PRELIMINARY SELECTION OF EASTERN COTTONWOOD CLONES

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The Southern Forest Experiment Station is identifying fast-growing clones of eastern cottonwood (Populus deltoides Bartr.) both to meet growing demands for genetically improved planting stock and to obtain a base population for future breeding experiments. We have completed a series of preliminary seedling and clonal tests and have gathered early data from some long-term clonal tests. This paper reports responses to extensive preliminary screening and outlines preliminary screening techniques we plan to use in the future.

MATERIALS AND METHODS

The tests began with selection of phenotypically superior female trees in natural stands and ended with long-term clonal tests (fig. 1). Five steps were taken:

1. Field selection (1961-1962). In stands with a large cottonwood component, candidate trees were located through reconnaissance. Growth and form of candidate trees were compared with those of the five closest dominants or codominants. Selection was confined to 20- to 30-year-old trees on the Mississippi flood plain between Clarksdale and Vicksburg, Mississippi. Twenty-five females were selected for parents of the study population. The intensity of selection in this step is unknown.

2. Open-pollinated progeny test (1962-1963). A seedling population of open-pollinated progeny from the 25 selected trees was tested on a silt-loam soil. Details of the procedure were reported by Farmer and Wilcox (1966). Spacing was 2 by 3 feet. Approximately 4,000 seedlings (about 160 per family) were evaluated. Selection was made in two substeps:

   2a. A population of 93 seedlings was selected after the first year of testing. These genotypes were tested again in step 3.

   2b. The seedlings studied were cut at groundline at the end of the first growing season. The next year the clumps of sprouts were thinned to a single stem per seedling. The 31 clones which made up population "b" were selected after 1 year of sprout growth and used in step 4.

3. Clonal test I (1963). The 93 seedlings selected in step 2a were cloned and planted on a silt-loam soil. Spacing was 5 by 5 feet. There were three replications, each containing a single ramet of each clone. An evaluation of first-year development led to retention of 67 clones which were tested in step 4.

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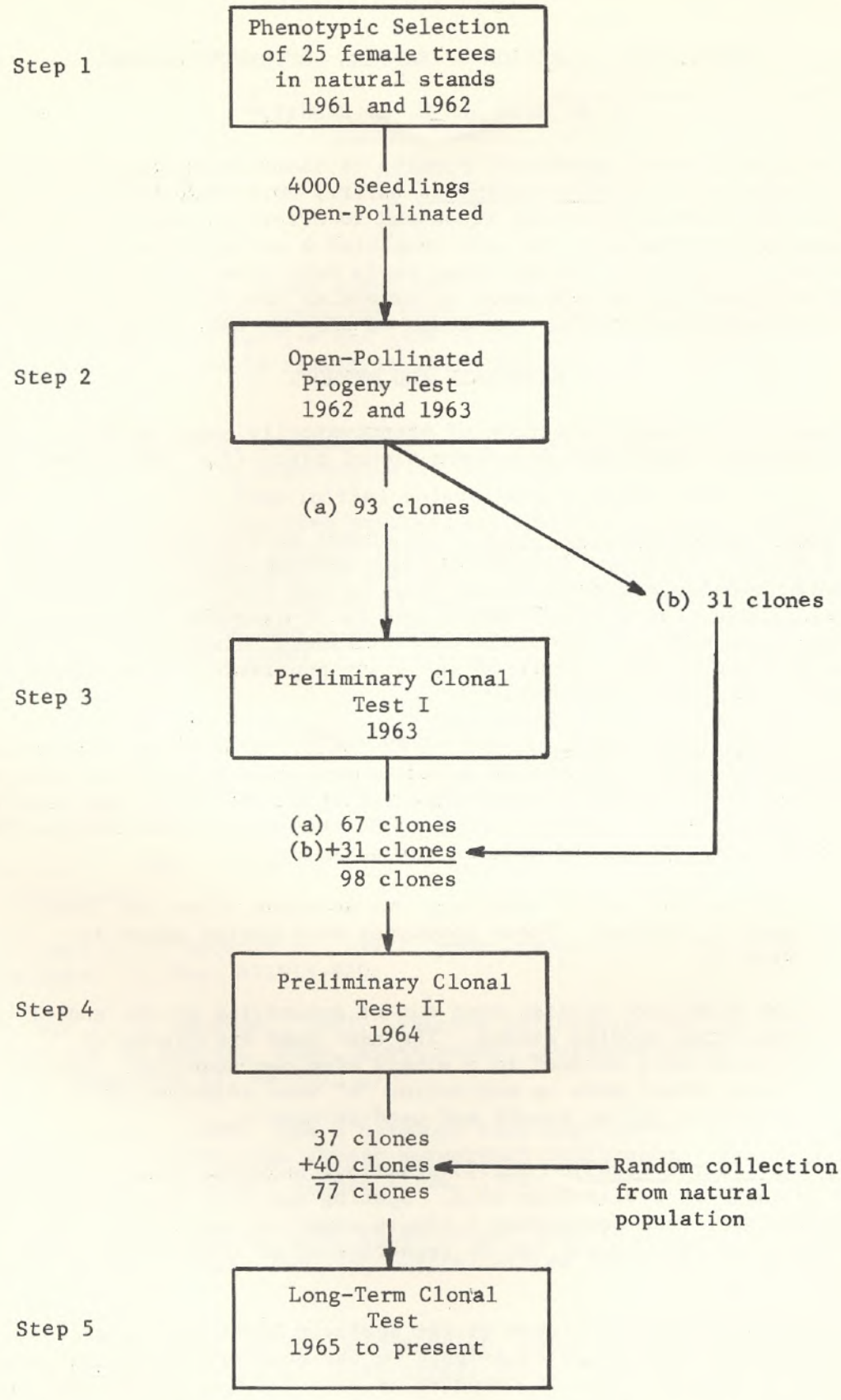

Figure 1.--Steps in the development of a population of clones now in a long-term clonal test.

4. Clonal test II (1964). The 67 clones obtained from step 3 plus the 31 from step 2b were evaluated. A triple lattice design provided for nine ramets per clone--three replications and three ramets per plot. Two clones commonly used in commercial plantings were used to raise the number of clones to 100. Spacing was 6 by 6 feet and the test was installed on two soil types: a silt loam and a heavy clay. Measurements made after one growing season were reported by Farmer and Wilcox (1968). The 37 clones selected at the end of the first year were entered in long-term tests.

5. Long-term clonal test (1965 to present). Performance of the 37 clones that survived preliminary selection is being compared with that of 40 cloned seedlings collected at random in the same area as step 1. A randomized complete block design was used with five replications on a heavy clay soil and five on a silt-loam soil. Plots contained four ramets. Spacing was the same as that commonly used in commercial plantings, 10 by 10 feet. Plots on the "good" site (silt-loam soil) were thinned after the third year, reducing stocking to two ramets per plot. Third-year height and fourth-year diameter data are reported here.

Selection

Selection was carried out at several stages, under a variety of conditions. In steps 1 and 2, individual trees were selected on the basis of their phenotypic values in the natural population or in an even-aged seedling population grown at a uniform spacing. In steps 3 and 4, clones were selected on the basis of the mean performance of several ramets. In the evaluation of phenotypes, several traits were considered and no rigidly defined criterion was common to all steps.

The complexities described and the relatively small amount of data available preclude an accurate quantitative description of the total selection process. Descriptions of selection were quantified individually for steps 2, 3, and 4. The treatment of data was related to the type of selection. In step 2, individual plant measurements and their variances were considered; in steps 3 and 4, clone means were the basic unit of analysis. Populations "a" and "b" in step 2 were treated separately. For convenient comparison, population "b" was described on the basis of first-year (seedling) data. Description was simplified by dealing with the two traits, height and diameter, independently. Descriptions include:

1. The proportion of the population selected.

2. The standardized selection differential (deviation of the select population from the test population mean in units of phenotypic standard deviation).

This value was computed directly from the data collected in each experiment.

3. The equivalent proportion of the population selected. Simultaneous selection for several traits upset the relationship between the proportion of the population retained and the standardized selection differentials (Falconer 1960, pp. 193-194). The proportion of the population retained, therefore, is

not particularly descriptive of selection for a trait. The standardized selection differentials were used to approximate the proportion of the study population which could have been retained to produce a select population with the observed means. Proportions equivalent to the selection differentials were obtained from tables for populations of given sizes (Becker 1967). Use of these tables required an assumption of normal distribution. The distributions of phenotypic values in the two clonal tests (steps 3 and 4) were approximately normal when graphed.

Values were computed to relate the select population at the end of each step to the mean of the seedling population. The products of the equivalent proportions selected in the successive steps were used to provide an estimate of the proportion of the seedling genotypes retained. Thus, if the equivalent of 10 percent of the population was retained in the first step, the retention of 50 percent of the test population in the second step would result in a "maximum equivalent proportion of genotypes" of 5 percent. This approach was used in all cases, except when populations were combined and appropriate maximum standardized selection differentials were obtained from standard tables. In combining populations, weighted averages of the maximum standardized selection differentials for the populations being combined were computed and used to obtain the equivalent percents. These calculations were made under the invalid assumption that the performance of materials in all steps was perfectly correlated. The selection intensities therefore were inflated, and they are termed "maximum" in the tables.

RESULTS AND DISCUSSION

The select population in the long-term tests performed considerably better than the random population. Height gain in standardized units was 0.993 on silt loam and 0.673 on clay (table 1). Diameter gain was 0.826 on silt loam and 0.465 on clay. These gains demonstrate that preliminary selection is advantageous.

Table 1.--Response in long-term test to preliminary selection for height and diameter growth

Population mean	Site			
	Silt loam		Clay	
	Third-year height	Fourth-year diameter	Third-year height	Fourth-year diameter
	Feet	Inches	Feet	Inches
Select	38.89	5.96	19.24	2.95
Random	36.97	5.49	18.05	2.76
Gain[1/]	.993	.826	.673	.465

1/ In standardized units: $\frac{\text{select} - \text{random}}{\sigma_{\text{random}}}$

No direct measure can be made of the effectiveness of selection in the individual steps. The expected response (R) to preliminary selection can be described as R = ricp, where r is the correlation coefficient for performance of clones in the preliminary and the long-term tests, σ_P is the phenotypic standard deviation, and i is the standardized selection differential. Some insight into the relative effectiveness and efficiency of each step is provided by examination of r and i.

Table 2 gives selection intensities for each step and maximum standardized selection differentials for steps 2 through 4. The differences between the actual and the equivalent proportion retained indicate the loss in potential selection intensity caused by the selection procedure. Contributing to this loss were consideration of several traits rather than one and the retention, for experimental purposes, of materials which would normally have been discarded. Selection was most intensive in step 2a because of the large number of genotypes screened and the high weight given to growth traits.

Table 2.--Quantification of selection in steps 2 to 4

Step	Step values					Cumulative values		
	Test mean[1/]	Number of plants retained	Proportion of population selected	Standardized selection differential	Equivalent proportion of population selected	Proportion of genotypes retained	Maximum equivalent proportion of genotypes	Maximum standardized selection differential
				Height				
2a (progeny test)	3.83	93	0.023	1.973	0.062	0.023	0.062	1.973
3 (clonal test I)	13.67	67	.720	.331	.810	.017	.050	2.063
2b (progeny test)	3.83	31	.007	.110	.949	.007	.949	.110
2b + 3	...	98	...	...	...	.024	.184	1.445
4 (clonal test II)								
(silt loam)	12.61	37	.375	.608	.620	.009	.114	1.692
(clay)	11.49	37	.375	.586	.637	.009	.117	1.679
				Diameter				
2a (progeny test)	13.6	93	.023	1.342	.222	.023	.222	1.342
3 (clonal test I)	1.50	67	.720	.357	.789	.017	.175	1.473
2b (progeny test)	13.6	31	.007	.459	.726	.007	.726	.459
2b + 3	...	98	...	...	...	.024	.304	1.152
4 (clonal test II)								
(silt loam)	1.71	37	.375	.426	.749	.009	.228	1.325
(clay)	1.61	37	.375	.334	.810	.009	.244	1.286

[1/] All means for heights are given in feet; mean diameter in step 2 is in millimeters; all others in inches.

The correlation coefficients (r) presented in table 3 provide a rough index of the efficiency of selection in each step. These coefficients must be viewed with reservation because of the large errors associated with their calculation.

Data in table 3 suggest that preliminary clonal tests are valuable. The use of even a small number of ramets in these tests substantially increased the correlation with the long-term performance on the silt-loam soil. If the increase was as substantial as indicated, the gain would more than offset the loss in selection intensity associated with the reduction of genotypes in tests with an equal number of plants.

On the clay soil, there was no clear indication that cloning would increase the effectiveness of preliminary evaluation. The data may have reflected a confounding influence of soil type, since the progeny test and first clonal test (steps 2 and 3) were carried out only on a silt-loam soil. In step 4, correlations were apparently increased by running the tests on similar soils. Preliminary tests should probably be made on soils similar to those on which the material will be utilized.

Low or even negative correlations were found between growth of sprouts from clipped seedlings and growth of the same genotypes in long-term clonal tests. Apparently, it is not advisable to evaluate on the basis of sprout performance.

No apparent changes in the correlation coefficients were associated with the increase in plot size from one to three ramets in step 4. On the basis of these data, it is recommended that plot size be kept small (one or two ramets) in preliminary clonal tests.

Phenotypic selection in natural stands may also have contributed to the observed gain. Farmer (in press) found that field selection of parents, using the system employed in step 1, was "completely ineffective" in terms of 1- and 2-year growth of progeny. There is, however, evidence that field selection contributed to the superiority of third-year height and fourth-year diameter growth of the select population.

The standardized gain in the long-term test (table 2) was divided by the maximum standardized selection differential reached after step 4. The quotient provides an estimate of the minimum average correlation coefficient between the preliminary and final tests required to obtain the observed response. The values calculated were:

	Diameter	Height
Silt loam	0.61	0.59
Clay	.36	.41

Particularly for the silt-loam soil, they are well above any reasonable estimate of the actual mean correlation coefficients based on the values in table 3. Under these conditions it is difficult to rationalize the gain observed on the basis of selection in steps 2 to 4 alone. It seems reasonable to conclude that

the select clones were derived from a seedling population whose mean was higher than the random population as a result of the selection of parents.

Table 3.--Correlation coefficients between values for clones in preliminary tests and comparable values in long-term tests

Steps in the program	Long-term test			
	Silt loam		Clay	
	Fourth-year diameter	Third-year height	Fourth-year diameter	Third-year height
Open-pollinated progeny test (step 2)				
2a seedlings--1962	0.1211	0.0806	0.2280	0.3551*
2b sprouts----1963	-.1626	.0206	-.1348	-.0452
Clonal test I (step 3)	.4563*	.5160*	.2815	.3481
Clonal test II (step 4)				
Silt loam	.3415*	.4431*	.2514	.0590
Clay	.1905	.1781	.4142*	.2614

* Significant at 0.05 level with 36 degrees of freedom for steps 2 and 4 and 30 degrees of freedom for step 3.

CONCLUSIONS

Data from the present tests and from earlier results reported by Farmer (in press) are conflicting with respect to the value of phenotypic selection for growth in natural stands. Experiments now in progress will show conclusively the gains, if any, to be expected from such screening.

Based on the results of the present tests, we plan in the future to do very little selection among seedlings. Rather, we plan to do extensive clonal selection. Large numbers of clones will be included to maintain a high selection differential. Each clone will be replicated several times to avoid excessive losses of promising material. Experiments will be designed with two-tree plots, and all will be on excellent cottonwood sites. After one or two growing seasons, less than 10 percent of the clones will be selected for long-term tests on a variety of sites.

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