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Original article

Growth trends and geographic variation in a *Quercus alba* progeny test

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Summary — Genetic variation in a *Quercus alba*, white oak, open-pollinated progeny test was analyzed. The study was established in 1969 and consists of families from select and candidate trees in the western and eastern regions of the Tennessee River Valley in North America. Best linear unbiased prediction (BLUP) means were generated for growth measurements in 1969, 1974, 1978 and 1988. A ranking of 1974 height means reveal geographic variation patterns in growth. These patterns of growth, as evidenced by height mean rankings, continued through 1988. Small differences between families from select trees and candidate trees, within a region, indicate that intense plus-tree selection may not be effective. Correlation coefficients among height variables suggest that early selection is possible.

***Quercus alba* / genetics / geographic variation / best linear unbiased predictor (BLUP) / selection**

Résumé — Variabilité géographique et corrélation âge–âge de la croissance en hauteur chez *Quercus alba*. *La variabilité génétique de la croissance en hauteur d'un chêne blanc* (Quercus alba) *a été étudiée dans un test de descendances issues de pollinisation libre en forêt. La plantation comparative a été mise en place en 1969 et comprend des familles d'arbres plus et d'arbres candidats situés sur les rives orientales et occidentales du Tennessee en Amérique du Nord. Les moyennes familiales ont été estimées pour les hauteurs de 1969, 1974, 1978 et 1988 en utilisant la méthode BLUP* (best linear unbiased prediction). *Le classement des moyennes de hauteur de 1974 révèle un gradient géographique de variabilité. Ce gradient est toujours présent pour les hauteurs de 1988. Des différences minimes entre familles d'arbres plus et d'arbres candidats à l'intérieur d'une région suggèrent qu'une sélection phénotypique sévère peut ne pas être efficace. Les corrélations âge–âge entre hauteurs indiquent qu'une sélection précoce est possible.*

***Quercus alba* / génétique / variabilité génétique / BLUP / sélection**

INTRODUCTION

Quercus alba L white oak, is endemic to the forests of eastern North America. The species provides lumber and veneer for the wood products industry, pulp for paper manufacture and mast for wildlife. Veneer quality *Q alba* logs are exceeded in value only by native black walnut, *Juglans nigra* L, and black cherry, *Prunus serotina* Ehrh and are frequently exported to other countries.

Genetic studies of *Q alba* have been limited. Range-wide acorn collections are difficult, as the species has episodic seed crops that vary in occurrence in different regions. In 1967, the Tennessee Valley Authority collected acorns from a limited portion of the species' range for progeny testing. Studies were established in 1969 at western and eastern Tennessee Valley sites. In this report, the genetic variation of growth at age 19 years in the western Tennessee study is analyzed.

MATERIALS AND METHODS

Plant materials, site and experimental design

Open-pollinated progenies were collected from select and candidate trees in western and eastern regions of the Tennessee Valley of eastern North America (fig 1; table I). The select mother-trees were from an intensive phenotypic selection program to choose the best trees in the Tennessee Valley region on the basis of growth and form (KA Taft, Jr, personal communication). Candidate mother-trees were chosen for acorn production and good form/growth and were often in the same locality as the select trees. Designation of select and candidate trees were made by Tennessee Valley Authority tree improvement personnel. Twenty-five separate families, representing 9 locations, were germinated in 1968 and planted as 1–0 bareroot stock at a west Tennessee location (fig 1). The planting site is a low terrace in a creek valley and has very fine sandy loam soils. The experimental design was a randomized complete block, with 10 replications and 10-tree row plots.

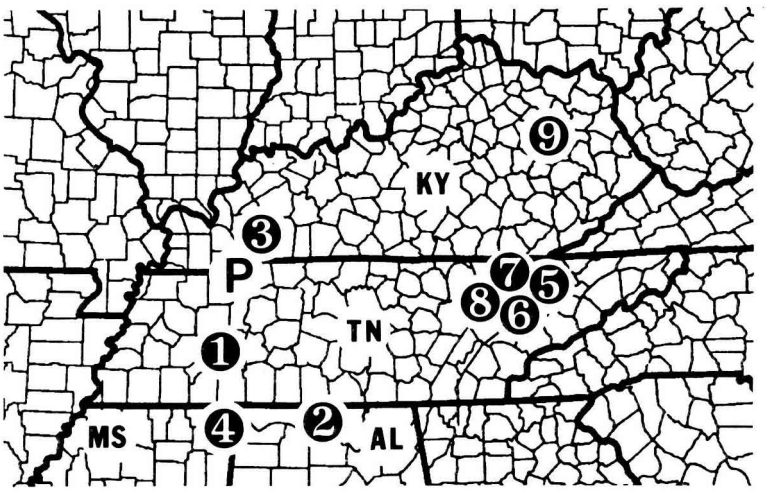

Fig 1. Location of seed sources (1–9) in the open-pollinated progeny test of *Quercus alba*. The plantation site is designated by P. TN: Tennessee; KY: Kentucky; MS: Mississippi; AL: Alabama.

Table I. Origin and description of *Quercus alba* families represented in the open-pollinated progeny test.

No	*Origin*			*No parental select trees*	*No parental candidate trees*	*Total no families*
	county	*state*	*region*			
1	Henderson	TN	western	1	3	4
2	Limestone	AL	western	1	0	1
3	Trigg	KY	western	0	3	3
4	Tishomingo	MS	western	0	1	1
5	Union	TN	eastern	1	4	5
6	Anderson	TN	eastern	1	6	7
7	Campbell	TN	eastern	1	0	1
8	Morgan	TN	eastern	1	0	1
9	Menifee	KY	eastern	1	0	1
Unknown			–	–	1	1
Plantation total				7	18	25

Growth measurements and analyses

Height growth was measured at ages (after plantation establishment) 1, 6, 10 and 19 years. Diameter measurements, at 1.4 m, were taken at age 19 years. Statistical analyses were conducted using mixed model methods, with family and block classified as random effects. A software program developed by Louisiana State University, GLMM (General Linear Mixed Models), was utilized for the analyses. Sprouts or injured trees were deleted from the analyses. Family means were generated through BLUP (best linear unbiased prediction) procedures for all variables. Progenies from the western Tennessee Valley region were distinguished from eastern region progenies, and specific linear contrasts were made to detect differences between the regions in growth. Pearson correlation coefficients were calculated to detect associations among characteristics.

RESULTS

Differences in height growth among the families were evident after 1 growing season. The difference between the tallest and shortest family means at age 1 year was 13 cm, but had increased to 1.77 m by age 19 years. Variation in height growth among families from the same geographic area was large. For example, 5 families from Union County, Tennessee, including one select tree family, were represented in the study. At age 19 years, the difference between the tallest and shortest of these families was 1.24 m.

Specific linear contrasts between western and eastern region progenies reveals regional variation patterns for all growth variables in table II (P = 0.0001). Overall, trees from the western seed sources were superior in growth (table II). Height differences between western and eastern families were apparent at the end of the first growing season and continued through age 19 years.

Height growth differences between select trees and candidate trees from the western region were small (table II). By age 6 years, the average height of candi-

Table II. BLUP (best linear unbiased prediction) growth means (cm) by regional groups and parental types.

Region/type [a]	*No of families*	*Height*				*Diameter*
		Age 1	*Age 6*	*Age 10*	*Age 19*	*Age 19*
W/S	2	23.1	97	249	688	9.66
W/C	7	22.8	96	260	707	9.97
E/S	5	16.4	83	224	642	9.53
E/C	10	18.9	84	218	635	8.64
Plantation	25 [b]	19.9	89	234	661	9.91

[a] W: western region; E: eastern region; S: select tree families; C: candidate tree families. [b] 1 family seed-source unknown.

date tree families was actually greater than the average of select trees. This trend continued through age 19 years. A similar trend of growth differences existed between select and candidate trees in the eastern region through 1978. However, by age 19 years, the average diameter of eastern select tree families exceeded eastern candidate tree families by 0.89 cm and approaches the average diameter of western select tree families.

Correlation coefficients among the growth variables are presented in table III. Age 1 year height growth is weakly correlated with later growth measurements. Strong correlations (ca $r > 0.78$) exist between age 6 years height growth and other height and diameter measurements.

Table III. Pearson correlation coefficients among growth variables. All coefficients are significant at $P = 0.0001$.

Height age	*Height*			*Diameter age 19*
	Age 6	*Age 10*	*Age 19*	
1	0.34	0.36	0.28	0.21
6		0.87	0.79	0.78
10			0.89	0.87
19				0.90

DISCUSSION

The regional variation trends detected in this study should be important considerations when planning and implementing future research and development programs in *Q alba*. The overall superior performance of western families suggests that future research on this species in the western Tennessee Valley should use only acorns from the same geographic area. The results also should be used to guide seed procurement for planting *Q alba* seedlings in the western Tennessee Valley. Seed collections for nursery production should be limited to trees in this western region.

The slight growth differences between candidate and select tree families, in each respective region, suggests that intensive plus-tree selection programs may not be effective in *Q alba*. Observations on form and branching habit, however, have not

yet been considered and will be important factors in evaluating the overall worth of intensive selection.

The correlation coefficients between height growth at ages 6 and 19 years (r = 0.79) and ages 10 and 19 years (r = 0.89) indicate that selection of the fastest growing families can be made at a relatively early age. The above statement is predicated upon the assumption of no dramatic changes in family height rankings. This assumption is reasonable, as the plantation currently (age 23 yrs) is experiencing crown closure, and the shorter families will gradually become suppressed or slow in growth.

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