*Reprinted from:* PROCEEDINGS: SYMPOSIUM ON EASTERN COTTONWOOD AND RELATED SPECIES, p. 385-391. 1976.

# BIOLOGICAL RESPONSE OF PLANTATION COTTONWOOD TO SPACING, PRUNING, THINNING

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Abstract.--A literature review and a sampling of data obtained from cottonwood growers of the biological response of plantation-grown cottonwood trees to initial spacings in the Midsouth have indicated the following trends: as spacing increased, dbh increased, height of dominants not practically affected, total cubic volume decreased, basal area decreased, natural pruning decreased, and, regardless of spacing, mean annual diameter growth peaked in the second or third year. Thinnings have neither increased diameter growth of residual trees nor greatly changed total cubic volume yields. Pruning should be restricted to less than 50 percent of total tree height. Mid-growing season pruning seems to produce less branching than dormant or early season pruning.

Additional keywords: *Populus deltoides*, growth, artificial regeneration, increment.

Studies and observations on species mainly other than cottonwood have shown that biologically there is a relationship between initial spacing and tree and stand characteristics (Evert 1971). Within limits, it is a matter of putting more wood on fewer trees or less wood on more trees. With fewer trees per acre, tree size and rate of tree growth increases as shown by larger crowns, diameters, and volumes. Also, wider spacing leads to larger limbs and a slower rate of natural pruning, and greater taper in the bole. On a stand basis, as initial spacing increases, average diameter increases, but basal area, total cubic volume, and rotation age decreases. Thinning provides space for crown enlargement and resulting tree growth while pruning, though reducing the crown size, tends to improve quality and tree form (Larson 1963).

As with most other species, growth models are not available for cottonwood. For example, it is not possible to predict how much an increase in, say, 2 feet of initial spacing would increase the average tree size at age 8.

## SPACING

Experimental cottonwood plantations were established in the 1940's in the Midsouth, and were followed by commercial-scale plantations in the 1960's (McKnight 1970). An early spacing recommendation was 6 by 10 feet (Bull and Muntz 1943) as it was believed anything closer was unnecessarily close and anything wider could result in understocked stands of poor quality trees. In

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1951 spacing recommendations ranged from 6 by 9 to 9 by 9 feet (Maisenhelder 1951), and within 10 years were revised slightly to range from 6 by 10 to 10 by 10 feet (Maisenhelder 1960). These spacings provided at least one-way cultivation for weed control and were thought adequate for the production of both pulpwood and sawlogs. They would require minimum pruning, and would produce a pulpwood size first thinning. By 1975, it appeared there was no one best spacing for all products, although 12- by 12-foot spacing was suggested as an all purpose compromise considering pulpwood production, dominant tree growth, and tree quality--at least through 10 years (Krinard and Johnson 1975). Only actual 20- to 30-year rotation figures, which are not available, will tie together cottonwood growth characteristics beyond the pulpwood stage.

Three important factors which always affect cottonwood tree response to initial spacing are site quality, first-year cultural practices, and survival. For instance, medium-textured soils are capable of producing larger trees for a given spacing at a given age than fine-textured soils, and, within a given soil series, moisture conditions can greatly change growth rates. Moreover, where good first-year cultural practices are not maintained, growth and survival are reduced. First-year loss in growth cannot be regained, but some of the loss can be offset by second-year weed control. Mortality irregularly increases spacing between surviving trees. Mortality is usually greatest in the first year, then decreases until stand closure and competition cause an increase in mortality.

Growth differences between medium-textured soil--Commerce--and fine-textured soil--Sharkey--are considerable. At a 10- by 10-foot spacing, using the same clonal material, mean diameters and heights after 5 years were 6.3 inches and 51 feet on Commerce and 3.3 inches and 28 feet on Sharkey (Mohn and others 1970). Two years later the mean values were 7.8 inches and 62 feet, Commerce, and 4.1 inches and 32 feet, Sharkey (Randall 1973). Thinning was done after third and fifth year on Commerce and after fifth year on Sharkey in a systematic manner, taking half the trees at each thinning in an attempt to maintain tree growth. The five Stoneville select clones in the study averaged 9.4 inches and 69 feet on Commerce and 4.5 inches and 35 feet on Sharkey after 7 years.

On the same general Commerce soil area as above, at Huntington Point, Mississippi, a 10- by 20-foot spacing averaged 7.3 inches dbh and 60 feet in height after 5 years. The planting was then thinned to 20- by 20-foot spacing, and after 7 years averaged 9.0 inches dbh and 72 feet tall. A 12- by 12-foot spacing on the same Commerce soil area was thinned systematically of half its trees after the fourth year and averaged 7.0 inches dbh after the fifth year. While the results of the three spacings on Commerce soil have been confounded with the effect of thinnings, diameters have increased as initial spacing increased.

Two more studies confirm the cottonwood growth trend as a response to spacing. The first, planted on the same Huntington Point Commerce soil, used Nelder's design and illustrates spacing differences on diameter and height growth. In this design trees were planted along what amounted to spokes of a wheel, with the angle between spokes and distance along spoke determining spacing. There were six spacings, with about 80 percent more growing space per tree provided by each outward planting spot along the spoke. The spacings ranged from 1,135 trees per acre, closest spacing, to

63 trees per acre, widest spacing. After 4 years, average dbh increased as spacing increased, and ranged from 3.9 inches to 8.0 inches. Average height was minimum for the closest spacing, 44 feet, probably from suppression of next wider spacing leaning in, while other average heights ranged from 49 feet, both 637 and 63 trees per acre, to 52 feet, 201 trees per acre. After 6 years, the two closer spacings were eliminated because of suppression and mortality. Spacings of 358, 201, 113, and 63 trees per acre had average dbh's of 7.0, 8.4, 9.7, and 10.8 inches; and average heights of 64, 67, 67, and 67 feet (Randall *in press*). For the same spacings, ninth-year average dbh's were 8.1, 9.8, 11.4, and 13.1 inches; average heights, 72, 75, 77, and 77 feet.

Another spacing study planted in the mid-1960's near Fitler, Mississippi, on Commerce and Convent soils showed the greatest diameter growth on the widest spacing (Krinard and Johnson 1975). Initial spacings were 4 by 9, 8 by 9, 12 by 12, and 16 by 18 feet. After 10 years, average dbh for unthinned plots was 5.3, 7.0, 8.2, and 10.2 inches, closest to widest spacing, with largest trees in the 14-inch class. For all spacings the maximum diameter growth occurred in the first 4 years and gradually decreased the next 6 years. Mean differences in average height of dominants varied by 3 or 4 feet after the fourth, sixth, and eighth years. After 10 years, mean heights of the five tallest 3-P sampled trees per approximately half-acre plot ranged from 83 feet at 4 by 9 spacing to 88 feet for 16- by 18-foot spacing. For uncut plots through 10 years, survival increased as spacing increased, while basal area growth and total volume production were inversely related to spacing. Annual basal area growth peaked prior to the fifth year for the two closer spacings, in the fifth year for the 12 by 12 spacing, and in the seventh year for the 16 by 18 spacing. Total volume mean annual increment peaked at from 7 to 9 years for the three closest spacings but did not peak through 10 years for the widest spacing. If volume in trees ≥5.0 inches dbh to a 4-inch top were considered, spacings ranked 8 by 9, 12 by 12, 4 by 9, and 16 by 18 feet.

## THINNING

The effects of both selective and systematic thinnings on various spacings, and the resulting growth responses, have been studied and observed on an informal basis.

Four intensities of selective thinning, including a control, were applied in two differently spaced cottonwood plantations (Alford 1972). At the time of treatment, 8- by 9-foot control plots averaged 5.4 inches dbh, 43 feet in height, and had 53 square feet of basal area and 740 cubic feet of volume per acre after 4 years. The 5-year-old, 6- by 9-foot spacing control plots averaged 4.5 inches dbh, 42 feet in height, and had 76 square feet of basal area and 610 cubic feet of volume per acre.

For the 4 years after cutting, average annual height growth ranged from 5 to 6 feet at both spacings, and over all treatments. Average annual diameter growth ranged from 0.3 to 0.5 inches at the 8 by 9 spacing and from 0.5 to 0.6 inches at the 6 by 9 spacing; diameter growth increased as tree size increased and number of trees decreased. Neither total volume production nor annual volume growth was affected by thinning. Using cumulative cubic-foot volume figures corrected for differences in original stocking, through age 8 or age 9, current annual increment and mean annual increment curves intersected at about 8 years. Alford estimated that a minimum of 45 to 50 percent crown would be needed for maximum growth.

Two selective thinning treatments were used in the Fitler study. Basal area was reduced to either 40 or 65 square feet whenever these values were exceeded by 15 square feet or more. Diameter growth did not respond to thinning.

Some data are available from cottonwood growers on tree growth response to row thinning treatments as applied to portions of commercial plantations. In one case, every other row of a 10- by 10-foot spacing on Commerce soil type was thinned at the end of the fourth year, removing 4 cords per acre to a 4-inch top, when trees averaged 5.6 inches dbh. After 7 years, the thinned area averaged 8.5 inches and 15 cords per acre compared to the unthinned stand's 7.4 inches and 21 cords. Fifty percent of the trees in the thinned stand were 9.0 inches or larger as contrasted with only 11 percent of the trees in the uncut stand.

In a 12- by 12-foot planting on a very good site south of Vicksburg, again on Commerce soil, thinning treatments after 2 years removed either every other diagonal, every other row, or maintained an unthinned check. Average diameters, for check, diagonal, and row thinning, were 6.2, 6.0, and 6.3 inches after 3 years, and 8.1, 8.5, and 9.3 inches after 6 years; corresponding heights after 6 years were 67, 63, and 70 feet.

In an attempt to maintain maximum growth in another part of the planting south of Vicksburg, every other row thinning after the second year was followed by every other tree thinning after the third year to establish a 24- by 24-foot spacing. Average diameters were 4.1 inches at 2 years, 6.7 inches at 4 years, and 9.4 inches at 6 years. Although annual diameter growth was nearly the same from age 2 through age 6, the greater diameter growth the first 2 years produced a decreasing mean annual diameter increment for the last 4 years.

Maisenhelder (1960) mentions a thinning in a 55-year-old cottonwood stand producing a 50 percent increase in diameter growth 2 years after the cut. Thus far, thinnings in cottonwood plantations have not produced such pronounced results as shown above.

Several possible reasons for lack of diameter growth response may be the combination of close planting spacings, waiting too long to thin so crown length and width were reduced too far, or not removing enough trees. The Fitler study would fall in the category of thinning too little too late as crown conditions and number of trees left after thinning indicated. Mohn and Randall systematically cut half the trees from a 10- by 10-foot spacing after the third year when average dbh was 4.6 inches and basal area 50 square feet per acre (Mohn and others 1970, Randall 1973). During the next 2 years, average diameter growth was only 1.7 inches. At the widest spacing in the Nelder's design, the one equivalent to about 26-foot square spacing, maximum diameter growth occurred in the second year and mean annual increment peaked in the third year.

This data on thinning may indicate that an increase in dbh growth as a result of thinning may not be possible in young cottonwood plantations on good sites for trees less than 10 years old. Upper stem diameters may be responding but have not been measured. Observations at Fitler are that released trees in the 6- to 10-year age class show very little, if any, crown growth into openings.

Another possible explanation for the lack of response to thinning by diameters and crowns in plantations as compared to natural stands may be in the way that the crowns, and thus trees, have developed. Natural stands generally start with many more stems, but each stem competes without assistance from man. In contrast, plantations provide a uniform growth environment for each tree. The uniform spacing and cultivation to control weed competition in plantations helps trees which in a natural stand would have been suppressed, and trees which would have jumped out as dominants in natural stands are held back by competition from individuals nature would not have provided. As a result, crowns in plantations are not readily differentiated by size because each one is boxed to the same dimensions.

## PRUNING

Pruning reduces crown size which may reduce growth, may change form class, and may stimulate epicormic branching, depending on the age and size of tree, percentage of live crown removed, time of year pruned, and spacing of trees. In a 14-year-old cottonwood plantation planted at 8 by 8 feet where survival had been high, pruning 35 percent of the average height in the spring produced only two epicormic branches on the 13 treated trees the year after pruning. Pruning height was 17.4 feet on trees which averaged 8.9 inches dbh and about 50 feet tall. For the 3 years after pruning, pruned trees averaged 1.8 inches in diameter growth and unpruned trees 1.7 inches. Diameters of the pruned limbs measured 2 inches from the main bole ranged from 1/4 to 3 inches. Wounds healed quickly: 44 percent were closed after the first year, 89 percent after the second, and 98 percent after the third year. Although 35 percent of the limbs were dead when pruned, wounds from live and dead limbs healed at equal rates (Johnson 1959).

Pruning cottonwood trees in May of their second year to 4 feet produced a minimum number of epicormic sprouts by the end of June as compared to earlier prunings in February, March, and April. Trees were about 12 feet tall when pruning started, and were planted at 20 by 20 feet (Woessner 1972).

Pruning cottonwood trees to 9, 13, and 17 feet during the third year in either spring (March-April) or summer (June-July) significantly reduced diameter growth as compared to unpruned trees during that year. However, only 2 years after pruning, diameter increment was nearly the same for all treatments, but total diameter growth for the 3-year period was significantly better for controls than pruned trees. Epicormic branching increased with spring pruning and with greater pruning heights (Krinard 1976).

A fourth test examined time of pruning and incidence of sprouting in a 12- by 12-foot planting thinned to 24 by 24 feet after the third year. Trees were pruned to 16 feet in July of the fourth growing season, July of the fifth growing season, or in September near the end of the fifth year. Percentages of trees producing epicormic branches were 79, 30, and 6 percent, for earliest to latest pruning. Average diameters at the three pruning dates were about 6-1/2, 7, and 7-1/2 inches.

Another study in the same planting applied four pruning treatments of 10 trees each in April at the start of the second growing season. Treatments were: prune none, prune one-third, prune one-half, and prune two-thirds of total height. Trees were thinned to 24 by 24 feet at the time of pruning. Average heights were 18 to 19 feet, and average diameters ranged from 2.4 to 2.7 inches by pruning treatment. Pruning treatments were applied again after the second and third years but never more than to 20 feet. After 4 years, average diameters were 9.6, 8.9, 8.2, and 7.2 from least to most severe pruning.

## CONCLUSIONS

The above data indicate the following trends in the biological response of plantation-grown cottonwood trees to the initial spacings used in the Midsouth: as spacing increased, dbh increased, heights of dominants were not practically affected, total cubic volume decreased, basal area decreased, and natural pruning decreased. Regardless of spacing, mean annual diameter growth peaked in the second or third year. Thinnings may maintain diameter growth, but they have not increased diameter growth of residual trees. Thinnings have not greatly changed total cubic volume yields. Pruning, if severe enough, can reduce diameter and height growth, and should be restricted to less than 50 percent of total tree height. Trees pruned from May to July seem to have fewer epicormic branches than trees pruned in the dormant or early growing season.

Many more years will be required to quantify these trends, and the response of other tree characteristics for which measurements are now mostly or completely lacking. Whether generating the additional information is a worthwhile effort will probably depend on the future importance of cottonwood.

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