GENETIC DIFFERENCES IN HEIGHT GROWTH AND SURVIVAL OF COTTONWOOD FULL-SIB FAMILIES

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Abstract.--Sixteen full-sib families from crosses between four fast-growing female and four fast-growing male clones of cottonwood (*Populus deltoides* Bartr.) were clonally evaluated for 1 year in a replicated field test. Seedling size had no effect on clonal performance. Approximately 70 percent of the genetic variance for height and 20 percent of that for survival were additive. The cloned families survived better and grew taller than 12 Stoneville select clones included for comparison, but this difference may have been due to repeated propagation of the select clones.

Additional keywords: *Populus deltoides*, genetic variances, clonal propagation.

The experiment described here was designed to learn how the genetic superiority of fast-growing clones of *Populus deltoides* Bartr. can be exploited through breeding and selection. Four fast-growing female and four fast-growing male clones were crossed. The resulting 16 full-sib families plus 12 clones selected in the Stoneville cottonwood improvement program were evaluated in a replicated clonal test. Age-1 survival and height, two important characters in plantation establishment, were studied.

Additive and dominance components of variance were estimated. The relative sizes of these components indicate the probable effectiveness of selecting and breeding for genetic improvement. Effects of seedling size on clonal performance were determined, and performances of the full-sib families and of the Stoneville select clones were compared.

MATERIALS AND METHODS

The parents were four female and four male clones, including the five clones with most rapid diameter growth through age 6 from a study by Mohn and Randall (1971) and three of the 14 Stoneville select clones described by Mohn et al. (1970). All originated from within 50 miles of Stoneville, Mississippi. The parents were crossed in all possible combinations to produce 16 full-sib families. Seeds were planted in small peat pots in June 1970 and seedlings were transferred to the nursery at 12- by 40-inch spacing after 1 month. They were cut back to near ground level during February 1971 and allowed to regrow for 1 more year.

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From each of the 16 families, two groups of 12 seedlings were randomly chosen. Seedlings within each group were ranked and labelled according to height in January 1972. Eight 18-inch cuttings were prepared from each seedling.

Cuttings from 12 of the 14 Stoneville select clones described by Mohn et al. (1970) were also prepared. These had been cloned from seedlings 8 years earlier, cut back to ground level each year, and occasionally moved in the nursery by planting unrooted cuttings.

The material was arranged as two adjacent plantings, with two replications in each planting. Within each replication were 18 blocks, one for each of the 16 families and two for the Stoneville select clones. Blocks were randomly assigned. The two groups of clones from each family were placed in different plantings. Clones were randomized within each block.

The areas were planted on January 18-19, 1972, on a newly cleared Commerce silt loam riverfront site at Catfish Point, 30 miles north of Greenville, Mississippi.[3/] Unrooted 18-inch cuttings were placed in freshly made subsoil trenches. Four-tree, row plots were planted at 12- by 12-foot spacing. Standard cultural practices for cottonwood as described by McKnight (1970) were used.

At the end of the first growing season survival was recorded and the height of each tree was measured to the nearest foot. Mean height was computed for each plot excluding trees which had obvious signs of mechanical injury.

The mean over all families was compared with the mean of the Stoneville select clones by analysis of variance. Clones from large seedlings were compared with clones from small seedlings by paired observation t test.

Components of variance were estimated from an analysis of the 16 families. The model was:

$$Y_{ijk\ell m} = \mu + L_i + R_{i(j)} + P_k + M_\ell + PM_{k\ell} + LP_{ik} + LM_{i\ell} + LPM_{ik\ell} + \delta_{ijk\ell} + C_{k\ell(m)} + \varepsilon_{ijk\ell m}$$

Where: $Y_{ijk\ell m}$ = Observation

L_i = Location effect

3/ The site was provided and maintained by U.S. Gypsum Company.

$R_{i(j)}$ = Replication within location effect

P_k = Paternal parent effect

M_ℓ = Maternal parent effect

$PM_{k\ell}$ = Paternal x Maternal effect

LP_{ik} = Location by paternal effect

$LM_{i\ell}$ = Location by Maternal effect

$(LPM)_{ik\ell}$ = Location x Paternal x Maternal effect

$\delta_{ijk\ell}$ = Error associated with block variability within replicates

$C_{k\ell(m)}$ = Clones within full-sib family effect

$\varepsilon_{ijk\ell}$ = Error associated with plot variability within blocks within replicates

The model is considered to be completely random with the parents representing a random sample from a finite population size. The form of the analysis is presented in table 1.

RESULTS AND DISCUSSION

Survival of most families was very high under environmental conditions which caused survival of the Stoneville select clones to be poor. Inadequate soil moisture during February and March appeared to be the cause of poor survival.

Mean survival for families was 78 percent and mean height was 14.1 feet (table 2). Family means for survival ranged from 41 to 91 percent. More than 100 of 384 clones had perfect survival. Family means for height ranged from 13.0 to 15.0 feet.

Performance of the 12 Stoneville select clones was significantly poorer than that of the families. Survival averaged only 43 percent and mean height, based on nine clones with adequate survival, was 13.6 feet (table 3). Only five of these clones, ST66, ST67, ST74, ST92, and ST109, are presently recommended for commercial use. Their mean survival was 63 percent and mean height was 13.3 feet.

Two of the 12 Stoneville select clones, ST66, and ST107, were also parents. Survival was 78 percent for ST66 but only 31 percent for ST107. Their cloned progeny averaged 82 and 79 percent survival, respectively. Another parent, ST81, was not clonally evaluated in this test but had poor survival in several other plantings. Two of the four families involving ST81 had very poor survival.

Table 1.—Form of the analysis for estimating variance components

Source of variation	Expected mean squares
Location (L)	
Replicates/L	
Paternal (P)	$\sigma^2_\delta + j\sigma^2_c + (1 - \frac{\ell}{L})\, mj\sigma^2_{LPM} + \ell mj\sigma^2_{LP} + (1 - \frac{\ell}{L}) ijm\sigma^2_{PM} + \ell ijm\sigma^2_P$
Maternal (M)	$\sigma^2_\delta + j\sigma^2_c + (1 - \frac{k}{K})\, mj\sigma^2_{LPM} + kmj\sigma^2_{LM} + (1 - \frac{k}{K}) ijm\sigma_{PM} + kijm\sigma^2_M$
PXM	$\sigma^2_\delta + j\sigma^2_c + mj\sigma^2_{LPM} + imj\sigma^2_{PM}$
LXP	$\sigma^2_\delta + j\sigma^2_c + (1 - \frac{\ell}{L})\, mj\sigma^2_{LPM} + \ell mj\sigma^2_{LP}$
LXM	$\sigma^2_\delta + j\sigma^2_c + (1 - \frac{k}{K})\, mj\sigma^2_{LPM} + kmj\sigma^2_{LM}$
LXPXM	$\sigma^2_\delta + j\sigma^2_c + mj\sigma^2_{LPM}$
Error I	σ^2_δ
Clones/Family/L	$\sigma^2_\varepsilon + j\sigma^2_c$
Error II	σ^2_ε

Definition of symbols:

- i = number of locations
- j = number of replications within locations
- k = number of randomly selected paternal parents
- K = number of population of paternal parents
- ℓ = number of randomly selected maternal parents
- L = number in population of maternal parents
- m = harmonic mean of clones within family.

Genetic interpretation of components of variance (Comstock and Robinson, 1952):

$\sigma^2_{pm} = \frac{1}{4}\sigma^2_{Dominance}$

$$\sigma_m^2 = \tfrac{1}{4}\sigma^2_{Additive}$$

$$\sigma_p^2 = \tfrac{1}{4}\sigma^2_{Additive}$$

$$\sigma^2_{Dominance} = 4\sigma^2_{pm}$$

$$\sigma^2_{Additive} = 2(\sigma_p^2 + \sigma_m^2).$$

Table 2.--Survival and age-1 height of the 16 cottonwood crosses

Maternal parent	Paternal parent				
	DF16	DF43	ST66	ST107	Mean
	SURVIVAL (PERCENT)				
DF1	79.7	91.2	86.5	83.9	85.3
DF12	75.0	81.8	89.6	89.1	83.9
DF47	78.1	72.4	76.0	81.8	77.1
ST81	82.8	42.2	76.6	62.0	65.9
Mean	78.9	71.9	82.2	79.2	78.0
	HEIGHT (FEET)				
DF1	14.3	14.0	14.7	14.3	14.3
DF12	14.1	13.9	14.6	14.5	14.3
DF47	13.7	13.0	14.2	13.7	13.7
ST81	14.6	13.2	15.0	13.5	14.1
Mean	14.2	13.5	14.6	14.0	14.1

Based on these limited comparisons, there appears to be little relationship between survival of parents and progeny.

It is possible that at least part of the inferiority of the Stoneville select clones was not genetic. They had been propagated for 8 years in the nursery and may have lost some potential for survival and early vigor.

Seedling size did not significantly affect survival or age-1 height. Clones from large seedlings averaged 79 percent survival and 14 feet in height. Clones from small seedlings averaged 78 percent survival and 14 feet in height. It appears that selection for height among seedlings in a closely spaced nursery would be ineffective for improving clonal survival or age-1 height. At wider spacing, the situation may be different.

Table 3.--Survival and age-1 height of the Stoneville select clones

Clone number	Survival	Height
	(Percent)	(Feet)
ST63	15.6	--
ST66	78.1	14.0
ST67	43.8	13.1
ST70	3.1	--
ST71	71.9	13.8
ST72	31.3	14.5
ST74	59.4	13.5
ST91	28.1	13.4
ST92	59.4	12.9
ST107	31.3	14.2
ST109	75.0	13.1
ST124	21.9	--
Mean	43.2	13.6

Approximately 70 percent of the genotypic variance for height was additive, but only 18 percent of that for survival was additive (table 4). The errors associated with these estimates were not calculated, but both, and particularly that for survival, may have been large. A large error for survival is indicated by the discrepency between clonal variance calculated from the variance within families and its expected value, 1/2 additive genetic variance plus 3/4, dominate genetic variance, estimated from the variance among families.

Genetic superiority due to additive genetic variance can be accumulated through repeated cycles of selection and intermating. Since 70 percent of the genetic variance for height appears to be additive, it should be possible to obtain considerable cumulative improvement. Since only 18 percent of the genetic variance for survival was additive, little improvement in this character can be accumulated. Most efforts to improve survival should be made in the final stages of improvement prior to commercial release of plants.

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Table 4.--Mean squares and estimates of variance components for height and survival

Source	Survival df	Survival MS	Height df	Height MS	Component estimated	Survival	Ht
Location (L)	1	20573.75	1	88.6930			
Replicates/L	2	5664.88	2	17.3490			
Family (F)	15	6960.45	15	13.7583			
Paternal (P)	3	3648.81	3	34.2977	σ^2_P	1.07	0.0913
Maternal (M)	3	15037.71	3	19.7670	σ^2_M	42.13	.0889
PXM	9	5371.91	9	4.9090	σ^2_{MP}	98.10	.0348
LXF	15	1325.47	15	5.8284			
LXP	3	612.79	3	17.0593	σ^2_{LP}	-1.21	.1535
LXM	3	4024.25	3	2.9547	σ^2_{LM}	34.27	-.0045
LXPXM	9	663.43	9	3.0427	σ^2_{LPM}	-7.37	-.0351
Error I	30	657.93	30	3.1279	σ^2_δ	657.93	3.1279
Clones/F/L	352	544.14	336	1.2409	σ^2_c	91.15	.3492
Error II	352	361.85	336	.5425	σ^2_e	361.85	.5425
					σ^2_a	86.40	.3604
					σ^2_d	392.40	.1392
					$\sigma^2_G = \sigma^2_a + \sigma^2_d$	478.8	.4996
					$1/2\sigma^2_a + 3/4\sigma^2_d$	337.50	.2846

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