AVOID EARLY SELECTION FOR GROWTH RATE IN COTTONWOOD

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Abstract. A sample of 37 cottonwood clones from a selection program was compared with a sample of 40 random clones in a 14-year test at two sites near Stoneville, Mississippi. Throughout the test period, the select sample was slightly better in mean growth rate, but this difference decreased with age. Performance of "blue tag" clones selected at age 5 and planted commercially was good. But a group of clones selected at age 14 showed from two to three times as much improvement in diameter and height as the group selected at age 5.

Eastern Cottonwood (*Populus deltoides* Bartr.) is an important, fast growing plantation hardwood in the South. Because of its widespread occurrence, high variability, large number of seeds per catkin, and ease of vegetation propagation, many more genotypes can be assembled than can be evaluated adequately. In most breeding programs many genotypes are eliminated after only minimal evaluation, and such rapid elimination can result in the loss of much useful variability. In the long run, expedient selection may prove more costly, as results from a 14-year clonal test near Stoneville, Mississippi, illustrate.

MATERIALS AND METHODS

We studied two populations of clones. Twenty-five female parent trees with good growth and form were selected in various stands along the Mississippi River from 50 miles north to 50 miles south of Greenville, Mississippi. This was followed by selection in the nursery from among 160 seedlings from open-pollinated seed from each of these trees. One or two stages of one-year clonal tests were used to select the 37 most promising clones from these 4,000 seedlings. The other population was sampled by cloning 40 random trees from a total of six natural stands from 2 to 4 years old along the same segment of the river. The two samples represented the practical extremes of selection intensity that might be represented in preliminary cottonwood clonal test outplantings.

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In 1965, the clones were outplanted in 4-tree linear plots with 10 x 10 ft. spacing. A randomized-complete-block design with 5 replications was used at each of two locations. One outplanting was made on Sharkey clay soil at the Delta Experimental Forest (DEF) near Stoneville, Mississippi. The other was on Commerce silt loam soil at Huntington Point (HP) 10 miles north of Greenville, Mississippi, and about 20 miles from the first site. Both sites have comparable rainfall and temperature patterns. Differences in growth rates presumably would result mainly from differences in soil type. These two soil types bracket the range of soil types likely to be planted to cottonwood in the Lower Mississippi Valley. Both sites were planted with 20-inch unrooted cuttings of comparable quality, with 3 cuttings planted per spot. To improve uniformity, each spot was thinned to the best tree in June of the first growing season. Both sites were clean-cultivated the first year.

The HP location was thinned at age 3 by removing alternate rows across clones. The poorer of the two remaining trees per plot was removed at age 5. A third thinning occurred at age 8 when a few of the poorest remaining trees, those most likely to be crowded out, were removed, resulting in some missing plots. At DEF the single thinning consisted of removing alternate rows across clones at age 3.

Analyses of variance and covariance based on plot means were conducted separately for the select and the random samples within and between locations. Components of variance and covariance were computed from the mean squares and mean products for use in computing broad sense heritabilities, genotypic gains, and genotypic correlations. Clones not present in at least 3 of 5 replicates at both locations were omitted from analysis of variance, leaving 30 select clones and 27 random clones.

RESULTS AND DISCUSSION

Growth rate at DEF was poor, resulting at age 14 in less than half the height and diameter at HP (44 ft. vs 90 ft.; 5.7 in. vs 12 in.). Since sites now being recommended for cottonwood often are similar to the HP site, with possibly a slight tendency toward the soil characteristics of DEF, our main interest is in the results from HP.

Throughout the 14-year test, the selct sample was slightly better in mean growth rate than the random sample (Table 1), but this difference decreased with age. Variation among clones for diameter was similar for the two samples (Table 2). The random sample was somewhat more variable for height than was the select sample. Since means were not greatly different, superior clones probably could be selected from either population. However, those clones that were best for height and diameter at both locations were from the select sample.

Table 1.--Mean performance of the select sample as a percentage of the random sample mean for height and diameter at each location.

	HP		DEF	
Age	D.b.h.	Height	D.b.h.	Height
1	110	108	107	108
2	111	107	114	109
3	109	106	109	107
4	109	---	106	---
5	108	106	104	---
6	108	---	103	---
7	108	106	102	104
8	108	---	---	---
14[a]	101	102	98	101

[a] Values across the table would be 105, 106, 101, and 104 if all clones rather than only those remaining in 3 or more replications at both locations were included.

Table 2.--Estimates of Genotypic (σ^2_C) and Genotype - environment (σ^2_{CE}) components of variance.

	Select sample population			Random sample population		
Character	σ^2_C	σ^2_{CE}	$\sigma^2_{CE}/\sigma^2_C + \sigma^2_{CE}$	σ^2_C	σ^2_{CE}	$\sigma^2_{CE}/\sigma^2_C + \sigma^2_{CE}$
Height						
age 3	1.039	.851	.45	2.050	.838	.29
age 7	7.081	2.224	.24	7.029	3.841	.35
age 14	17.378	12.395	.42	145.960	49.027	.25
Diameter						
age 3	.084	.038	.31	.067	.031	.32
age 7	.398	.230	.37	.217	.207	.49
age 14	1.018	1.068	.51	1.910	.504	.21

To determine whether clonal selection from the nursery or from very early replicated field tests would be effective in identifying clones with long-term growing potential, we examined data from the random sample. We found that by age 14 the top 25 percent of the clones for height or diameter at age 1 at DEF or HP were little better than random clones for height or diameter (Table 3). The genotypic correlation between measurements at age 1 and at age 14 was negligible.

Table 3.--Effect on performance at age 14 of selecting the top 25 percent of random sample for height or diameter at HP or DEF expressed as a percentage of the random sample mean.

	Performance at age 14			
	D.b.h.		Height	
Type of selection	HP	DEF	HP	DEF
Selection at age 1 for d.b.h.				
HP	104	103	100	102
DEF	108	104	101	101
Selection at age 1 for height				
HP	102	103	100	104
DEF	99	107	101	104
Selection at age 7 for d.b.h.				
HP	102	106	99	102
DEF	94	111	94	107
Selection at age 7 for height				
HP	101	105	98	103
DEF	98	110	98	106
Selection at age 14 for d.b.h.				
HP	113	102	104	99
DEF	100	113	98	106
Selection at age 14 for height				
HP	108	97	107	98
DEF	95	109	96	108

Because each clone was represented by 4 widely spaced trees in each of 5 replications at age 1, the data presumably were better and the small amount of improvement possible from selection greater than would occur from selection in nonreplicated field tests or in most clonal nursery evaluations that are close-spaced and replicated. However, little was accomplished by one-year evaluation.

Assuming selection at age 7 rather than age 1, we examined the random sample further. Clones in the upper 25 percent at age 7 for either height or diameter at each location were no better than the sample mean by age 14 at HP (Table 3). However, at DEF these tended to be superior at age 14.

Since the effects of selection in natural stands and in the nursery were confounded, only indirect methods of assessing their contributions in the select sample could be used. The reduction in superiority of the select sample with time could be due either to the tendency for early growth superiority from nursery selection to be poorly correlated with mature tree performance or to the increasing importance of the differences between natural stand environment and testing-site environment as plantation trees grew larger. These factors would tend to be offset by an increasing correlation between older plantation trees and natural stand trees. The importance of genotype-environment interaction increased little if any with age (Table 2), so it can be omitted as an important cause of change. For early selection, all that we can conclude is that the combination of selection in natural stands plus nursery selection resulted in a slight improvement in growth rate of about the same magnitude as that possible from selecting the upper 25 percent of a random population in a replicated, multiple-tree plot clonal test at age 1.

At age 5, 14 clones were chosen for possible commercial planting (Mohn et al., 1970). Eleven came from the select sample and three from the random sample. Five of these received "blue tag" certification and have become the primary cottonwood clones planted in the South. Mohn et al. (1970) pointed out that these clones were only partly tested, that risks were associated with their wide-scale planting, and that accurate predictions of their merits would require testing for at least half a timber rotation over a wide geographic area and on a range of sites for cottonwood planting. The clones are now about half the timber-rotation age.

The group of 5 blue-tag clones have grown 20 percent more rapidly in volume than has the random group, but a group could be selected that would have done much better (Table 4). For volume at age 14, the 4 best clones from the select sample, ST 66, ST 69, ST 70, and ST 72, averaged 74 percent better at HP, 65 percent better at DEF, and 71 percent better over both locations than did the random sample. Genotypic gain predictions were similar to actual values for individual locations but indicated that the 71 percent over both locations might be unrealistically high. When selecting the four best clones over such widely varying sites we can only expect gains of 23 percent over the select sample and 28 percent over the random sample. Nevertheless, the four best clones from our select population ranked at the top of HP and were among the 7 best at DEF. This performance suggests that development of clones with broad application is feasible, although the magnitude of genotype-environment interaction remains as important (Table 2) as it was at age 3, when Randall and Mohn (1970) recommended selection for specific sites.

Table 4.--Performance of clones and clonal groups at age 14 expressed as a percentage of the mean of the random sample.

Comparison Group	HP			DEF			Combined		
	D.b.h.	Ht.	D^2H	D.b.h.	Ht.	D^2H	D.b.h.	Ht.	D^2H
Random population	100	100	100	100	100	100	100	100	100
Selection population	101	102	104	98	101	106	102	102	105
Five "blue tag" clones[a/]	106	105	118	110	107	129	107	106	122
Fourteen Stonveille select[b/]	111	106	131	110	106	127	111	106	130
Four "best" clones[c/]	123	115	174	120	115	165	122	115	171
Stoneville 72	138	121	230	128	120	196	135	121	219
Stoneville 109	84	90	63	119	121	171	95	100	90

[a/] Consists of ST 66, ST67, ST 74, ST 92, and ST 109.

[b/] Consists of ST 63, ST 66, ST 67, ST 70, ST 71, ST 72, ST 74, ST 75, ST 81, ST 91, ST 92, ST 107, ST 109, and ST 124, selected at age 5.

[c/] Consists of ST 66, ST 69, ST 70, and ST 72, selected at age 14.

The disadvantage of early selection is illustrated further by the performance of ST 72, a clone in the new group of 4 "best" clones, and ST 109, one of the blue-tag clones planted widely.

At age 1, ST 72 ranked 23rd out of 37 for diameter and 18th out of 37 for height at HP. It ranked 15th out of 37 for diameter and 7th out of 37 for height at DEF. But, by age 14, it ranked first for both characters at both locations. It was 3 or 4 years old before it ranked in the upper 25 percent. ST 72 probably would have been discarded in a short-term preliminary test, yet by age 14 it had more than twice the volume of the mean of the select sample (Table 4).

ST 109 changed from about average at age 1 to one of the best by age 4. It retained that superiority at DEF, but at HP it slipped from third for diameter and fourth for height out of 40 clones in the random sample at age 5 to 26th out of 27 clones for both characters at age 14 and had only 63 percent of the volume of the random sample mean and less than 30 percent that of ST 72. Other data show that ST 109 is highly susceptible to diseases caused by <u>Melampsora medusae</u> Thüm. and <u>Septoria musiva</u> Peck, perhaps explaining its poor performance at HP. Loss of photosynthetic ability as a result of these diseases normally occurs late in the season when the more moisture deficient Sharkey clay at DEF is incapable of sustaining further growth. Thus, growth would not be affected at DEF, but it would at HP. Free from these diseases, ST 109 might have maintained its excellent early growth rate.

A substantial number of valuable clones undoubtedly were lost by outplanting only 37 of 4,000 clones. We can only speculate on the number. Perhaps, if nursery and single-year close-spaced clonal tests were totally ineffective, 99 percent of the good clones were never outplanted, and only the best 4 of 37 rather than the best 400 of 4,000 were saved. But if the best 4 of 4,000 rather than 4 of 37 had been saved, genotypic gain could have been twice as large.

Although it may be best to wait until age 14 or longer to choose clones for commercial use, breeders need to be able to identify superior clones by the time they flower (age 6 in the South) for crossing and at an earlier age for retesting. Errors in choosing clones for these purposes are less serious than those incurred in choosing clones for commercial use. Clues available at an early age would expedite breeding programs. Traits that contribute to an efficient crown seem particularly important. These may include early foliation, late defoliation, resistance to foliar diseases and insects, large numbers and size of leaves, dark green leaf color, branch and leaf characteristics that allow maximum interception of light, and characteristics that hasten the death of leaves or branches that no longer contribute to the development of the tree. Characters that are measurable at an early age at little cost, are highly heritable, and are correlated with later performance should be used as substitutes for very early growth measurements or as supplements to later growth measurements.

Early testing techniques can be only partly substituted for long-term testing; so, when possible, studies should be installed and managed to provide data over long periods. Except for careful choice of sites, adequate plot size, fire protection and a willingness to wait, long-term testing requires little extra effort.

LITERATURE CITED

Mohn, C. A., Randall, W. K. and McKnight, J. S. 1970. Fourteen cottonwood clones selected for midsouth timber production. USDA For. Serv. Res. Paper SO-62, 17 p. South. For. Exp. Stn., New Orleans, LA.

Randall, W. K., and Mohn, C. A. 1969. Clone-site interaction of eastern cottonwood. Proc. South. For. Tree Improv. Conf. 10: 89-91.