Mean square	F
Blocks (b)	5	89810.9	6.97
Stands (s)	8	49884.8	3.87
Blocks x Stands (bxs)	40	12887.8	0.73
Families in Stands (f(s))	45	17102.1	1.59
Blocks x Families/Stands (bxf(s))	206	10787.9	3.12
Error	410	3461.5	

Variance Component	Estimates based on data from 9 stands	Estimates based on data from 4 selected stands
$\sigma^2_{f(s)}$	418.2	176.7
$\sigma^2_{bxf(s)}$	3334.8	3325.2
σ^2_{error}	3387.2	3294.0

$$\text{heritability } (h^2) = \frac{4(418.2)}{418.2 + 3334.8 + 3387.2} = 0.23$$

Typically a multistage selection scheme uses some test of mean separation at each selection level; Duncan's New Multiple Range Test is probably the most commonly used because it is the most sensitive at detecting differences among means (Douglas et al. 1981). In this case the Duncan Test indicated that the stands from Kentucky and Tennessee grew significantly faster than all others (table 1). Yellow-poplar from these stands averaged 320 cm in height compared with an overall unselected plantation average of 295 cm, an 8.5 percent improvement. Gains of this magnitude are also expected from provenance selection in black walnut (Deneke et al. 1980). It is interesting to note that seedlings from southeast Illinois, the nearest to being a local seed source, grew the poorest. However, no correlation was found between 5-year height and either provenance latitude or longitude regardless of whether stand means or individual tree data were used.

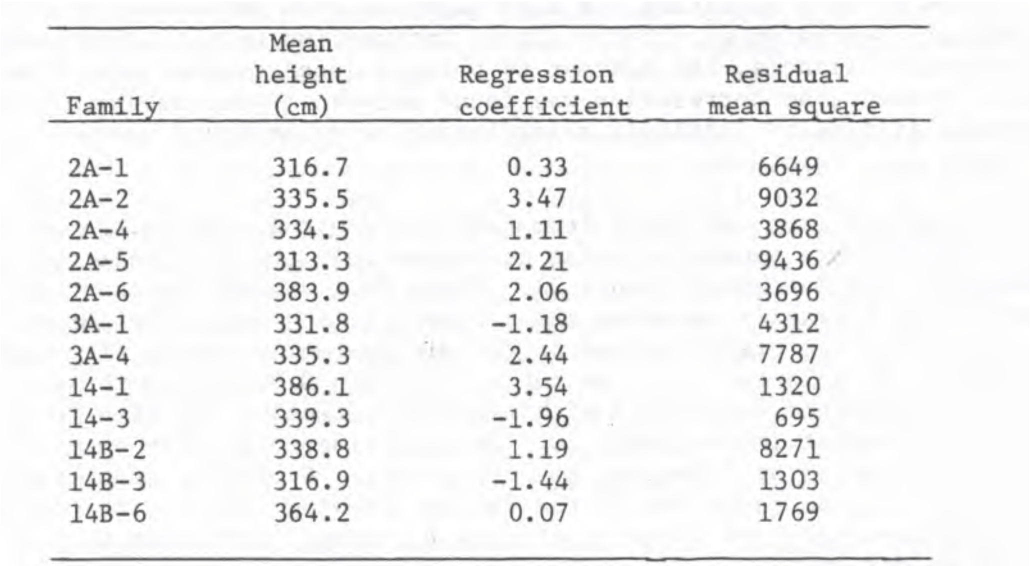
To calculate expected gains from family and within-family selection, variance components were generated using data from only the four selected stands from Kentucky and Tennessee (table 2). These four stands contained 24 families from which we arbitrarily selected the tallest 12 (i = selection intensity = 0.8). Selection was predetermined on the within-family level; after adjusting for mortality we selected one tree out of 2.3 (i = 0.9). With these selection intensities, combined family and within-family selection resulted in only an additional 3 percent improvement (10.4 cm), considerably lower than the 14 to 28 percent projected by Farmer et al. (in press). Bypassing stand selection and concentrating on selection of the fastest-growing trees in the overall 54 largest families resulted in gains of only 7 percent, even less than with three levels of selection.

The primary reason for the low gains is the high magnitude of the family x block interaction variance relative to the family component (table 2). With most tree species the within-plot variance is the single largest component; in this case, the family x block variance component equals the within-plot component. Such large interaction components were also demonstrated by Farmer e al. (in press) for 5-year-old yellow-poplar.

If a 1 hectare site can be considered relatively uniform after acknowledging microsite variation, and if additive variance (i.e., general combining ability) were high, selected families would be expected to perform consistently in all blocks. However, if specific combining ability were high, as suggested by Taft (1966), half-sib family performance could be expected to vary from block to block leading to a genotype x environment interaction. Stability parameters for the 12 selected families indicate that the latter situation is in effect; regression of mean family height on environmental indices resulted in coefficients that varied from -2 to over 3, a pattern that might be expected of a site-specific species with a substantial specific combining ability component (table 3). Unfortunately, the specific combining ability variance component cannot be estimated from this experimental design.

The 12 families used to calculate expected gains were selected on the basis of their average height (table 3). However, a stability analysis provides two additional parameters that should be considered at the time of selection: the regression coefficient and the residual mean square, both of which are calculated separately for each genotype. According to the method of Eberhart and Russel (1966) a desirable combination of stability parameters includes a high mean height, a positive regression coefficient approaching unity, and a residual mean square approaching zero. In this study, none of the selected families have residual mean squares approaching zero, and the regression coefficients are extremely variable. Therefore, selection of half-sib families of yellow-poplar

Table 3.--Family stability parameters for 12 families selected from four fast-growing stands



Family	Mean height (cm)	Regression coefficient	Residual mean square
2A-1	316.7	0.33	6649
2A-2	335.5	3.47	9032
2A-4	334.5	1.11	3868
2A-5	313.3	2.21	9436
2A-6	383.9	2.06	3696
3A-1	331.8	-1.18	4312
3A-4	335.3	2.44	7787
14-1	386.1	3.54	1320
14-3	339.3	-1.96	695
14B-2	338.8	1.19	8271
14B-3	316.9	-1.44	1303
14B-6	364.2	0.07	1769

for a seedling seed orchard on the basis of mean height alone should probably be avoided and the seedling seed orchard approach would not improve yellow-poplar growth, as suggested by Wilcox and Taft (1969).

In summary, these results demonstrate that yellow-poplar height growth can be increased up to 10 percent by selecting the proper seed source; in southern Illinois this seed source is southwest Kentucky or Tennessee. Individual-tree selection in the progeny test resulted in gains of only 3 to 7 percent depending on whether applied with or without provenance selection. These low gains may also reflect the ineffectiveness of mass selection in wild hardwood plantations, in spite of the fact that no rigorous criteria were used for selecting parent trees. It is possible that gains from second generation selections made in progeny tests may be much greater than those from initial mass selection, as suggested by Schmitt and Webb (1969). Therefore, if additional gains in growth of yellow-poplar are needed, a long-term improvement program would be required involving second-generation clonal selection and controlled pollination.

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