BREEDING STRATEGY FOR E. ROBUSTA IN SOUTHERN FLORIDA

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Abstract.--*Eucalyptus robusta* Sm. has undergone two cycles of improvement in southern Florida. In the first cycle, mass selection produced the following realized gains at 4.5 years: height 20%; diameter 6%; and volume 17%. In the second cycle, family plus within family selection produced the following realized gains at 2.6 years: height 40%; diameter 37%; and volume 91%. Combined gains for both cycles indicated the following improvements: cold hardiness 19%; height 27%; diameter 33%; volume 63%; branch size and angle 14%; and stem straightness 9%. Introductions from natural stands in Australia proved to be vastly superior, especially in cold hardiness, to material obtained from naturalized stands in Florida. Future gene pool enrichment efforts in the E. *robusta* program will place emphasis on Australian collections. Sib analysis estimates of heritability were higher than realized heritability values for the traits assessed in the second and third generation based populations. Generally poor agreement between sib analysis estimates and realized heritability values suggests caution must be exercised in using these estimates of heritability in genetic gain prediction formulas for E. *robusta* in southern Florida.

Additional Keywords: Mass selection, combined (family plus within family) selection, realized gain, sib analysis, coefficient of relationship.

INTRODUCTION

The *Eucalyptus robusta* Sm. breeding program has undergone two cycles of improvement in southern Florida. A seedling seed orchard-progeny trial approach was used to provide improved seed to commercial nurseries in the shortest time. Mass selection was used in the first cycle of improvement. As family information was available for the second cycle, the mass selection strategy changed to a combination of family plus within family selection. The objective of this study was to determine the efficacy of the two selection methods for eucalyptus breeding programs. Realized gains were calculated on a per cycle basis and for both cycles combined. Predicted and realized gains were compared to determine the reliability of forecasted gains.

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ESTABLISHMENT OF BASE POPULATIONS

The two cycles of improvement in southern Florida result from the establishment of three generations of genetic base populations summarized below.

First generation: Immokalee

In 1961, the Florida Forests Foundation established a species screening trial near Immokalee, Florida. The trial included. 7 eucalyptus species represented by 40 seed sources, 9 of which were E. *robusta.* Measurement at age 4.5 years showed that E. *robusta* offered the best combination of local adaptability, commercial growth rate and acceptable stem form expressed in a suff icient number of seed sources to provide reasonable breadth in a genetic base population.

In 1966, 119 E. *robusta* trees were mass-selected (from 2,304 originally planted) based on phenotypic superiority to their neighbors in the seed source plots. Selection traits were stem volume, stem straightness and branch habit. All nine seed sources of E. *robusta* contributed at least one select, but the better seed sources contributed most of the selects. All nonselect trees were rogued to convert the Immokalee site to a pollen-isolated, first-generation genetic base population and seed production area for E. *robusta.*

Second generation: Burgess

Only 57 of the Immokalee selects bore sufficient seed to contribute progeny families to the second-generation base population and progeny test planted in 1967 at the Burgess site. The Burgess planting also included five of the originally imported seedlots planted at Immokalee, which came to be referred to as "ancestral" seed sources. Two newly imported seedlots were also included at Burgess, bringing the base population to 57 families and 7 seed sources represented by 6,275 seedlings.

Based on freeze damage scores at 3.5 years and measurements at 4.25 years, 94 trees were selected from 39 families with no more than 4 selections in any family. Selection criteria combined individual and family values for wood production, stem straightness, branch habit, and cold hardiness. All nonselect trees were rogued to convert Burgess to a seedling-seed orchard.

Third generation: R-POP

Eighty-four selected trees at Burgess bore sufficient amount of seeds to be represented in the 1975 base population known as R-POP. Thirty-seven second-generation families, principally from Immokalee select trees that had not produced seed in time for the Burgess planting, but also offspring of phenotypically superior trees in other research plots of known origin, were also included in the R-POP seedling-seed orchard progeny study.

To broaden the E. *robusta* genetic base which was being narrowed by selection, seeds from 98 parent trees in natural stands in Australia and 105 parent trees from naturalized stands in central and south Florida were also included in the

R-POP study. It was hoped that the new genetic combinations from outcrosses with this naturalized material would be well adapted to the mosaic of micro-sites present in southern Florida. The Florida naturalized stands arose from E. robusta sources of unknown origin established around old homestead sites as amenity plantings as early as the turn of the century (Franklin and Meskimen, 1973). In addition to the 203 Australian and Florida families, 23 entries, consisting of E. robusta families from Hawaii and bulk collections from various regions around the world, and the 5 ancestral seedlots were included in the R-POP seedling seed orchard-progeny trial (Table 1, Figure 1).

METHODS

Realized gains were calculated on a per cycle basis from Immokalee to Burgess (first to second generation) and Burgess to R-POP (second to third generation). Realized heritability was calculated for selections at Immokalee and at Burgess. Realized gain, expressed as a percentage of the mean of the previous generation was calculated by:

$$\frac{\text{Response to selection}}{\text{Mean of parental population}} \times 100 \qquad (1)$$

Realized heritability was calculated by:

$$\frac{\text{Response to selection}}{\text{Selection differential}} \qquad (2)$$

Response to selection and the selection differential were standardized to adjust for different population variances and for environmental differences at the two sites. These calculations are detailed elsewhere (Franklin and Meskimen, 1973).

Estimates of narrow sense heritability were calculated from sib analyses (see Falconer, 1960). Analyses of variance from single-tree plot experiments at both Burgess and R-POP were conducted using the NESTED procedure of the Statistical Analysis System (SAS)®. Estimates of heritability were calculated from:

$$h^2 = \frac{3\,\sigma^2 f}{\sigma^2 P} \qquad (3)$$

where h^2 = narrow sense heritability

$\sigma^2 f$ = family component of variance of open-pollinated families

$\sigma^2 P$ = phenotypic variance on an individual basis

The coefficient of relationship among open-pollinated families is .25 if every offspring of a half-sib family is the result of the mating between a common female and different, unrelated males. This value probably underestimates the true coefficient of relationship since some offspring are likely to have a

Table 1.--Summary of information from genetic base populations of E. robusta in southern Florida.

Trial Name	Established	Location	Design	Spacing	Type of Selection
Immokalee	1961	Collier Co.	randomized complete block; 4 blocks of 64-tree plots	2.4m x 1.8m	Mass
Burgess	1967	Charlotte Co.	completely random single-tree plots; average 98 trees per family	3.6m x 1.8m	Family & within family
R-POP	1975	Glades Co.	completely random single-tree plots; average 69 trees per family	3.0m x 1.8m	

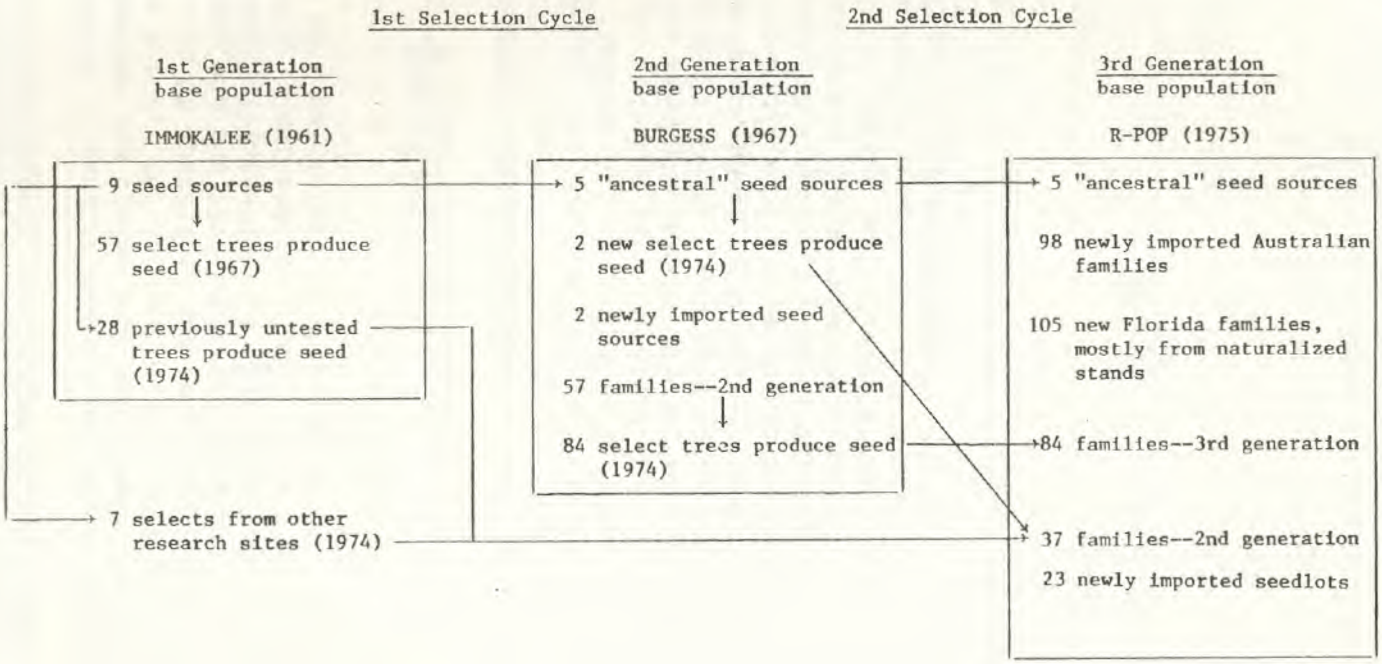

Figure 1.--Schematic diagram of two cycles of improvement for E. robusta in southern Florida.

common male parent and thus be related as full-sibs. The coefficient of relationship among full-sibs is .5. Based on these considerations, we chose to multiply the numerator by 3 (coefficient of relationship of .33) rather than 4 (coefficient of relationship of .25) because it assumes that some progenies are half-sibs and some are full-sibs (Squillace, 1974). The coefficient of relationship would also be inflated if male parents are related to the female parent.

Material at different levels of genetic advancement was included at R-POP. Realized gains were calculated for two cycles combined (Immokalee to Burgess to R•POP) from data collected at R-POP. The success of introducing material from Australia and Florida could also be quantified and compared. The common base to which all comparisons were made was the five ancestral seed sources. These ancestral seed sources consisted of three lots of bulk seed from Australia, one from Morocco and one from Zaire. Realized gains calculated from data collected only at R-POP were expressed as a percentage of the mean of the ancestral seed sources as follows:

$$\frac{\text{-Mean of Population}}{\text{Mean of 5 ancestral seed sources}} \quad (4)$$

RESULTS AND DISCUSSION

Realized gains for E. robusta for the first cycle of improvement (Immokalee to Burgess) were height 20%; diameter 6%; and volume 17% (Table 2). These values are similar in magnitude to the realized gains obtained in tests from rogued first generation seed orchards in the North Carolina State University-Industry loblolly pine tree improvement program (Weir, 1975). Realized gains for the second cycle (Burgess to R-POP) were height 40%; diameter 37% and volume 91% (Table 2). At least two factors contribute to more genetic gain in the second cycle than in the first. First, combined selection utilizes genetic information from sib analysis but mass selection relies only on phenotypic performance of candidates. Second, outcrossing of relatively inbred individuals between seed sources was enhanced by the completely randomized single-tree plot design at Burgess. This may have resulted in hybrid vigor in the offspring.

Table 2.--Realized percentage gains of E. robusta by cycles of improvement in southern Florida.

	Trait		
	Height	Diameter	Volume
1st cycle (Immokalee - Burgess) [a]	20	6	17
2nd cycle (Burgess - R-POP) [b]	40	37	91

expressed as the percentage of the mean of the Illunokalee population and based on data from 40 open-pollinated families measured at 4.5 years.

[b] Expressed as the percentage of the mean of the Burgess population and based on data from 76 open-pollinated families measured at 2.5 years.

Reliable estimates of genetic gain depend on accurate estimates of heritability. Estimates of heritability using sib analysis were higher than realized heritability values for all traits assessed (Table 3).

Table 3.--Comparison of estimated heritability and realized heritability for 2 cycles of E. *robusta* improvement in southern Florida.

	Second Generation Base Population [a]		Third Generation Base Population [b]	
	Sib Analysis	Realized h^2	Sib Analysis	Realized h^2
Height	.46	.38	.38	.34
Diameter	.50	.09	.39	.24
Volume	.42	.08	.23	.11

[a] based on data from 40 open-pollinated families **at** 4.5 years of age.

[b] based on data from 76 open-pollinated families at 2.5 years of age.

Results indicate that caution must be exercised in using sib analysis estimates of heritability from E. *robusta* trials in southern Florida to predict genetic gains for future generations. This seems especially true for predictions of genetic gain for volume.

Realized **gains** calculated for material at different levels of genetic advancement at R-POP are presented in Table 4. Genetic material which had undergone two cycles of improvement in southern Florida showed sizable gains for height, 27%; diameter, 33%; and volume, 63%; at 2.6 years (Table 4). Realized gains estimated on a per cycle basis (Table 2) are different from those estimated for both cycles together (Table 4) because the reference base population used in making the calculations are different.

Table 4.--Performance of advanced generation and introduced material at R-POP 75. (Expressed as a percentage of increase or decrease of population means to mean of the ancestral seed source.)

Degree of genetic advancement	Cold Hardiness	Height	DBH	Volume	Branch Habit	Stem Straightness
Generation 3						
(Immokalee - Burgess - R-POP	+19	+27	+33	+63	+14	+9
Introduced Material						
Australia (natural stands)	+24	+11	+20	+26	+8	0
Florida (natural stands)	-15	-4	-8	-13	-2	-3

Australian introductions were superior to Florida collections in all traits measured. The results suggest that future efforts to expand the genetic base of the E. *robusta* populations in southern Florida should concentrate on acquiring new genetic material in Australia, not in Florida. Single-tree collections from good sources within the native range of a species may provide the best possible source of material for other hardwood breeding programs. Seed should be kept separate by individual trees in provenance trials so that provenance variation can be closely examined and selections of known pedigree can be made for advanced-generation programs.

Families obtained from Florida naturalized stands performed poorly. Florida naturalized areas are small in size and have originated from only one or a few parent trees of unknown origin. Selfing probably occurred which might have reduced the level of progeny performance.

SUMMARY

Relatively few results have been published on realized gains in hardwood programs in the United States. Results from the E. *robusta* program indicate that this exotic hardwood is extremely responsive to genetic manipulation. Mass selection resulted in moderate gains in volume for the first cycle of improvement in southern Florida. Combined (family plus within family) selection produced much greater percentage gains in volume in the second cycle. Progenies of trees from good sources of E. *robusta* in natural stands in Australia outperformed progenies of selections made in Florida naturalized stands. Estimates of heritability from sib analyses should be used with caution when predicting genetic gains for future generations of E. *robusta* in southern Florida.

The seedling seed orchard-progeny trial breeding strategy was effective in the E. *robusta* program. Tree improvement programs for other hardwood species should consider using the seedling seed orchard-progeny trial approach.

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