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Cottonwood Development Through 19 Years in a Nelder's Design

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SUMMARY

Survival, heights, and diameters at five ages, from 2 to 19 years, over six planting densities, from 63 to 1,135 trees per acre, are given for cottonwood planted in a Nelder's design.

Additional keywords: *Populus deltoides.*

INTRODUCTION

Tree diameter and survival over time in cottonwood (*Populus deltoides* Bartr. ex Marsh.) plantations are related to initial spacing. The closer the spacing, the slower the diameter growth and the sooner mortality becomes a factor. This paper presents information on tree development through 19 years of cottonwood planted in a Nelder's design, a systematic design wherein the area per tree changes in a constant manner.

METHODS

The study was planted in February 1966 at Huntington Point, Bolivar County, Mississippi (near Stoneville), on land of the Chicago Mill and Lumber Company in the Mississippi River batture. The soil was cleared Commerce silt loam, a member of the fine-silty, mixed, nonacid, thermic family of Aeric Fluvaquents, which has an estimated site index range for cottonwood of 105 to 125 feet in 30 years (Broadfoot 1976). Multiple cuttings were planted at each planting spot but were reduced to one living stem during the first growing season.

There were four "circles" or "wheels," with each wheel containing 22 "spokes." Two adjoining spokes served as border spokes, and a different clone was randomly assigned to each of 20 other spokes. The angle between spokes, other than border spokes, was 16.63° (Namkoong 1966) (fig. 1).

Each tree outward from the center of a wheel along a spoke had about 78 percent more growing space than the previous tree in the spoke. Six trees per spoke, representing 1,135, 637, 358, 201, 113, and 63 trees per acre, were measured for height and diameter after years 2, 4, 6, and 9; diameters of all trees and heights of trees of one clone were taken after year 19. A closer spacing of 2,020 trees per acre was not measured after 9 years because of poor survival and therefore was not considered. In addition to the measurement trees, an outer and an inner border tree were planted per spoke.

A randomized complete block design seemed reasonable for analyses, even though spacings were fixed relative to each other rather than occurring randomly. The wheels were replications and the spacings were treatments, with clones considered only as a random sample of the cottonwood population. Testing was at the 0.05 level of significance.

RESULTS

Survival differences among spacings first occurred in the sixth year, with the closest spacing having the least survival (table 1). By the ninth year, survival was inversely related to the number of trees per acre, although the three wider spacings did not differ. At age 19, the five

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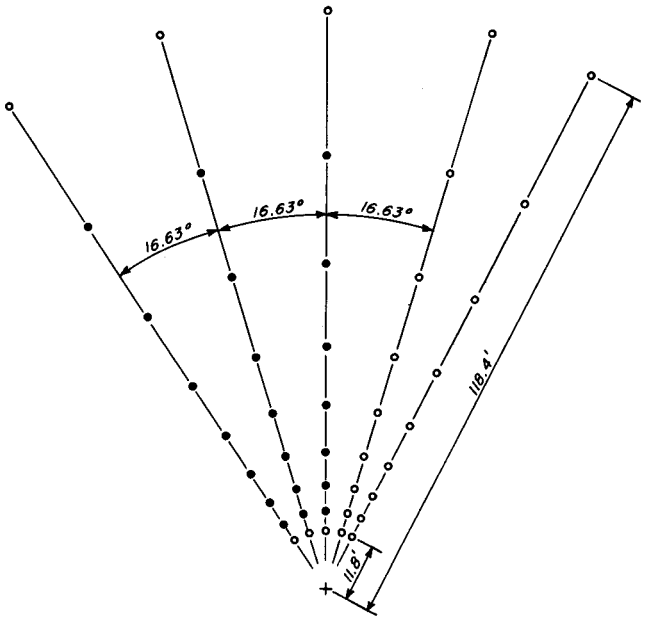

Figure 1.—*Partial layout of Nelder's design showing three measurement spokes and the two border spokes with measurement (•) and border (o) tree locations.*

Table 1.—*Survival by years and trees per acre planted*[1]

Trees/acre	Years				
	2	4	6	9	19
	----------	----------	*percent*	----------	----------
63	100	100	99ab	99a	72a
113	100	100	100a	99a	56b
201	99	99	96b	94a	38c
358	100	100	98ab	86b	22d
637	100	98	84c	68c	8e
1,135	100	94	71d	54d	8e

[1]Means appearing with the same letter are not significantly different within each column at the 0.05 level by Duncan's new multiple range test; where no letters appear, overall test is nonsignificant.

wider spacings all differed from each other in survival.

Average diameters differed among spacings at every age except 19, with the largest diameter at the widest spacing and the smallest diameter at the closest spacing (table 2). The largest tree at age 19 was 21.4 inches d.b.h. Average annual growth of trees at the widest spacing was 0.86 inch per year.

Height differences among spacings occurred at each of the first four measurements when all trees were measured (table 3). Trees in the widest spacing were shortest at age 2 but did not differ from spacings with the tallest trees at ages 6 and 9. As a measure of dominant heights, the four tallest trees per spacing per replication were also analyzed (table 4). Relationships among spacings over years were similar, with dominant heights being 2 to 3 feet taller than average heights after 2 years and 6 to 8 feet taller after 9 years. Heights of trees at the two closer spacings apparently suffered some suppression from trees at the next wider spacing by year 6.

Only one clone had all trees survive at the four widest spacings through 19 years. Data from these trees were used to compare growth over the 19 years where mortality was not a factor. Total heights did not differ among spacings at the five ages. Also, height mean annual increment (m.a.i.) by growth periods never differed (table 5). Diameters between adjacent spacings did not differ at age 2 but were different among all spacings at ages 4 and 6. The diameter of the widest spacing for ages 9 and 19 was greater than that of the next widest spacing, which in turn was greater than the two closest spacings. Diameter m.a.i. did not differ among spacings over the fifth and sixth years or over the last 10 years. During the other three periods, diameter m.a.i. of the widest spacing was greater than that of the two closest spacings (table 5).

Mean annual cubic-foot volume growth in cottonwood plantations usually peaks at 7 to 10 years for pulpwood spacings. A relative assessment of cubic volume production for the Nelder's spacings was made by using (trees per acre)·(survival)·(average d.b.h.)^2·(average height at age 9). Relative productivity expressed as a ratio to the lowest value (by planting density) was as follows: 1 (63), 1.4 (113), 1.5 (637 and 1,135), 1.7 (201), and 1.8 (358). Thus, the maximum yield in 9 years, in this case, would have been at an equivalent 11- by 11-foot spacing.

Only two of the spacings in 19 years, based on average d.b.h., could be considered for sawtimber. Using a form class of 78 and an average d.b.h. to a 10-inch top, the average tree of the two wider spacings had 60 and 133 board feet (Doyle) in 19 years.

Table 2.—*Average diameter by years and trees per acre planted*[1]

Trees/acre	Years					
	2	4	6	9	19 (range)	
	----------	----------	*inches*	----------	----------	----------
63	4.1a	8.6a	10.8a	13.0a	16.4a	(10.7–21.4)
113	4.0b	7.9b	9.7b	11.4b	14.0b	(7.8–18.7)
201	3.8c	7.0c	8.4c	9.8c	12.9bc	(8.7–16.9)
358	3.6d	6.0d	7.0d	8.1d	11.6cd	(8.8–16.1)
637	3.1e	4.8e	5.8e	6.6e	10.3d	(8.3–13.4)
1,135	2.6f	4.0f	4.8f	5.8f	8.8e	(5.2–12.1)

[1]Means appearing with the same letter are not significantly different within each column at the 0.05 level by Duncan's new multiple range test.

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Table 3.—*Average height by years and trees per acre planted*[1]

Trees/acre	Years				
	2	4	6	9	19[2]
	feet				
63	25.6c	49.4b	67.3a	76.7a	100.0
113	26.7b	51.0a	67.1a	76.4a	105.2
201	27.4ab	52.0a	67.2a	74.8b	104.8
358	28.0a	51.4a	63.8b	70.4c	101.2
637	28.1a	48.7b	59.7c	63.4d	....
1,135	27.8a	44.7c	54.6d	58.2e	....

[1]Means appearing with the same letter are not significantly different within each column at the 0.05 level by Duncan's new multiple range test; where no letters appear, overall test is nonsignificant.
[2]Based on trees of one clone that survived in all four repiications.

Table 4.—*Height of four tallest trees per replication per spacing by years and trees per acre planted*[1]

Trees/acre	Years			
	2	4	6	9
	feet			
63	29.0	54.2b	72.8a	82.2a
113	30.1	56.5a	72.1a	83.4a
201	30.5	57.1a	72.1a	81.0a
358	30.9	56.7a	69.5b	78.1b
637	30.6	54.2b	65.9c	70.9c
1,135	29.8	50.4c	60.5d	65.8d

[1]Means appearing with the same letter are not significantly different within each column at the 0.05 level by Duncan's new multiple range test; where no letters appear, overall test is nonsignificant.

DISCUSSION

Tree development by spacings in Nelder's design may be compared to run-of-the-bar trees in a spacing study at Fitler, Mississippi (Krinard and Johnson 1984). The trees at Fitler were on similar soils—mainly Commerce—where trees per acre were 151 (16 by 18 feet), 302 (12 by 12 feet), 605 (8 by 9 feet), and 1,210 (4 by 9 feet). Measurement plots were 144 feet squared. In annual height growth, dominant trees at Fitler averaged about 12 feet a year for the first 4 years, 8 feet a year for the next 4 years, 3 feet a year for the following 7 years (83 feet in 9 years vs. about 81 to 83 feet for the tallest trees in Nelder's), and 1 foot a year for the next 5 years (106 feet in 20 years vs. 103 feet in 19 years in Nelder's). Diameter growth differed, probably due in part to clonal variation between the two tests, with better growth through age 9 for the Nelder's trees. Individual regression equations of diameter over spacings by years between sites, where d.b.h. = $b_0 + b_1$ log (ft^2/tree), had significantly different intercepts and slopes at ages 4 and 19 and different intercepts at ages 6 and 9 (fig. 2). Greater competition from better survival at younger ages and from wider spaced trees with increasing age may have

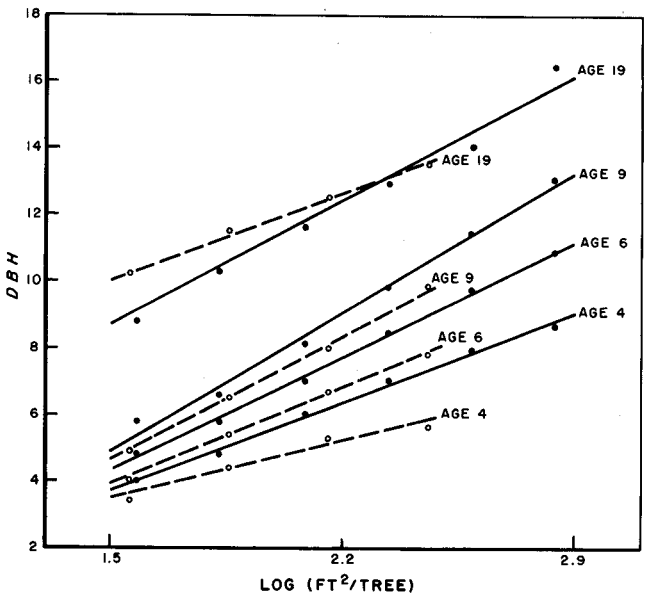

Figure 2.—*Average d.b.h. by spacing for Nelder (•) and Fitler (o) trees after 4, 6, 9, and 19 years where regression lines calculated from d.b.h. = $b_0 + b_1$ log (ft^2/tree).*

Table 5.—*Average annual growth in diameter (D) and height (H) of one clone by age group periods and trees per acre planted*[1]

Trees/acre	Years									
	1&2		3&4		5&6		7–9		10–19	
	D	H	D	H	D	H	D	H	D	H
	ipy[2]	*fpy*[3]	*ipy*	*fpy*	*ipy*	*fpy*	*ipy*	*fpy*	*ipy*	*fpy*
63	2.6a	14.6	2.5a	13.9	1.1	7.9	1.0a	3.3	0.5	1.7
113	2.4ab	14.8	2.2b	14.2	1.1	8.2	0.7ab	3.3	0.5	2.0
201	2.2bc	15.2	1.7c	13.9	1.0	7.6	0.6b	3.1	0.4	2.2
358	2.0c	15.2	1.5c	13.4	0.8	7.1	0.6b	2.7	0.5	2.2

[1]Means appearing with the same letter are not significantly different within each column at the 0.05 level by Duncan's new multiple range test; where no letters appear, overall test is nonsignificant.
[2]Inches per year.
[3]Feet per year.

been a factor in subsequent lower survival and smaller average diameter by age 19 for the four closer spacings in Nelder's design compared to the Fitler plots.

Nelder's design is rather unique and has been of interest to a number of visitors to Stoneville over the years. But, because of increasing mortality and a thick understory of sugarberry (*Celtis laevigata* Willd.) and boxelder (*Acer negundo* L.), the wheels are no longer very apparent. The remaining cottonwood trees are not impressive because of numerous limbs or limb stubs and general lack of both straightness of stem and well developed crowns. Nelder's design, at least in this example with cottonwood, appears to be a way to compare relative tree development in height, d.b.h., and volume over a number of spacings in a minimum area, which could mean less site variation, and with a minimum number of trees. A disadvantage of the design is that it does not allow for mortality effects. Due to intertree competition in the Nelder's plots, 6 years may be the maximum time period for comparing cottonwood trees with less than 70 square feet of growing space. For whatever reasons, survival at the wider spacings at age 19 was lower than what ordinarily would be expected; conversely, survival through age 9 was unusually high. Biomass-type spacings—more than 700 trees per acre—may only have a 5- to 6-year useful life. Without thinnings, pulpwood spacings of 200 to 700 trees per acre would not be expected to have more than 12 to 14 years of useful life. Additional spacings wider than those used in this study would be desirable to follow sawtimber tree development through 20+ years.

LITERATURE CITED

Broadfoot, Walter M. Hardwood suitability for and properties of important Midsouth soils. Res. Pap. SO-127. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1976. 84 p.

Krinard, Roger M.; Johnson, Robert L. Cottonwood plantation growth through 20 years. Res. Pap. SO-212. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 11 p.

Namkoong, Gene. Application of Nelder's designs in tree improvement research. In: Proceedings, Eighth Southern Conference on Forest Tree Improvement; 1965 June 16–17; Savannah, GA. Sponsored Publication No. 24 of the Committee on Southern Forest Tree Improvement. Macon, GA: Georgia Forest Research Council; 1966: 24–37.

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