

GENETICALLY IMPROVED COTTONWOOD--A RESEARCH
AND DEVELOPMENT SUCCESS

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ABSTRACT

Planting and cultural treatments developed for cottonwood (Populus deltoides) by research and private industry have succeeded on thousands of acres in the Lower Mississippi River Valley. From thousands of progeny of trees in the region, 14 cottonwood clones for commercial production were chosen by researchers at the Southern Hardwoods Laboratory through nursery and field tests.

I hope the word "success" in the title of this paper will lead no one to believe that research and development efforts with cottonwood are complete. Work so far has been highly successful, but the cottonwood program is not terminated and it will not be in the foreseeable future. We have learned a great deal (Farmer and McKnight, 1967), but we still have a long way to go. An indication of the job ahead may come from Europeans who have been working with Populus for the last 250 years (Schreiner, 1959). Their efforts continue with more intensity than ever.

Let's take a look at the cottonwood program at Stoneville--where we have been, where we are, and where it looks like we are going. First, why did we choose cottonwood? Why not oak or cypress, for example? Phenomenal growth, relatively easy vegetative propagation, and favorable wood properties recommended cottonwood. Commercially, the species is growing in importance. Lumber and veneer are still used for wirebound boxes and crates, mainly beverage cases, and for furniture parts. And demand for cottonwood pulp for high-grade book and magazine paper is increasing.

In the early years at Stoneville (1936 to 1950), foresters made important observations in the natural forest that were reported later (Maisenhelder and Heavrin, 1957; Putnam et al., 1960). For example, they found that cottonwood would establish itself only on fresh soil of medium to coarse texture

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formed by river flooding. Clay soils were not favorable for cottonwood and seeded to the other pioneer species common to major waterways in the Lower Mississippi River Valley--black willow. It became clear that cottonwood could not tolerate herbaceous competition because the species grew primarily in pure stands on land free of other vegetation. Codominant trees in natural, unmanaged stands were found to be growing about 5 feet in height and $\frac{1}{2}$ to 1 inch in diameter per year. Natural stands were yielding 1,000 board feet and 1 to 2 cords per acre annually (Williamson, 1913).

These stands were harvested by single-tree selection, group selection, and occasionally by clearcutting. But none of these techniques encouraged regeneration of cottonwood; they led to mixed stands that included sweet pecan, sycamore, sugarberry, and frequently boxelder. Thus, it became apparent that future stands of cottonwood were dependent on formation of new land by major waterways, particularly the Mississippi River.

While they were gathering information and experience from the natural forest, researchers were also doing preliminary planting tests. For a variety of reasons early ventures often failed or succeeded only partially. In 1936, Donahue took cuttings from the previous year's growth in the tops of large trees and planted them on Sharkey clay soil near Stoneville, Mississippi. All of the planted cuttings died, but scattered natural seedlings within the test area grew well. Later, tests showed that cuttings should be taken from trees less than 3 years old, that less than 10% of cuttings from the tops of older trees root unless a hormone is applied. Tests also showed that cottonwood is very exacting in site requirements. In one 25-year-old planting, trees on a Sharkey clay ridge averaged only 8 inches d.b.h. and 65 feet in height, whereas trees on an adjacent area, a Sharkey clay flat, averaged about 16 inches d.b.h. and 100 feet tall. The difference was due to more available moisture on the lower site. Even the faster growing trees have performed poorly because Sharkey clay is considered marginal for cottonwood planting (Broadfoot, 1960). Early plantings were small, and weed control was always less than complete. These early attempts to shortcut weed control were related to economics, but such shortcuts have always been costly.

Basic requirements for establishing and growing cottonwood were presented by several researchers between 1940 and 1960 (Bull and Muntz, 1943; Maisenhelder, 1951; Maisenhelder, 1960), but the program included only pilot tests until 1960. Then, planters began to realize that cottonwood was disappearing. It represented only about 3% of the available timber volume in the Lower Mississippi Valley (McKnight, 1970), and channel straightening and bank stabilization along major rivers had drastically reduced the formation of soil deposits suitable for cottonwood establishment. No simple silvicultural system was available to regenerate cottonwood naturally (Johnson, 1965). One technique that had given some promise was trenching 6 to 8 inches deep on sites where natural seedfall was adequate, but there was only about a 50/50 chance that this system would work. Thus, it became obvious that if cottonwood was to be perpetuated it would have to be grown on existing land in plantations.

In 1960, cottonwood planting began in earnest when Crown Zellerbach Corporation purchased a 15,000-acre cattle and cotton plantation in the Mississippi Delta near Fitler, Mississippi. Plans were made to plant 3,000 acres

annually, an undreamed of undertaking up to that time. As might be expected, there were many problems. Nurseries could not supply cuttings, proper spacing was (and still is) a question, and equipment such as tractors, disks, and cultivators for weed control had to be chosen. Soon after Crown Zellerbach's planting, several other companies began large-scale operations. In one way or another, the companies were basing their decision on economics. They thought cottonwood plantations would pay.

Technical information and cost data for establishing cottonwoods, barring some unforeseen catastrophe, have been pretty well documented (McKnight, 1970). In an operation where 1,250 acres of cottonwood were planted annually, the investment in equipment was about \$63,000, and establishment costs ran \$107 per acre. The most expensive task is clearing, which costs \$75 to \$85 per acre.

Returns from cottonwood plantations are still unknown but they have been estimated on the basis of preliminary growth and yield data (Dutrow et al., 1970). Rate of return varies with costs and stumpage values but, based on today's prices, cottonwood grown for a combination of pulpwood and sawtimber on a good site and over a single rotation should return about 10% on the investment. This estimate is based on a predicted yield of 16,500 board feet (Doyle) and 35.8 cords per acre in 20 years. Returns should be higher on perpetual rotations because subsequent establishment costs will be lower.

There is still not enough information to know whether growth projections are accurate. Recently collected data do not conflict with the projections, but indicate the need for certain refinements in plantation management.

Planted stock on good sites has grown $1\frac{1}{2}$ inches or more in diameter and 10 to 15 feet in height annually over the first 5 years. There are indications, though, that this growth rate will not continue over the life of a cottonwood plantation, regardless of how it is managed. Yields of 3 cords per acre per year have been documented over a 9-year period; greater yields should be possible once spacing and thinning techniques have been refined. It appears that a spacing of 12 by 12 feet, with subsequent thinnings, may be suitable for producing a combination of pulpwood and sawtimber. Time of thinning appears critical since data indicate that cottonwood does not respond well to thinning after it has been crowded. Where pulpwood is the only objective, initial spacings of 10 by 10 or 11 by 11 feet may be best, and where the aim is to grow sawtimber as rapidly as possible, tree spacings of 18 feet by 18 feet or 20 feet by 20 feet may be more desirable. A critical factor at the narrow spacings is to grow the bulk of the trees to a commercial size and then harvest before mortality becomes severe. Wide spacings promote side branching and will necessitate pruning at least to the height of the first log to insure high wood quality. Total wood yield will be highest in plantations managed for pulpwood only.

Research has provided guides for selecting sites, producing and handling cuttings, planting cuttings, and controlling weeds. Industry adapted the recommendations to field conditions and solved the deer problem on its own. In most areas where cottonwood is grown, deer are numerous. Through trial and error, planters found that the best way to protect their

plantations during the first year was to build crude fences by piling debris cleared from the outer portions of the planting area. These fences must be 10 to 12 feet high. At the base they are about 20 feet across. They exclude deer for a year or two, after which the cottonwood will be beyond the reach of the animals. Although deer can completely destroy a plantation, research has shown that trees grazed repeatedly the first year can recover during the second year if they are protected.

In the early 1960's when it became obvious that cottonwood plantations were not a passing fancy, researchers and industrial foresters realized the need for better planting stock. With improved stock, more fiber could be produced over a short rotation. There also appeared to be advantages in having trees that would foliate at about the same time, making cultivation easier, and that would grow at about the same rate, providing equal spacing of crop trees after thinnings.

Maisenhelder (1961) during the 1950's did preliminary work in cottonwood tree improvement. He selected the best natural seedlings from sandbars and propagated them in the nursery. Some of his early selections are still being tested. Maisenhelder (1970) also worked with hybrid poplars that had created excitement in the Northern United States and in Europe. He found, however, that on high-quality sites in the Lower Mississippi Valley hybrid poplars were inferior to local cottonwood in growth and susceptibility to insects and diseases.

Maisenhelder's findings provided some background for the existing cottonwood tree improvement program, which had its real beginning in 1961 when a full-time geneticist was hired at Stoneville. One of the first tasks of the genetics program was to determine natural variation in the cottonwood population of the Lower Mississippi Valley. The information was gathered through direct sampling in natural stands, clonal tests of randomly selected trees, and progeny tests. Results showed wide tree-to-tree variation in specific gravity, fiber length, date of flowering and seed dispersal, and resistance to Melampsora rust, which infects leaves during August and September and may cause defoliation. The tests seem to indicate that the cottonwood population in the Lower Mississippi Valley was very heterogeneous. Most of the variation appears to be between trees within stands. Phenology and morphology appear to be under strict genetic control (Farmer, 1966).

Outstanding phenotypes were selected from natural stands, and cuttings, seeds, or both were collected from them for clonal and progeny tests. From these tests, the best clones were selected for commercial use (Mohn and Randall, 1969). Since cottonwood can be easily propagated by cuttings, an improvement once expressed in a single genotype can be maintained indefinitely. Improved juvenile growth received the most attention, since this is one of the top priorities to the planters.

The six steps by which 14 clones were developed for release by the Southern Hardwoods Laboratory in 1970 were:

1. In 1961-62, 25 female cottonwoods, 20 to 30 years old, were selected from natural stands between Clarksdale and Vicksburg, Mississippi.

2. In 1962-63, seedling populations from the 25 select trees were evaluated in nursery tests.
3. In 1963, 93 of the approximately 4,000 seedlings observed in step 2 were cloned, planted on a silt-loam soil, then reevaluated after one growing season.
4. In 1964, clones selected from steps 2 and 3 were planted on silt-loam and clay soils, and after one growing season 37 still appeared promising.
5. In 1965 to 1970, the 37 clones surviving step 4 were planted along with 40 clones chosen at random on both silt-loam and clay soils. Plantings were at 10- by 10-foot spacing and were handled as in a commercial operation.
6. In 1970, 14 of the clones evaluated in step 5 were released for commercial use. Eleven of the chosen clones had demonstrated above average first-year growth in steps 2, 3, and 4. The other three clones are of unknown parentage and were not evaluated prior to step 5. Fifth-year mean diameter of clones on the silt-loam soil was the primary basis for selection. The final 14 each had mean fifth-year diameters in the top 25% of the test population and did not exhibit serious defects, such as low forking, extremely large persistent branches, or extremely crooked boles (Mohn et al., 1970).

Five-year growth of select clones was compared with that of controls or 40 clones chosen at random. Mean diameter growth of the 14 select clones exceeded the controls by approximately 20% (7.6 versus 6.3 inches) on silt-loam soil and by about 13% (3.8 versus 3.3 inches) on clay soil. Height growth of the select clones was nearly 10% better than that of the controls on both sites. On silt-loam soil, which is more typical of the sites where cottonwood is planted, mean stem volume to a 3½-inch top (bark included) was 6.5 cubic feet in the select group and 3.7 cubic feet in the control group. Seven-year data, though not yet reported, show the early trend continuing. Select clones on the silt-loam site averaged 9.4 inches d.b.h. and 68 feet tall, compared to an average diameter of 7.8 inches and height of 62 feet for the controls.

Although the 14 select clones appear to have above-average growth qualities, there is risk that some may be undesirable in an unforeseen way. A more conservative approach would require testing over at least one-half of a timber rotation and over a wide geographic area and range of soils. Such tests are being conducted but will not be completed for 10 to 15 years. Still, in this particular situation all clones were selected from a population adapted to local conditions. Stoneville scientists recommend that the 14 clones be planted in mixture for insurance against adverse factors that might affect a few of the clones.

Considerable progress has been made in supplying improved planting stock for cottonwood. But the system to date is limited to that improvement that could be attained from the natural population. That is why scientists at Stoneville are conducting full-sib progeny tests and are using as parents 14 clones selected to date, plus many other clones that have outstanding characteristics. Through this system, we may be able to improve on natural material by combining the favorable attributes of various parents to produce

trees with outstanding growth and wood characteristics and with resistance to insects and diseases--true super trees.

Clones being distributed for commercial planting may stimulate new research at Stoneville. The cultural techniques practiced so widely with run-of-the-bar stock may have to be modified for the new clones. Spacing now recommended may have to be altered, or timing of thinnings changed. Which clones, if any, will respond significantly to fertilization and irrigation and under what conditions? Will insect and disease problems now being controlled with systemic insecticides become more acute even in mixtures of select clones? Only time and experience will tell. One thing seems certain--cottonwood growing can help meet the timber needs of this country. As foresters we would be remiss if we did not take advantage of the opportunity.

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