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COTTONWOOD BREEDING STRATEGIES FOR THE FUTURE

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Abstract.--A large number of genotypes of eastern cottonwood of diverse parentage should be evaluated followed by multiple-stage selection for the most important characters to obtain substantial gains per sexual cycle while retaining genetic diversity. More intensive testing should be practiced in selecting clones for commercial use than for use as parents of the next generation. The number of parents should be kept large. All feasible means should be employed to minimize effects of non-genetic variability.

Additional keywords: *Populus deltoides*, multiple-stage selection.

Development of genetically improved eastern cottonwood (*Populus deltoides* Bartr.) is needed to meet future demands for wood from the species. To improve cottonwood efficiently, it is necessary to start with genetically varied natural populations and to practice selection for characters of importance. In general, the desired products are multiple-purpose clones that have good growth rates, good natural pruning ability, straight trunks, and wood properties suitable for pulpwood, sawtimber, and veneer. Trees should have sufficient genotypic stability to grow well on a range of good cottonwood sites, at a range of latitudes, and with somewhat less than ideal management. Other genetic traits should be considered to the extent that they are convenient selection aids or provide insurance against loss.

Insuring Genetic Variability

To assure adequate genetic diversity in a breeding program, it is necessary to select trees from many stands. Ledig (1974) suggested using only one tree per stand for testing, but testing enough trees per stand that one tree from each of the better stands can be retained after testing is more realistic. Another way to increase genetic diversity is to use trees from different geographic areas. However, much valuable time and effort may be spent studying provenances that will prove to be unsuitable. Although data from young trees sometimes indicates that considerable movement is feasible, the practical range from which to obtain cottonwood probably extends from 100 miles north to 200 miles south of the sites on which the trees are to be grown. Considerable east-west movement is practical as long as moisture and soil characteristics are suitable. Outstanding clones may come from great distances, but decisions to retain clones of non-local origin for commercial use need to be based on a greater fraction of a rotation than

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decisions involving local material. Provenances not well adapted to an area may contain genes that are needed in a breeding program, but it may be difficult to recognize the merits of such material.

Minimizing Nongenetic Variability

To conduct an efficient breeding program, nongenetic effects on genotypes must be minimized. To keep nongenetic effects low selection in natural stands should usually be made only for characters with high heritabilities. Effective selection for characters with lower heritabilities can be practiced only if the site is uniform, the stand is even-aged, and the trees are well-spaced. Most selection should be restricted to plantation experiments consisting of progeny or direct clonal descendents of selected trees. In such experiments, sites should be uniform, at least within a replication, and poor areas should be avoided. Cuttings should be planted well before foliation begins; careful cultivation should be practiced; and trees should be thinned before competition becomes excessive. Cuttings from the various clones should be from the same aged rootstocks, from the same nursery, of uniform size, and free of damage from insects and disease. Adherence to these criteria not only reduces nongenetic variability, but prolongs the useful life of small-plot experiments.

Statistical designs can be used to remove from consideration much of the nongenetic variability not removed by careful cultural techniques. The randomized complete-block design is the traditional approach for statistical removal of nongenetic variability, but more complex designs are frequently better, particularly when large numbers of entries are compared. Snyder (1966) pointed out the advantages of using lattices in forest genetics research. Triple, balanced, and cubic lattices have been used with cottonwood to remove soil gradient effects within replications, and should be effective for reducing nongenetic variability due to insect gradients and unavoidable differences in cultural practices in experiments that cover large areas.

Direct Clonal Evaluation of Select Trees From Natural Stands

If resources are very limited, selection among pole-sized trees in local natural stands, followed by asexual propagation, rejuvenation in the nursery for one or more years (Farmer 1966), and establishment of replicated clonal outplantings from clones having good survival and good early growth is practical. After several years the best clones can be selected and propagated for commercial use. Additional tests of this type and tests that involve nonlocal material should be installed from time to time, and the best clones from the various tests should be retested to refine the selection process further.

Schreiner (1971) recommended the method. It is fairly simple and inexpensive and normally involves no more than a few dozen clones at a time or a few hundred clones over several years. Clones chosen for development have already proven themselves to an extent in the natural stand, and require less testing than clones derived from seedlings.

Disadvantages of the method are that it depends upon trees being rejuvenated enough that they will root well, and some good clones may be eliminated because they lack good rooting ability or have poor early growth.

Evaluation of Open-Pollinated Progeny

Since many male parents may be represented in the seed from one female tree, evaluating open-pollinated progeny samples the variability in a natural stand more thoroughly than direct clonal evaluation of select trees. However, only a portion of the superiority of the female parent is retained by the progeny. The approach is best when it is important to screen for characteristics for which selection in natural stands in ineffective. It often involves thousands of genotypes.

Multiple-Stage Selection

The best method of evaluating large numbers of cottonwood clones is multiple-stage selection, which consists of preliminary evaluation of many genotypes followed by one or more stages of intensive evaluation of the genotypes that appear best. Each stage usually consists of smaller replications than the preceding one, more replications per location, and more locations.

In the early stages of multiple-stage selection it may not be practical to replicate individual clones. However, families or stands can be replicated, and although considerable precision will be lost with regard to individual clones, entire families and the poorer members of the better families can be eliminated with confidence. By not replicating individual clones and by obtaining cuttings for further testing from the outplantings rather than from the nursery, labelling of individual clones in the nursery and of the material to be outplanted is unnecessary. Field maps need only show positions of the families. If several clones are included per family plot, the opportunity exists for convenient visual selection among clones within families for characteristics not measured. Thus, selection among families and to some extent within families might be based upon growth rate, and characters not measured such as straightness and branch characteristics might be considered in choosing the best overall clone per family plot. The selected clones would be included in the next stage of the multiple-stage selection program, in which clones would be replicated.

Advanced Generation Breeding

The portion of the population retained after intensive selection is far less variable than the initial population, and it is then necessary to make crosses among the select clones to provide the genetic recombination required to produce the variability needed for further improvement. Any of several mating schemes could be used. Burdon and Shelbourne (1971) discuss some of the possible mating designs and suggest using as many as 200 parents to start each new breeding cyle. Each selected female could be crossed with each selected male, but this would require a tremendous number of crosses if very many parents were involved. Crossing could be restricted to several small sets of parents, or single-pair mating could be practiced, using each parent only once. A mixture of pollen from several males could be used to pollinate each female. Other possibilities exist, but in any realistic breeding program involving a large number of parents, only a few of the possible crosses can be made and evaluated.

Selection Indices

A selection index that takes into consideration genetic and phenotypic variances and correlations and relative economic values of different traits was developed more than 30 years ago (Hazel and Lush 1942). The index has been modified for situations where economic values of traits are unknown or are subject to so much change that they are best ignored. A selection index also has been formulated for use with multiple-stage selection (Cunningham 1975). Selection schemes, however, do not currently take into account the costs of measuring different characters, and considerable work remains to be done in determining the best method of utilizing all pertinent information.

A Model of A Cottonwood Breeding Schedule

The following is a schedule which should be practical for a cottonwood breeding program in the South:

Year	
1	Obtain appropriate seed. Plant.
2	Produce suitable material for cuttings. Possibly practice some nursery selection on highly heritable characters.
3	Plant preliminary clonal test.
5	Make tentative selections of 3-year-old trees. Collect limb cuttings.
6	Multiply cuttings. Eliminate some clones based upon age 4 observations of performance in multiplication nursery.
7	Plant advanced clonal test at three or more locations. Include appropriate checks. Also retain these clones in the nursery.
9	Measure advanced clonal test, which is now 3 years old, and remeasure preliminary clonal test, which is now 7 years old. Select clones for use in the crossing program and for multiplication for additional testing and/or commercial use.
10	Make crosses in preliminary clonal test, which may take 2 years, and repeat all previous steps. Also increase cuttings of select clones.
11	Rigorously evaluate select clones for survival, early growth, and other juvenile characters. Continue to increase cuttings of select clones.
12	Establish additional field planting (highly select clonal tests) of the best clones and appropriate checks at several locations. Continue multiplication of clones doing well and eliminate any doing poorly in the new outplantings. Make quantities of cuttings available to production nurseries.
13	Multiply clones in production nurseries.
14	Further multiply clones in production nurseries.

15 Establish commercial plantations. Growers will be able to obtain adequate quantities of the new clones at the beginning of the fifteenth season. At that time, the clones will be 12 years old in the preliminary clonal test, 8 years old in the replicated advanced clonal tests, and 3 years old in the replicated, highly select clonal tests.

The schedule requires final decisions on choice of parents based upon one 7-year-old tree per clone and several 3-year-old trees at different locations. More information on performance would be required on a clone that is commercially planted than on a clone to be crossed. Methods might be devised to shorten the breeding cycle but then adequate field evaluation would not be possible. In most cases, it is better to concentrate on increasing the amount of gain per cycle for a combination of the most important characters than to shorten cycles. In the North, breeding cycles will be longer as will the time required for adequate field evaluation.

CONCLUSION

The systematic, long-term improvement of cottonwood outlined here is a conservative approach that minimizes risk and utilizes procedures that have worked with agronomic crops. The use of materials developed from such a program should result in increased growth rate, quality, and profit.

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