

PRACTICAL BREEDING OF COTTONWOOD IN THE NORTH-CENTRAL REGION¹

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More than 20 years ago Scott Pauley (1949) designated the genus *Populus* as the "guinea pig of forest-tree breeding." This designation is still appropriate as evidenced by the steady, almost overwhelming, stream of publications related to the genetics and breeding of poplars. A good indication of the scope and depth of genetic work with poplars can be found in the recent review of poplar breeding by Muhle Larsen (1970) and discussions of cottonwood genetics and breeding by Schreiner (1971) and Farmer and Mohn (1970). These reviews cover a variety of research and breeding activities at widely dispersed locations and support the contention that our knowledge of poplar genetics is comparable with that available for any other group of forest trees. My assignment is to relate this knowledge to the "practical" breeding of cottonwood (*Populus deltoides*) in the North-Central Region. While I will concentrate on eastern cottonwood, the biology of the genus *Populus* requires consideration of the other species and hybrids commonly called poplars. Aspens will not be considered.

For a breeding program to qualify as "practical" it must be undertaken with a high probability of producing improved material within a reasonable time. At this meeting Farmer (see page 9) has pointed out the strong evidence of potential for genetic improvement in cottonwood. In addition, the experience of Europeans in poplar breeding (FAO 1958, Muhle Larsen 1970), the progress in poplar hybridization in the Northeast (Schreiner 1949, 1950), and the work with cottonwood in the Lower Mississippi Valley (Farmer and Mohn 1970, Mohn *et al.* 1970) all indicate that we can design programs for this region that will rapidly produce genetically improved poplars (cottonwoods, balsam poplars and their hybrids). While additional genetics work is needed to design optimum

programs, neither a lack of knowledge nor a lack of biological potential is a major stumbling block to the initiation of practical breeding in our region.

"Practical" in breeding implies a use for the product, not just the production of biologically improved material. The reason many forest geneticists in this region take a "guinea pig" approach to work with poplars is that poplars aren't planted extensively enough to justify breeding programs. We can speak about practical breeding of cottonwood at this meeting because our theme is the future and there are strong indications that our future may include a demand for improved poplar planting stock. Poplars can have great value as a crop on the "fiber farms" Westell (1969) foresees developing in this region. They are ideal for use with systems of intensive cultivation on selected sites because: (1) they have the potential for rapid growth essential to making highly mechanized "forest farming" pay, (2) we have the technology for effective utilization of their wood, and (3) a wealth of experience has been acquired that can be used to quickly develop plantation management systems suited to our region.

The development of intensive culture of cottonwood or poplars in this region will probably be centered on some of the 4 million acres of excellent and good quality elm-ash-cottonwood sites Dawson and Pitcher (1970) reported. It can logically be expected to follow a progression from experimental plantings to pilot-scale plantings to commercial plantations such as McKnight (1970) described for the lower Mississippi Valley.

At this time most of the work in the North-Central Region is in the experimental stage. We've been in that stage for a considerable period of time. For example, a 1913 USDA publication includes a photograph of a fine 12-year-old cottonwood plantation in southern Minnesota with trees of pulpwood size (Williamson

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1913). Records of hybrid poplar plantings go back at least to 1888 and other test plantings have been established periodically (Rudolf 1948). Results have been mixed, but encouraging enough to sustain interest.

The next step will be the development of systems for cultivating poplars in our region on a large scale. This means we must define the elements of these systems from planting to utilization and bring them together in a workable package. This task will take the combined efforts of silviculturists, field foresters, utilization specialists, and others. Ironically, in this critical step in the development of viable breeding programs, the role of the forest geneticist is small.

TESTING COTTONWOOD SELECTIONS AND POPLAR HYBRIDS

The immediate task for forest geneticists is the identification of materials suitable for use in small-scale experimental or demonstration plantings. The goal is to find materials that will perform well; the guideline should be reliability based on sound biological reasoning or past testing. This step is analogous to the delineation of seed collecting zones or seed source recommendations in other species. It is most critical in poplars because a relatively small number of "well-traveled" genotypes, not seedlings of a local origin, have traditionally been used for planting stock. Often these materials are planted because they are available and not because of their performance in local tests.

The task is complicated by the variety of materials available. In our region the native cottonwood can be considered. *Populus balsamifera* is also native to a part of our region and the potential for fiber production under plantation conditions of this species is unknown. In some Minnesota tests *Populus nigra* and *Populus trichocarpa* have grown at impressive rates and these species, along with other exotics, are candidates. Hybridization occurs between many *Populus* species naturally and nearly all can be artificially crossed (Muhle Larsen 1970), adding many hybrids to our list. The complexity of species and hybrids is compounded further by the capacity for asexual propagation common in poplars. Individual genotypes are used on a wide scale and the clone as a unit of genetic identity increases the number of options almost to infinity.

The task of making recommendations becomes manageable when two biological considerations come into play. The first of these is the need to avoid excessive

genetic uniformity. Schreiner (1959) and others have stressed the increased danger of disease and insect attack in monoclonal plantations. To maintain genetic diversity, planting of individual clones should be avoided, and recommendations should only consider mixtures of at least 15 to 20 genotypes. Seedlings can also be used to ensure genetic diversity and this may be the only reasonable alternative when propagation difficulties are encountered.

The second consideration is the need to use materials that are well adapted to the conditions under which they are to be grown. To ignore this factor invites poor growth or excessive injury due to climatic stress, disease, and insects. Because the trees we plant must be adapted to the planting site, our choice will be among materials that have been adequately tested in the locality, and selections from local wild populations.

In some parts of the region work with cottonwood or poplars has progressed to the point where a group of high-quality clones can be identified, but in many areas the results of tests have been negative or inconclusive. There the local wild populations will be the best source of planting stock. Smith (1968) recommended this sort of alternative after reviewing experience in poplar planting in Canada, and Maisenhelder (1970) recommended the use of selections from local populations of cottonwood in the South, after a large array of hybrid materials failed to perform satisfactorily.

Cottonwood is the logical species to plant in most parts of our region. The simplest approach is to collect and use cuttings or seed from good stands. Some sort of phenotypic field selection may be practiced in an effort to get genetic improvements. Such selection should be based on genetic information — e.g., heritability estimates and character correlation — and on a critical assessment of characters to identify those with economic importance. Little information is available concerning the effectiveness of field selection for specific traits. However, traits that are known to be under strong genetic control, such as *Melampusora* rust resistance (Jokela 1966) should be given more weight than traits such as growth, for which the effectiveness of field selection is questionable (Farmer 1970, Mohn and Randall 1969). As a general rule it is best to choose trees that are outstanding for one or two economically important traits and satisfactory in other respects.

The number of trees selected in the field should be adequate to ensure genetic variability in the planting

stock. If the use of selection directly via asexual propagation is anticipated, an excess should be selected because a large proportion of the genotypes will be eliminated in the nursery as a result of propagation difficulties. Muhle Larsen (1970) reported a range in rooting success of cottonwood clones from 0 to 100 percent. Work with cottonwood in Mississippi has been plagued with propagation difficulties, causing Maisenhelder (1970) to recommend restricting field selecting to 3- to 5-year-old trees when developing a source of planting stock.

The procedures used in obtaining stock for immediate planting will vary greatly from locality to locality. Past testing, decisions regarding the best way to propagate, and the resources available will all be determining factors. No matter what procedure is followed, the emphasis always should be on obtaining reliable materials quickly for use in developing effective systems of plantation establishment and management.

BREEDING OF POPLARS

Cottonwood Breeding

Actual breeding will come in response to the demand for improved materials associated with increased planting. In designing breeding programs the first step will be the establishment of clearly defined goals. All aspects of the cultural systems in use, from planting to utilization, should be considered; priorities should be developed so efforts will be concentrated on making changes that have an actual impact on productivity.

Genetic improvement, as in other species, has two phases: (1) the production or definition of populations with which to work and (2) the selection of superior materials from these populations. In developing working populations, the objective is a high frequency of favorable genes or gene combinations.

In practice, materials with which to work can be expected to accumulate with astonishing rapidity. Identification of the superior materials is more difficult and time consuming. Large backlogs of promising, but unproven, materials are characteristic of poplar work. Evaluation in the nursery can be used to cull out material with poor propagation characteristics, susceptibility to pests, or obviously low vigor. However, experience with cottonwood in the South suggests that the most substantial gains will come from selection based on adequate field testing (Mohn and Randall 1969). Emphasis in a practical breeding program should be on

the establishment of such field tests using enough materials to permit the intensive selection necessary to obtain substantial genetic advances.

It is probable that asexual propagation will be used in cultural systems developed for this region and that clonal tests will be the basic tool in genetic evaluation. Clonal tests should be established and maintained using the same cultural techniques as are used in commercial plantations. Testing on several sites will most likely be required (Randall and Mohn 1969) and final selection should be delayed until trees have been tested for a half-rotation (Schreiner 1971). Relatively few ramets per clone are needed. Schreiner (1971) recommended from 10 to 20 per site and this number was adequate in the Stoneville tests.

Concentration on field evaluation means that breeding programs should be designed so several hundred new clones are placed in field clonal tests annually. The acreage required is substantial but can be reduced by establishing an initial test on a single site with a large number of clones, conducting a preliminary evaluation at perhaps one-quarter rotation age, and then testing only the better clones on other sites. The cost of large-scale field testing can also be reduced by other means. In the Forest Service program at Stoneville we were able to place several hundred clones in a field test at a low cost by combining our test with a commercial planting. The arrangement was most satisfactory to the cooperator (who cultivates and maintains the planting) because he will harvest the test along with the rest of his plantation.

In this region I recommend that the first series of clonal tests be aimed at evaluation and selection of clones from local cottonwood populations. This will ensure that materials selected in the early stages of the breeding program are well adapted to local conditions. Phenotypic selection can be used to obtain the candidate clones; but since the emphasis is to be placed on relatively large numbers of clones, its intensity will be relatively low. If the pollarding and nursery propagation techniques described by Schreiner (1971) can be used effectively, selections can be placed in field tests directly. If not, the most practical alternative is the cloning and testing of open-pollinated seedlings from the plus-trees. Materials currently being used as planting stock should be included in these, and all tests, as a basis for comparisons.

The process is a kind of mining of the natural population that should not be carried out indefinitely. The

effectiveness of selection in terms of usable gain per unit effort will decrease as additional materials are tested. A limit should be set and when it is reached the emphasis shifted. A reasonable approach would be to continue establishing tests until 1,000 clones are being evaluated. If the top 5 percent of the clones tested were selected, this phase of the program would yield a group of 50 clones suitable for use in commercial plantings and as a base population for further breeding.

After adequate numbers of local cottonwoods are under test, new populations that have a high probability of containing favorable genotypes should be located or created. Results of provenance tests, such as those coordinated by J. J. Jokela of the University of Illinois, may indicate that nonclonal populations of cottonwood are worth considering. In Minnesota, for example, a high proportion of the exceptional phenotypes in a 6-year-old provenance test are of a Missouri origin. We, in Minnesota, should consider practicing selection in populations obtained from central and northern Missouri if this trend continues.

While work is being carried out with nonlocal populations, selective breeding should be initiated using the best local cottonwood. The same types of procedures employed with seed-propagated species can be used. The first phase will involve the crossing of the best field selection to produce improved populations, screening these populations of progeny in the nursery, and placing the most promising materials in clonal tests. Selecting and mating can be repeated through several generations or discontinued if alternative methods of generating working populations appear more profitable.

Poplar Species Hybridization

While *Populus deltoides* should serve as a base for improvement in this region, it is improved poplars that really interest us. The whole genus *Populus* should serve as a gene pool for constructing the base populations. Schreiner (1959, 1966) has repeatedly urged this approach. Recently he proposed an ambitious program for obtaining maximum genetic improvement of poplars (Schreiner 1971). Many of the procedures outlined in this scheme, including both intra- and inter-specific hybridization, can be used to develop working populations in our region's long-term improvement programs.

Species and racial hybridization using the best local materials as one parent should also be initiated early in the program. The objective is to produce populations that either express hybrid vigor or combine the favorable traits of two or more *Populus* species. Crossability patterns for species of poplars are fairly well defined and there are some indications of the combinations that produce vigorous offspring (Wright 1962). In a practical breeding program this sort of information should be used to concentrate effort on producing the good combinations. In this region crosses of cottonwood with *Populus nigra* and several of the balsam poplars are good possibilities. Initial crosses should be designed to sample several provenances of the non-local components. Mixtures of pollen from several trees can be obtained from cooperators and used to make these crosses.

In the first stages of hybridization, relatively small numbers of seedlings from each combination should be produced so efforts can be centered on producing more combinations. Results from nursery or short-term tests of these materials should be used as a basis for planning additional hybridization. Exceptional phenotypes from the hybrid population should be placed in clonal tests that permit their evaluation relative to the best local cottonwood.

In addition to recurrent selection schemes and hybridization, less conventional techniques, such as the production of polyploids, may be employed in the production of better populations from which to select. No matter what techniques are used to generate materials, practical breeding programs should be aimed at continuous improvement of planting stock through intensive selection. This can be achieved most effectively through field testing of large numbers of clones.

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