

Five-Year-Old Cottonwood Plantation on a Clay Site: Growth, Yield, and Soil Properties

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ABSTRACT. A random sample of Stoneville select cottonwood (*Populus deltoides* Bartr.) clones planted on recent old-field clay soils at 12- by 12-foot spacing averaged 75-percent survival after five years. The growth and yield was about half that expected from planted cottonwood on medium-textured soils. Soil moisture analysis showed more height growth in years with greater moisture late in the growing season. Significantly less soil N, P, K, Ca, Mg, and organic matter were in the plantation after five years than at the start. Also, no clear relationship existed between nutrient level and fifth-year average height.

Cottonwood plantations have been established on more than 40,000 acres in the Mississippi River Valley (Burkhardt and Krinard 1976). Because of the expense of site preparation, planting, and first-year culture, the species has been planted mostly where it grows best—on recently cleared ground where soil is of medium texture. Old-field clay soils are representative of poor cottonwood sites of less than 100 site index and generally have been avoided. However, growth may be improved with select planting stock. Based on limited tests, 14 select cottonwood clones were found that exceeded the growth of unimproved planting material by an average of 13 percent in diameter and 11 percent in height on Sharkey clay soil (Mohn, Randall, and McKnight 1970). Four of the clones were randomly selected as representative of above-average material and planted on a fine-textured site. The study was not designed to compare clones, which were considered to be equivalent, but to determine growth of select stock on a difficult site. This paper is a report on five-year growth and annually monitored soil properties in the plantation.

The study area is located on the Mahannah

Plantation of the Anderson-Tully Company, Issaquena County, Mississippi. The site is an old-field with clay soils of a Sharkey-Tunica complex. The area was cleared and planted to soybeans for 6 years through the 1970 growing season. In spring 1970 prior to the last soybean crop, 3 tons per acre of lime were applied to the area by the farm management. To help in first-year weed control, the study area was fallowed in summer and early fall in 1971, and cuttings were planted in December 1971 at 12- by 12-foot spacing.

Clones planted were Stoneville 66, 67, 92, and 124. There were nine plots per clone, with each plot 17 rows square. Interior measurement plots were 10 rows square. The plots were disked four times the first year and once the second year for weed control.

Heights of all measurement-plot trees were taken yearly, and diameters were taken with calipers from the second through fifth years. In March 1977, at the beginning of the sixth growing season, 120 randomly selected cut trees were measured for volume, and the stem and branches of 20 trees were weighed.

Regression equations were developed using D^2H (d.b.h.² × total height) as the independent variable for outside-bark volume and total-tree dry weight and stem dry weight, including bark. The volume equation was weighted by $1/(D^2H)^2$.

Soil moisture for the mid- to late-growing season was determined with a neutron probe in soil moisture tubes at 1-, 2-, and 3-foot soil depths. Readings nearest July 15, August 15, and September 15 of each year were analyzed for each soil depth for the second through fifth years. At least

two days were allowed to elapse after a rain before soil moisture measurements were made.

Bulk soil samples from 0- to 6-inches deep were collected from each plot at the start of the first growing season and during the first two weeks of September each growing season. Three samples were collected from the same locations within a measurement plot and a composite was made each year. Standard laboratory analyses were used for chemical determinations. (Individual plot samples were air dried and ground to pass a 2-mm sieve. Total N was determined by the Kjeldahl process. Soil pH was measured with a glass electrode in a 1:1 soil/water mixture. Extractable P was determined with a colorimeter using the Mississippi soil test method (Soil Test Work Group 1974). Exchangeable K, Ca, and Mg were determined by atomic absorption spectrophotometry. Oxidizable organic matter was determined by chromic acid oxidation and titrations with $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$.

Six plots were sampled for soil texture because of height differences noted during the first five years. Two plots each with above average-, below average-, and average-sized trees were sampled; two holes per plot were punched with a hydraulic probe. Soil texture was determined by the hydrometer method.

RESULTS

Survival, Height, Diameter, and Basal Area

Survival averaged 83 percent after the first year, with a range in plot values of 63 to 98 percent. Second-year survival varied from 51 to 96 percent and averaged 75 percent. One plot lost 69 percentage points during the second year, probably influenced by spraying of the adjoining agricultural field, and was dropped from the study. Four plots adjacent to the dropped plot lost 24 to 32 percentage points, while other plots in the study lost from none to 16 percentage points. After the second year, only one tree died.

Average height after each of the first five years was 8, 17, 23, 36, and 43 feet. Both height mean annual increment (m.a.i.) and current annual increment (c.a.i.) peaked in the fourth year. Means for individual plots varied from 34 to 57 feet.

Average diameter after the second year was 1.9 inches. Diameter growth for both the third and fourth years was 1.4 inches but dropped to 0.8 inches during the fifth year. M.a.i. was greatest the fourth year. After five years, average diameter was 5.5 inches and plot means ranged from 4.8 to 6.1 inches. Fifth-year basal area averaged 38 square feet per acre, and plot means varied from 23 to 51 square feet.

Volume and Weight

Total cubic feet per acre of stem volume outside bark averaged 683, with a standard error of estimate of ± 36 cubic feet. Volumes varied from 319 to 1,131 cubic feet per acre.

Total dry weight of the stems plus branches and bark, in tons per acre, averaged 9.52 with a standard error of estimate of ± 0.52 ton. Tree weights varied from 4.31 to 16.12 tons per acre. Stem weight averaged 84 percent of the total weight of trees.

Site Differences

Site differences as shown by height growth were noticeable after the second year. Five of the six plots sampled for soil texture had clay contents of 73 to 79 percent and were classified as Sharkey clay (site index 90) (Broadfoot 1960). The plot with the tallest average tree height was a mixture of Sharkey and Tunica (site index 110) soils with an average clay content of 63 percent. Sharkey soils are clay throughout the profile, while Tunica soils have up to a 28-inch thick clay cap over loamy material.

Soil Moisture

For all three soil depths, the second and fourth years had significantly greater available moisture content (from 3 to 10 percent by volume more moisture) from July through September than the third and fifth years. Differences in soil moisture content were related to mean height growth; years with lower moisture content gave poorer growth.

Soil Chemical Properties

Analyses of variance on the seven soil elements showed year 0 (start of first growing season) had the largest value, or was not significantly different from the largest value, for P, K, Ca, and organic matter (Table 1). Year 5 had the lowest value for P, K, Ca, and Mg; was intermediate in organic matter; and had the highest pH. Changes from year 0 to year 5 for P, K, and Ca varied with soil moisture. Correlation of soil nutrients with soil moisture content has been reported by McKee (1973), McColl (1976), and Moore *et al.* (1976). Organic matter was least in year 2 after a flood, and pH was lowest the third year.

Total N was highest for year 0 and decreased significantly during the first and second growing seasons (Table 1). There was a slight increase at the end of the third growing season but not significantly different from the second. Nitrogen then significantly increased during the fourth and fifth growing seasons. Even with these increases,

Table 1. Means and standard errors of seven soil properties by year of cottonwood plantation (36 samples per year)

Year	N	P	K	Ca
Lbs/A.....			
0	3782 ± 68a ¹	162 ± 6a	934 ± 14a	11006 ± 126ab
1	3554 ± 64b	150 ± 4b	892 ± 16b	11140 ± 120a
2	2370 ± 88e	124 ± 4c	820 ± 16c	10694 ± 108c
3	2468 ± 60e	114 ± 4d	772 ± 12d	10416 ± 102d
4	2926 ± 80d	126 ± 4c	798 ± 12cd	10816 ± 92bc
5	3256 ± 72c	110 ± 4d	702 ± 12e	7808 ± 138e

Year	Mg	OM	pH
	Lbs/A	Percent/wt	
0	2448 ± 30b	3.85 ± 0.07a	6.77 ± 0.03b
1	2440 ± 28b	3.59 ± 0.08b	6.76 ± 0.03b
2	2566 ± 46a	2.23 ± 0.11e	6.47 ± 0.06d
3	2518 ± 44a	2.34 ± 0.07e	6.29 ± 0.05e
4	2560 ± 34a	2.81 ± 0.10d	6.60 ± 0.07c
5	1992 ± 46c	3.26 ± 0.08c	7.15 ± 0.04a

¹ Means in each column followed by same letter do not differ significantly at the 0.05 level by Duncan's multiple range test.

total N was still significantly lower at the end of the fifth growing season than at the beginning of the study. The low nitrogen content after the second growing season could be a result of the flood that year. During the fourth and fifth growing seasons, tree crowns had completely closed and apparently enough leaves and twigs were being returned to the soil for the N content to begin to be built up. The correlation between some of the other elements being more available during years with high soil moisture did not exist for total N.

No apparent relationship existed between fifth-year average height and either soil total N content or other measured soil elements.

DISCUSSION

The 1973 Mississippi River flood was related to second-year mortality and occurrence of stem cankers in the plantation. On April 9, backwater created by the flood topped the private levee which had been protecting the cottonwood plantation and adjacent farmland, reached a depth of 10 feet by May 22, and dissipated by the last of June. An August 1973 stem canker survey by plots showed that 4 to 60 percent (average 14 percent) of the stems had cankers. *Fusarium solani* [Mart.] Sacc. was isolated from a sample of the cankers but was not proven causative.

Cottonwood height growth is normally greatest the first year or two and then tapers off to more uniform growth (Mohn and Randall 1971). The



Figure 1. Seven-year-old cottonwood planted at 12- by 12-foot spacing on clay soil. After five years this plot averaged 5.5 inches d.b.h. and 49 feet in height.

spurt in height growth that occurred during the fourth year must be attributed to soil moisture. Previously reported fifth-year heights of the same clones planted on similar but recently cleared Sharkey clay soil at 10- to 10-foot spacing averaged 31 feet (Mohn *et al.* 1970), compared to 58 feet on Commerce soil. Differences in growth between the two studies on Sharkey clay are most likely due to moisture conditions. In the earlier study, the first three years had less than 40 inches of rain per year, while three of the five years at Mahannah had 70+ inches of rain per year.

A comparison of total volume outside bark yields between clay soils with select clones and medium-textured soils with random planting stock may be made using the Mahannah data and Fitler, Mississippi data (Krinard and Johnson 1975). Four unthinned plots at Fitler on old-field and pasture Commerce soil at 12- by 12-foot spacing averaged 577 cubic feet per acre more in five years than Mahannah plots. Fitler plots had 7 percent more survival, 16 square feet per acre more of basal area, and averaged 0.5 inch larger at d.b.h. and 12 feet taller in height of dominants. Mahannah only had 54 percent of the Fitler yield.

After this study was installed, only 5 of the 14 select clones (Mohn *et al.* 1970) were certified by the Mississippi Seed Improvement Association (Land 1974). Clones were dropped mainly for poor survival. The one non-certified clone in this study had 60-percent survival. The three certified clones had fifth-year survival of 80 percent.

The Mahannah area is typical of large acreages of clay soil that have been cleared of native forests, planted to soybeans for a few years, and limed sometime during soybean production. Soil data in this study are used to characterize what one could expect if the soybean farming were abandoned and the field reverted to a hardwood plantation. Liming done two years before planting could have made some elements slightly more available than if the area had not been limed. Liming also raised the pH of the soil.

It is generally accepted that over a long period agronomic crops gradually deteriorate soil structure and reduce soil nutrients (Gilmore and Bog-gess 1976). Our study area had been cleared only seven years before the cottonwoods were planted, and it is doubtful that enough deterioration had occurred to have affected growth. Although there has been a reduction in the levels of most nutrients since planting, the trend may reverse as trees get older and more litter is returned to the soil.

In conclusion, cottonwood can be planted and grown on clay soils which have been in soybean

production less than 10 years. Yields may be nearly one-half less than on medium-textured soils, but other bottomland species such as sycamore, green ash, Nuttall oak, and sweetgum cannot match cottonwood growth at this age on fine-textured sites.¹ The amount of moisture present during mid- and late-growing-season on clay soils has a noticeable influence on cottonwood height growth. Also, soil moisture influences some soil measurements so that comparison of soil properties over time is not straightforward.

¹ Kennedy, H. E., Jr. Soil nutrients and moisture, growth, and survival of six hardwoods are influenced by cultural treatments. (Manuscript in preparation by Southern Forest Experiment Station, New Orleans, La.)

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