United States Department of Agriculture

Forest Service

Southern Forest Experiment Station

Research Note

SO-316
September 1985

Ten Years' Growth of Pruned and Unpruned Cottonwood Planted at 40- by 40-Foot Spacing

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SUMMARY

Diameters at age 10 of cottonwood (*Populus deltoides* Bartr. ex Marsh.) select clone Stoneville 66 planted at 40- by 40-foot spacing varied from 13.4 to 16.4 inches depending on height of pruning. Pruning treatments, applied from the 2nd through 8th years, were (1) unpruned, (2) pruned to a third of height yearly, (3) pruned to half of height yearly, and (4) pruned to 17 feet when d.b.h. >8.5 inches. Total tree heights did not differ among treatments and averaged 94 feet.

Additional keywords: *Populus deltoides,* pruning.

INTRODUCTION

Early diameter growth of cottonwood (*Populus deltoides* Bartr. ex Marsh.) is spacing-dependent. Thus, spacing is an important consideration in plantation management in determining tree sizes and thereby rotation length, whether cubic volume or board-foot volume production is desired. Previous research has shown that maximum diameter growth of trees planted at four spacings, ranging from 4 by 9 to 16 by 18 feet, occurred in the first 4 years (Krinard and Johnson 1975). Even at a nearly open-grown spacing of 40 by 40 feet the mean annual increment (mai) for diameter peaked by the 4th year (Krinard 1979). Trees were planted at the 40- by 40-foot spacing for the purpose of using their growth characteristics as an indicator of ultimate cottonwood growth under conditions of minimal competition. Several pruning intensities were applied to follow the influence of crown length on growth and for quality growth. This paper provides stand information over 10 years for cottonwood planted at 40- by 40-foot spacing (fig. 1) and subjected to four pruning treatments, together with a comparison of unpruned trees planted at 10- by 10-foot spacing.

METHODS

The study was planted in January 1974 on cleared Commerce silt loam soil at Huntington Point in Bolivar County, Mississippi, on Chicago Mill and Lumber Company land. Commerce, a member of the thermic family of Aeric Fluvaquents, has an estimated site index range of 105 to 125 feet at age 30 for natural cottonwood stands (Broadfoot 1976). The 40- by 40-foot spacing consisted of 16 rows by 16 columns. Each of the 256 planting spots was planted with three 18-inch cuttings of select Stoneville clone 66 (Land 1974) and thinned to one tree per spot in June 1974.

A randomized complete block design was used with four replications. Each pruning treatment plot per block was 4 rows by 4 columns. Data were analyzed at the 0.05 level of significance (Duncan's Multiple Range Test).

Disking was used to control weeds during the first five growing seasons. In July of the 6th year, the area was rototilled to help eliminate ruts; thereafter, yearly weed control was by mowing.

Pruning treatments to control crown length were applied from the 2nd through 8th years. Treatments were: control or no pruning (C); pruning the bottom third of the tree annually (⅓); pruning the bottom half of the tree annually (½); and pruning the bottom 17 feet of the tree (17) when d.b.h. exceeded 8.5 inches, which occurred in the 4th year. Trees were pruned during the dormant season (January to March) for the 2nd through 5th years, delayed until the first week of July because of high water

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Figure 1. — *Cottonwood planted at 40- by 40-foot spacing in July of the 11th year (the tractor is mowing a dense johnson grass ground cover that still develops because of open stand conditions).*

in the 6th year, and during the first week of May in the 7th and 8th years. From the 2nd through 5th growing seasons, trees were examined monthly and any sprouts were removed. After the 5th year, epicormic branches were removed only at time of pruning.

Height and d.b.h. of each tree were measured annually. Measurements taken after the 5th and 10th years were maximum crown width in the north-south and east-west directions for all trees and diameters outside bark at 9, 13, and 17 feet on four trees per plot. Cut limbs of the inside four trees in each pruning treatment plot were counted through age 4.

Board-foot estimations for the 40 by 40 spacing were obtained from Barr and Stroud dendrometer measurements taken on two trees per plot in the 9th growing season. Equations used for trees $\geq$12.5 inches d.b.h. to a 10-inch top were:

BF (Int. ¼) = $-440.5 + 31.6D + 0.98H$, $R^2 = 0.96$, $S_{y.x} = 7.9$

BF (Doyle) = $-269.2 + 19.7D + 0.55H$, $R^2 = 0.94$, $S_{y.x} = 5.9$

where D = d.b.h. and H = total height.

All measured trees were included in analyses except four trees replanted the first year and trees with broken tops.

For comparison with the 40 by 40 spacing, two 10-tree replications of clone 66 in an adjacent study that were also planted in January 1974 but at 10- by 10-foot spacing were measured after the 5th and 10th years. The interior eight trees per replication were measured for d.b.h., height, diameter at 17 feet, length of live crown, and maximum crown width (Kennedy 1979). Statistical inferences are not implied in comparing the two spacings.

RESULTS

D.b.h. growth differences between pruning treatments began in the 2nd year with the first pruning and continued through the 6th year and during the 8th year (table 1). There were no differences in the 7th year or in the 9th and 10th years. D.b.h. growth generally declined from the 2nd through 8th years and was nearly constant during the last 3 years. Diameters differed among treatments by the end of the 3rd year and the differences continued through 10 years. D.b.h. growth of the 17-foot treatment differed from the unpruned trees only in the year of pruning and following year (5th and 6th years).

Yearly height growth never differed by treatments. The trend was for (½) to reduce height, but only after the 7th year were trees in that treatment shorter than other treatments (table 1).

The first pruning removed 56 percent of the branches

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Table 1. — *Average tree size and growth increment for height and d.b.h. by year and pruning treatment*

Treatment	Year 1	2	3	4	5	6	7	8	9	10
	height (feet)									
Control	10.5	23.8	36.9	49.9	62.5	71.6	80.9b[1]	83.8	90.8	94.8
One-third	10.8	23.6	36.0	49.9	62.3	71.8	80.5b	84.4	92.1	95.7
One-half	10.6	23.0	34.8	48.1	59.6	67.2	76.8a	80.7	88.1	91.8
17 feet	10.9	24.3	36.5	50.0	62.3	70.5	80.2b	82.2	91.1	95.6
Average	10.7	23.7	36.0	49.5	61.7	70.3	79.6	82.8	90.5	94.5
	height growth (feet)									
Control		13.2	13.2	12.8	12.6	9.1	9.4	3.0	6.9	4.0
One-third		12.9	12.4	13.9	12.3	9.4	8.8	3.9	7.7	3.6
One-half		12.4	11.8	13.3	11.6	7.6	9.6	3.8	7.4	3.7
17 feet		13.4	12.2	13.3	12.4	8.2	9.7	3.0	7.9	4.5
Average		13.0	12.4	13.3	12.2	8.6	9.4	3.4	7.5	4.0
	diameter (inches)									
Control	1.1	4.0	7.2c	9.6c	11.4d	12.9d	14.0d	14.8d	15.5d	16.4d
One-third	1.1	4.1	6.9b	8.9b	10.3b	11.6b	12.5b	13.2b	13.9b	14.7b
One-half	1.1	3.8	6.3a	8.1a	9.2a	10.5a	11.4a	12.0a	12.6a	13.4a
17 feet	1.1	4.1	7.3c	9.6c	10.9c	12.2c	13.2c	14.0c	14.7c	15.5c
Average	1.1	4.0	6.9	9.0	10.4	11.8	12.8	13.5	14.2	15.0
	diameter growth (inches)									
Control		2.9b	3.2c	2.4b	1.8d	1.5b	1.0	0.9b	0.7	0.8
One-third		3.0b	2.8b	2.0a	1.5c	1.2a	0.9	0.7a	0.7	0.8
One-half		2.7a	2.4a	1.8a	1.1a	1.2a	0.9	0.6a	0.6	0.8
17 feet		3.0b	3.2c	2.4b	1.3b	1.2a	1.0	0.8b	0.7	0.8
Average		2.9	2.9	2.2	1.4	1.3	1.0	0.8	0.7	0.8

[1]Means appearing with same letter not significantly different within each column at 0.05 level by Duncan's Multiple Range Test; if no letters, overall test was not significant.

with (⅓) and 79 percent with (½). Average number of branches cut per tree through age 4 were 55 for (⅓), 70 for (½), and 46 for (17). How limbs cut relate to photosynthetic area removed is unknown, as average limb size was inversely related to number (Krinard 1979).

The ratio of diameter at 17 feet to d.b.h., a measure of form, did not differ among pruning treatments at age 10 and ranged from 0.82 for (C) and (17) to 0.84 for (⅓) and (½). After 5 years, the ratios of (C) and (17) were 0.70, which were significantly different from the ratios of 0.73 and 0.74 for (⅓) and (½), respectively.

Diameter growth at 17 feet (d) was significantly greater than diameter growth at 4.5 feet (D) in all pruning treatments from years 6 through 10: (C)d = (17)d > (C)D = (17)D = (⅓)d > (½)d = (⅓)D, and (⅓)D = (½)D. Average diameter growth for the last 5 years tended to be numerically larger at 9 and 13 feet than at breast height (fig. 2).

Average maximum crown width at age 10 ranged from 29 feet for unpruned trees to 23 feet for one-half pruned trees. Crown width increase in 5 years varied from 4 feet for (C) to 8 feet for (17). For all treatments, crown width in a north-south direction was significantly larger than in an east-west direction. Average differences between directions within pruning treatments varied from 3 to 5 feet after 5 years and from 5 to 8 feet after 10 years (table 2).

After 5 and 10 years, live crown ratios by pruning treatments ranged from 60 to 97 percent and from 58 to 89 percent in the order (½), (⅓), (17), and (C). If crown shape is considered as a parabola, lateral crown surface area of pruned trees compared to (C) were 0.40 to 0.61 as large at age 5 and 0.50 to 0.90 as large at age 10; crown volumes were 0.27 to 0.49 as large at age 5 and 0.40 to 0.86 as large at age 10 (table 3).

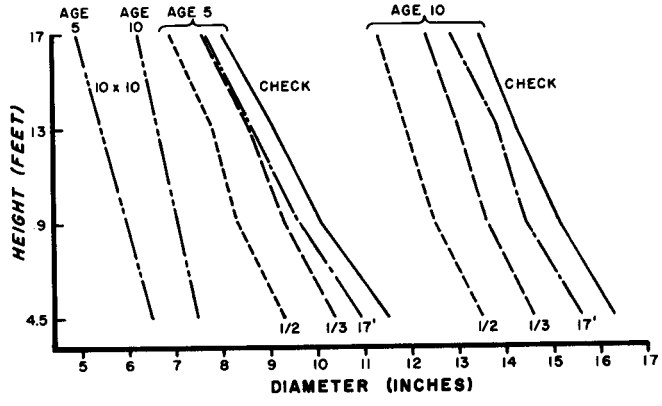

Figure 2. — *Average diameter at given stem heights for pruning treatments at 40- by 40-foot spacing and for 10- by 10-foot spacing at ages 5 and 10.*

Table 2. — *Maximum crown widths in a north/south (N/S) and east/west (E/W) direction at ages 5 and 10 by spacings and pruning treatments*

Spacing	Treatment	Age 5		Age 10	
		N/S	E/W	N/S	E/W
ft		*ft*			
40 by 40	Control	27.1	22.2	32.6	24.9
	One-third	21.8	18.0	29.0	21.3
	One-half	18.0	15.1	25.2	20.0
	17 feet	21.0	17.1	30.7	24.4
10 by 10	Control	[1]	[1]	9.1	7.3

[1]Directions not separated, overall average 8.8 feet.

Table 3. — *Crown surface areas and crown volumes at ages 5 and 10 by spacings and pruning treatments*

Spacing	Treatment	Age 5		Age 10	
		CSA[1]	CV[2]	CSA	CV
ft		*ft²*	*ft³*	*ft²*	*ft³*
40 by 40	Control	3,151	14,322	5,076	26,964
	One-third	1,924	7,086	3,625	16,798
	One-half	1,250	3,857	2,548	10,673
	17 feet	1,839	6,524	4,557	23,313
10 by 10	Control	364	603	426	682

[1]Crown surface area.
[2]Crown volume, where crown shape considered a parabola with base an ellipse using maximum crown width measurements.

Height to live crown averaged 10 feet (range 6 to 19 feet) after 10 years for (C). No dead limbs were noted above the 17-foot level pruned prior to the 5th year in (17) or above final 8th year pruning of 26.8 feet in (⅓) and 38.4 feet in (½).

Doyle board foot volume growth in the 10th year varied by pruning treatment from 470 to 500 board feet per acre, including ingrowth, for trees ≥12.5 inches d.b.h. to a 10-inch top (table 4). Board foot mai through 10 years ranged from 100 to 277 board feet per acre per year.

In contrast to trees in the 40- by 40-foot planting, cottonwood in the 10- by 10-foot planting from the 5th through 10th years increased in d.b.h. from 6.5 to 7.5 inches, in height from 60 to 73 feet, in ratio of diameter at 17 feet to d.b.h. from 0.76 to 0.83, in diameter at 17 feet from 4.9 to 6.2 inches, in height to live crown from 41 to 48 feet, and in live crown length from 19 to 24 feet. The trees decreased in average maximum crown diameter from 8.8 to 8.3 feet. Crown volume increased 13 percent, although crowns were very sparse and only 0.03 to 0.06 as large as crowns of trees at 40 by 40 spacing, depending on pruning treatment.

The 40 by 40 spacing had four to six times more volume per tree by pruning treatment after 10 years than the 10 by 10 spacing, but only 0.3 to 0.4 as much total volume per acre. Relative cubic volumes were calculated from mean values of trees where upper stem diameters were measured, using (d.b.h.)² * height * form.

DISCUSSION

It should be noted that the clone used in this study was classified as a select clone primarily because of fast early growth when planted at close spacings (Mohn et al. 1970). Other clones with different crown shapes and rates of crown development may respond differently at wide spacings.

In the last 3 years, d.b.h. growth of all pruning treatments has generally stabilized, rather than steadily decreased as during the earlier years. Thus, 17- to 19-inch pruned trees are a possibility in 15 years and 20- to 23-inch trees in 20 years. Although past experience indicates a slowing of d.b.h. growth with time rather than stable growth, past experience has not included wide spacings.

During periods of maximum d.b.h. growth (within the first 5 years), treatments that affect crown length have a greater effect on d.b.h. growth. While pruning tends to influence d.b.h. growth during the year of treatment, the effects have little influence on future growth.

Upper stem diameter growth in this study did not agree with several generally found stem form concepts (Larson 1963) of maximum growth occurring lower on the boles of open-grown trees than those of close-grown trees, and of open-grown trees differing markedly in stem form from close-grown trees. Results did agree with the concept of maximum growth moving up the tree as the crown recedes.

Two spacing systems for growing cottonwood through 10 years have produced quite different results. Trees under close spacing have fully utilized the site while individual trees under wider spacing have grown much faster. Either pulpwood from close spacing or sawtimber from wide spacing can be grown in 10 years.

Nearly equal 10-year returns of about $150 per acre are obtained for both pulpwood and sawtimber. Pulpwood estimates are based on average d.b.h. and height to give 9 cubic feet per tree at 10 by 10 spacing, 70 percent survival, and 90 cubic feet and $5 per cord stump-

Table 4. — *Doyle board foot volumes per acre in trees ≥12.5 inches d.b.h. to 10-inch top inside bark by pruning treatments for 8th through 10th years*

Treatment	8th year		9th year		10th year	
	N/A[1]	fbm/A	N/A	fbm/A	N/A	fbm/A
Control	26	1,795	26	2,261	27	2,770
One-third	25	942	26	1,428	27	1,899
One-half	4	98	14	502	22	1,004
17 feet	26	1,387	27	1,889	27	2,383

[1]Trees/acre.

age. Sawtimber estimates are based on 1,900 board feet from one-third pruning at 40 by 40 spacing and $80 per M stumpage.

But, there is no option to go on from this point with the 10 by 10 spacing as the stand is essentially stagnant, awaiting either cutting or mortality. Thinning now would not benefit leave trees as they could not respond; earlier thinning, which would have reduced volume, should probably have been done by age 5 when the live crown ratio was already reduced to 32 percent. With the wider spacing, however, options exist either to cut at age 10, or to let the trees grow.

True cost comparisons between the two spacings cannot be made because of inadequate economic information. Planting costs for the close spacing appear to be at least four times greater and cost of cuttings 16 times greater than for the wide spacing. However, near 100 percent survival is needed at wide spacing and the alternatives of long cuttings or multiple cuttings per planting spot would be more costly.

Pruning at wide spacing is necessary in order to produce quality lumber. But when and how much to prune? In this study (⅓) looked best, but annual pruning is not feasible. One possible method, which appears workable and not too severe, would be three prunings to a two-log height: prune by half-log increments, when tree heights are about three times greater than pruning heights, to a one-log height and then prune an additional log when a 55 to 60 percent live crown ratio can be maintained. By this method in this study, half-logs would have been pruned at the start of the 3rd and 5th years, and the second log at the start of the 7th or 8th years.

A better sawtimber spacing would be one that provided more trees but that would not greatly restrict diameter growth over the first 10 years compared to 40 by 40 spacing. The crown spread of (⅓) after 10 years suggests that possibly 50 to 55 trees per acre would have similar early growth. Nearly twice the trees would give better site utilization and would provide some safety against mortality.

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