Growth and Yield of Cottonwood in Central Oklahoma

by
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Cottonwood (Populus deltoides, Marsh.) is one of the few native tree species of Oklahoma able to maintain a reasonably good form despite an unfavorable climate. It is a tree of high value, being used in this area for sawlogs, box stock, and rotary veneer for boxes and crates. More recently, pulpwood buyers from distant points have increased the demand for Oklahoma cottonwood. In addition to pulpwood it is used for excelsior and ground wood for products such as insulation board. Young trees make suitable fence posts and poles when proper preservative treatment is applied.

The tree is extremely intolerant of shade. Dense young stands thin themselves due to their high light requirements. The loss of stems is so great that per acre growth is affected, even though the individual trees grow more rapidly than any other of our native species.

Thousands of acres of bottomland in central Oklahoma, much of it subject to intermittent flooding, are suitable for producing cottonwood timber. On the other hand, much of this type land is unsuited for producing annual crops.

Research reported herein was made to determine the development and yield of cottonwood in central Oklahoma. Data was also obtained on the patterns of natural mortality (competition), the effects of stocking rates on growth, and the effects of thinnings on stocking rates, mortality and growth.

Previous Studies in Cottonwood Production

Several studies of cottonwood growth and yield have been made. Each one was carried out, however, in a region of higher rainfall and soil moisture than applies in the area covered by the present study.

Williamson (9), working in the Mississippi delta region, prepared empirical yield tables for cottonwood in that area. Table 3 from that publication is reproduced here (Table 1).

Research reported herein was conducted under Oklahoma Station project number 870.

Table 1. Cottonwood Yield by Age of Stand, Mississippi Valley, 1924.*

Age	No. of trees/ac. 14"+ d.b.h.	No. of trees/ac. All	Avg. D.B.H.	Avg. Height	Yield Cu. Ft.	Yield Bd. Ft. (Scribner)	Mean Annual Increment Cu. Ft.	Mean Annual Increment Bd. Ft. (Scribner)
Years	Number	Number	Inches	Feet				
5			2.0	22			130	
10		699	5.7	56	1,800		180	
15	22	276	9.2	81	3,850	2,400	257	160
20	43	163	12.3	97	4,900	6,600	245	330
25	52	114	15.0	108	5,450	11,900	218	476
30	55	80	17.4	115	5,825	20,300	194	677
35	53	59	19.7	121	6,150	29,400	176	840
40	48	49	22.0	127	6,425	31,000	161	775
45	42	42	24.2	132	6,675	30,900	148	687
50	32	32	26.5	136	6,900	30,300	138	606

* Williamson, A. W. (9)

McDonald (3), working with cottonwood plantations in Iowa, reported that:

(a) A fair yield from 35-year plantations is 30,000 board feet (Maine rule) of lumber and 50 cords of firewood per acre.
(b) Creosote treated cottonwood fence posts will last 20-25 years in service.
(c) Plantation spacing should be 6 feet X 6 feet or 7 feet X 7 feet.
(d) The number of trees should be reduced in about three thinnings from approximately 900 trees per acre to between 125-175 trees per acre at the end of 35 years.

Swenning, (6), in studies conducted in 1924 with cottonwood and silver maple, concluded that:

(a) The rotation for cottonwood for pulpwood purposes had been placed empirically at 20 years.
(b) The underplanting of cottonwood with silver maple showed evidence of good future possibilities.
(c) Fair stands of 12-year old cottonwood have yielded 1.36 cords per acre per year.
(d) Average stands yield 1.5 cords per acre per year.

Broadfoot (1), analyzing cottonwood sites in the Mississippi delta region in Louisiana, Mississippi, Arkansas, Missouri, and Tennessee, has developed two field guides for evaluating site quality. One key is based on soil descriptions by textural classes fine, medium, and course. Soils of medium texture, inherently moist but well drained, provide optimum sites while fine-textured soils, inherently dry but having poor internal drainage, provide the poorest sites for cottonwood production. A second guide is based upon soil series and phase. Moist bottomland from loess (Collius), and moist soils of recent natural levees (Commerce) provide optimum sites while the dry phase of slack water alluviums (Alligator) are minimum sites.

Maisenhelder (4) has provided information on natural regeneration nursery production of seedlings and cuttings, site preparation and planting costs, and cultural work requisite to optimum production for the species.

Neebe and Fletcher (5), in studies with cottonwood on lands bordering the Mississippi River in Missouri, concluded that thinning increased growth rate of residual trees if the basal area was reduced to 50-60 square feet per acre. The increased growth rate was maintained when additional thinnings were performed as the basal area approached 100 square feet per acre.

Procedure

This study was started in 1946 with the establishment of a single rectangular $\frac{1}{8}$-acre plot on a Port slit-loam soil on Bear Creek bottom in west-central Lincoln County.

Initially, the stand contained about half cottonwood and half black willow, and there were many thousands of seedlings per acre. Seedlings were two and three years old at the time the plot was established.

A weeding in 1946 removed all willow stems and reduced the cottonwood stocking to 1,912 well-spaced stems per acre.

Most willow stumps produced sprouts in the spring of 1947, but they were definitely suppressed by the overtopping cottonwood. All were dead by 1950.

From 1946 until 1955, annual measurements were made in the $\frac{1}{8}$-acre plot without, however, keeping individual tree records. In 1956, the project was expanded in order to provide plot replication and thinning studies.

Three 1/5-acre circular plots were established in addition to the original $\frac{1}{8}$-acre retangular plot. Records of thinning, growth, and mortality were then kept on an individual tree basis for the thinned and unthinned plots. The record of the thinning, which was performed in September and October, 1956, is shown in Tables 2 and 3.

The record of development and a summary of mortality on the original $\frac{1}{8}$-acre plot from 1946 through 1955 is given in Table 4.

Table 2. Trees and Basal Area Removed in Thinning, 1956, Lincoln County, Oklahoma (All Figures on Per Acre Basis)

	Diameter Classes 2		3		4		5		6		Total Basal	Basal Area	
	Trees	Basal Area	Trees	Basal Area	Trees	Basal Area	Trees	Basal Area	Trees	Basal Area	Area Cut 1956	Before Cut	Cut
	No.	Sq. Ft.	No.	Sq. Ft.	No.	Sq. Ft.	No.	Sq. Ft.	No.	Sq. Ft.	Sq. Ft	Sq. Ft.	Percent
Plot 2	10	0.22	100	4.90	65	5.655	15	2.04	5	0.98	13.795	76.37	18.06
Plot 4	—	—	40	1.96	50	4.350	15	2.04	—	—	8.35	69.54	12.01
Avg./ac	5.00	0.11	70	3.43	57.5	5.005	15	2.04	2.5	0.49	11.07	72.955	15.17

Table 3. Percentages of trees, basal area, and volume cut and diameters of the trees of average basal area cut in the 1956 thinning, Lincoln County, Oklahoma.

	Trees Cut	Vol. Cut		Basal Area Per Tree Cut	Diameter of Tree of Avg. Basal Area (Cut)
	Percent	Cu. Ft.	Percent	Sq. Ft.	Inches
Plot 2	35.29	109.30	9.1	.071	3.60
Plot 4	30.35	78.75	6.8	.081	3.84
Average	32.82	94.03	8.0	.076	3.72

Results and Discussion

Competition Mortality

Although some merchantable cordwood volume had developed by age 10, few, if any, of the larger trees containing such volume had been lost to competition mortality at that age. In the first decade, therefore, natural mortality takes many trees and some basal area, but in terms of volume, the loss is unimportant.

Small trees in an unthinned stand have little chance for survival during the second decade. All two-inch trees (as measured in 1956) were lost during the following nine years. Their average survival period was one year. The record of trees lost with their average survival periods is given in Table 5. The linear regression equation describing the percentage of trees lost over diameter classes was computed as: $\hat{Y} = 138.74 - 18.48X$. The linear regression for years of survival after 1956 over diameter classes is written: $\hat{Y} = -0.78 + 0.771X$. (See Figures 1 and 2.)

Effect of Thinning on Competition Mortality

All trees in the 2″ and 3″ diameter classes were removed in the 1956 thinning at age 12. A considerable percentage of the 4″ trees, and a few in the 5″ and 6″ classes were also removed. Thinning resulted in prolonging the survival period of 4″, 5″, 6″, and 7″ trees. The record of the losses and the average survival period by diameter classes is given in Table 5.

The linear regression describing the loss in percentage of trees over diameter classes is: $\hat{Y} = 110.24 - 13.15X$, while the linear regression for years of survival after 1956 over diameter class is: $\hat{Y} = 4.181 + 0.163X$. (Figures 1 and 2).

Two points became quite obvious in this study of competition mortality: (1) the trees in 2″, 3″, and 4″ diameter classes have little vigor, and will succumb in relatively short time to competition, and (2) a thinning made at age 12 significantly prolongs the period over which the smaller trees will survive, but does not alter significantly the percentages of such trees that will die in the decade following the thinning. If a maximum recovery of wood volume is desired, thinnings must be performed at relatively short intervals of two or three years, and certainly not exceeding five years. In cottonwood stands, such thinnings must be made from below, i.e., removing trees of less-than-average

Table 4. Stand development and competition mortality of the original 1/8-acre plot in the first decade, 1946-1956, Lincoln County, Oklahoma

Age of stand	D.b.h. in inches 1	2	3	4	5	6	7	8	9	10	Total No.	Basal Area	Average diameter	Competition Mortality Per Acre	Mortality, in % of living stems
	Number of trees per acre											Sq. Ft.	Inches	Number	Percent
3 (1946)	1,520	336	56								1,912	19.3	1.35		
4	752	656	240	24							1,672	32.8	1.90	240	12.55
5	384	608	264	120	8						1,384	40.1	2.30	288	17.22
6	192	576	296	184	64	8					1,320	54.6	2.75	64	4.62
7	96	432	232	216	96	56					1,128	63.9	3.22	192	14.55
8	16	240	280	152	144	64	16				912	68.7	3.71	216	19.15
9		88	200	152	112	88	56	8			704	75.2	4.45	208	22.81
10		56	200	104	136	96	48	16	8		664	79.3	4.67	40	5.68
11	----	---	---	---	---	---	--	--	--	--	----	---	---	---	----
12 (1955)			104	88	136	104	72	32	24	8	568	97.0	5.6	96 (2 yrs.)	14.46

Table 5. Percentages of Trees Lost and Survival Periods by Diameter Classes (1956-1965), in Lincoln County, Oklahoma

	Unthinned Stand		Thinned Stand	
Diameter Class	Trees Lost	Average Survival Period	Trees Lost	Average Survival Period
Inches	Percent	Years	Percent	Years
2	100	1.00		
3	77	1.56		
4	71	2.25	60	4.75
5	65	3.05	50	5.00
6	11	3.67	22	5.40
7	10	5.00	9	4.00
8			15	5.50

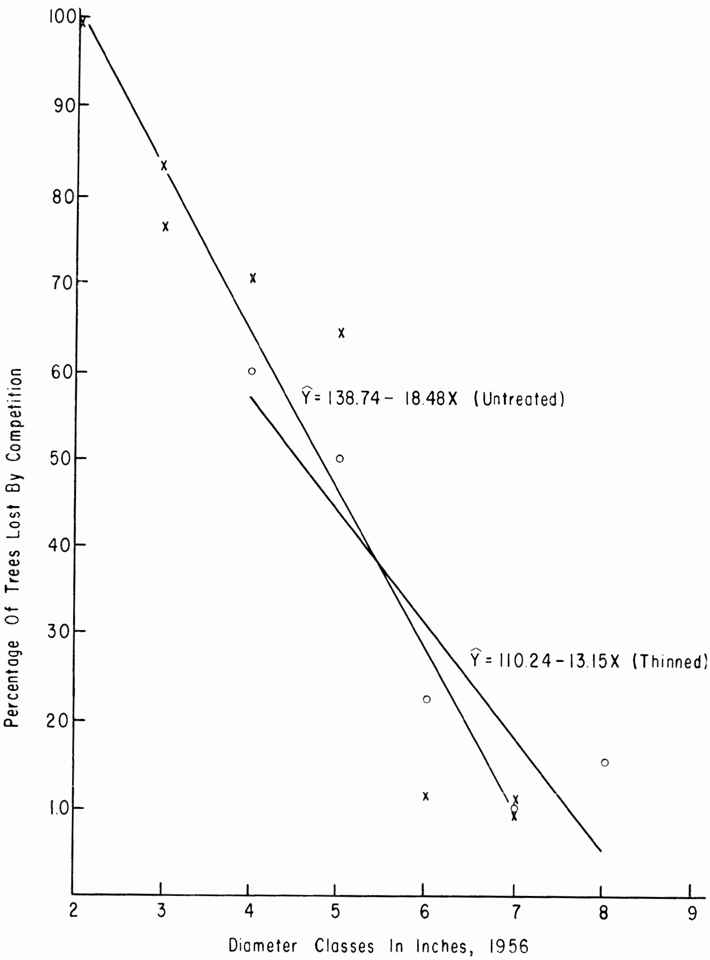

Figure 1. Percentage of Loss by Competition in the Second Decade, Thinned (O) and Untreated (X) Stands of Cottonwood, Lincoln County, Oklahoma.

diameter and those whose crowns are in intermediate or overtopped position.

In terms of volume lost by mortality in the second decade, the untreated stand sustained the greater loss, 662.8 cubic feet per acre as compared to 364.4 cubic feet per acre in the thinned stand. Calculated t was 4.18, significant at the 5 percent level. Competition mortality was not significantly different, but other mortality was significant at the 2

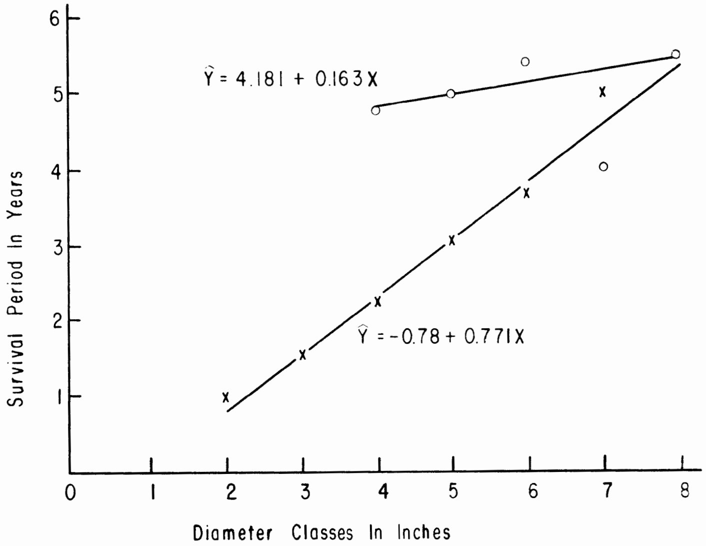

Figure 2. **Years of Survival After 1956 of Trees Lost by Competition in Thinned (O) and Untreated (X) Stands of Cottonwood, Lincoln County, Oklahoma.**

percent level, with calculated $t = 7.58$. Other mortality consisted of windfall, breakage (often due to the work of the cottonwood borer), and lightning. Such losses are usualy considered to be of accidental nature, and it is therefore difficult to read meaning into the large difference (360.9 cubic feet per acre in untreated stand; 122.0 cubic feet per acre in the thinned stand).

Since losses were greater in the untreated stand, and since the untreated stand carried a larger average stocking volume at the beginning of the second decade, it was decided to examine the relationship between the stocking volume and total mortality. Plots were subdivided into quadrants, and the loss in each quadrant compared with the 1956 net standing volume. The regression equation is $\hat{Y} = -73.97 + 0.444X$, and the relationship is shown in Figure 3.

GROWTH AND YIELD

A number of growth and yield variables were studied in the thinned and unthinned stands (Table 6).

Comparisons of the differences between thinned and unthinned stands in 1956, and again in 1965, are shown in Tables 7 and 8. The

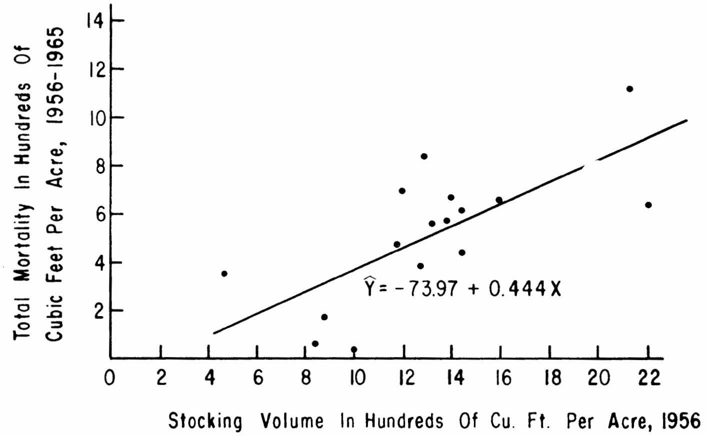

Figure 3. **Total Mortality, 1956-65, Related to 1956 Stocking Volume in Cottonwood Stands, Lincoln County, Oklahoma.**

Table 6. Volumes in Stocking, Net and Gross Increment, and Mortality, in Thinned and Unthinned Stands, Lincoln County, Oklahoma

Variable	Thinned Stand	Unthinned Stand
Standing Volume in Cubic Feet, 1956, before Thinning	1173.8	1566.8
Standing Volume in Cubic Feet, 1956, after Thinning	1079.7	1566.8
Standing Volume in Cubic Feet, 1965	2188.3	2644.1
Net Increment in Cubic Feet, 1956-1965	1108.6	1077.3
Total Mortality in Cubic Feet, 1956-1965	364.4	663.8
Gross Increment in Cubic Feet, 1956-1965	1473.0	1741.1
Total Gross Production in Cubic Feet over 21 Years	2646.8	3307.9

significant increase in the volume-basal area ratio brought about by the removal, in the 1956 thinning, of trees of less than average diameter lends additional weight to the differences observed in the basal areas, volumes, and average diameters following the thinning. As indicated in Table 8, all of these differences lost statistical significance by the second decade, nine years after the thinning.

Diameter Increment of Individual Trees

The diameter increase of trees that survived throughout the second decade was strongly associated with their diameters at the beginning

Table 7. Comparisons of the Stands Before and After Thinning in 1956, Lincoln County, Oklahoma

Variable	Mean Value			t		Level of Significance	
	Thinned		Unthinned	Before Thin.	After Thin.	Before Thin. Percent	After Thin. Percent
	Before	After					
Basal Area, sq. ft./ac	72.950	61.880	94.130	0.511	3.220	>20	8.0
Vol., cu. ft./ac	1173.800	1079.700	1566.800	1.730	2.720	>20	11.0
Diameter of tree of avg. basal area, inches	5.700	6.475	5.810	0.294	2.103	>20	17.0
Vol. - basal area ratio	16.110	17.450	16.630	1.061	6.87	>20	2.0

Table 8. Comparisons of the Thinned and Unthinned Stand in 1965, Nine Years After Thinning, Lincoln County, Oklahoma

Variable	Mean Value		t	Level of Significance
	Thinned	Unthinned		Percent
Basal Area, sq. ft./ac	89.89	108.67	1.006	>20
Volume per acre, cu. ft.	2188.25	2644.12	0.964	>20
Volume - basal area ratio	24.36	24.29	0.108	>20

of the period, as might be expected. Crown dominance and tree vigor are without doubt the telling factors. Thinning had no measurable effect upon the diameter increment (Figure 4). It is logical to conclude that for this fast-growing, early-maturing species, an enormous difference in the vigor of trees by crown classes (and hence, diameter classes) exists. If it were not so, the smaller trees would survive longer. Trees with dominant crowns apparently are able to overcome the competition of their weaker neighbors without sustaining a loss in diameter growth.

Basal Area and Volume Increment

Net growth in both basal area and in volume from 1956 to 1965 was greater in the thinned than in the unthinned stand. The differences are not significant. Furthermore, there was no correlation (regression) found between net stocking in 1956 and net increment in the following decade.

Gross increment in both basal area and in volume in the second decade was positively correlated with stocking in basal area and in volume at the beginning of the period. (Figures 5 and 6). The regression equation for basal area increment is $\hat{Y} = 38.73 + 0.2804X$, while the

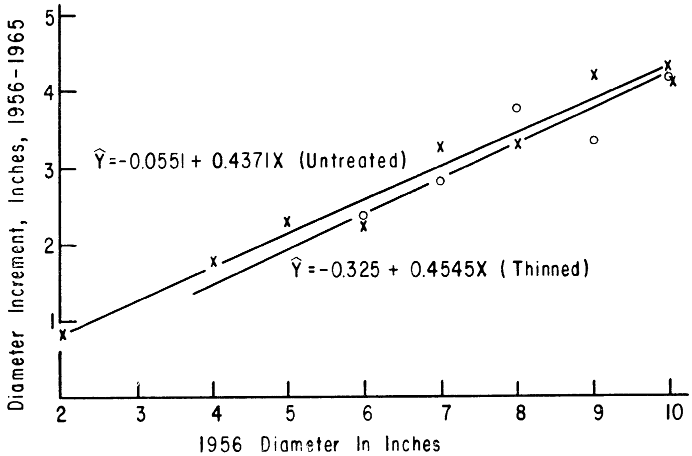

Figure 4. **Diameter Increment, 1956-65, of Trees Surviving in 1965 Related to 1956 Diameter Classes in Thinned (O) and Untreated (X) Stands of Cottonwood, Lincoln County, Oklahoma.**

equation for volume increment over stocking is $\hat{Y} = 844.22 + 0.6116X$. There was no significant difference in the increment between thinned and unthinned stands, although the unthinned stand showed the greater amount. The latter fact appears to be due to the average greater degree of stocking in the unthinned stand in 1956.

This question arises: If gross production during the second 10-year period is dependent upon the degree of stocking at the beginning of that period, would not a thinning performed at that time adversely affect the production? The answer appears to depend upon the degree of thinning. In the absence of a cut, gross increment consists of net increment plus mortality. Both mortality and gross increment increase with stocking density and, in this study, net increment was not associated with stocking density. At least within the range of stocking studied in the present case, thinnings heavier than required to minimize the mortality would likely cause a decline in total gross production. The nature of the silvics of the species, i.e., the great intolerance to shading, the sensitivity to competition, and the unusually short technical rotation, testify to the need for a strict regulating of stocking densities if a maximum product recovery is to be achieved.

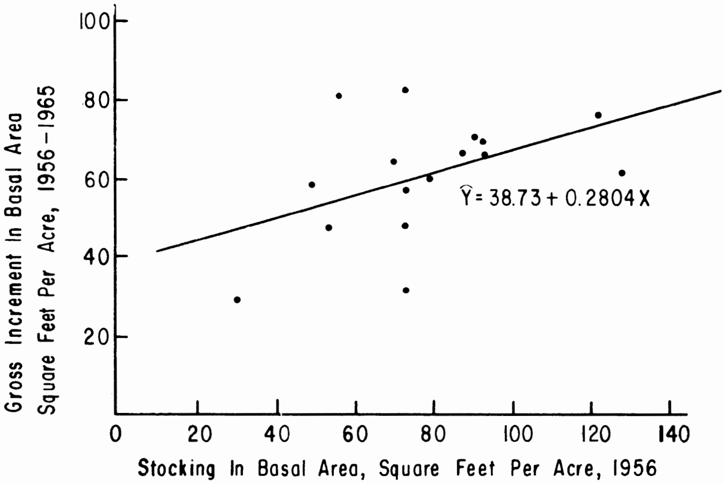

Figure 5. Gross Basal Area Increment, 1956-65, Related to 1956 Stocking in Basal Area, Cottonwood Stands, Lincoln County, Oklahoma.

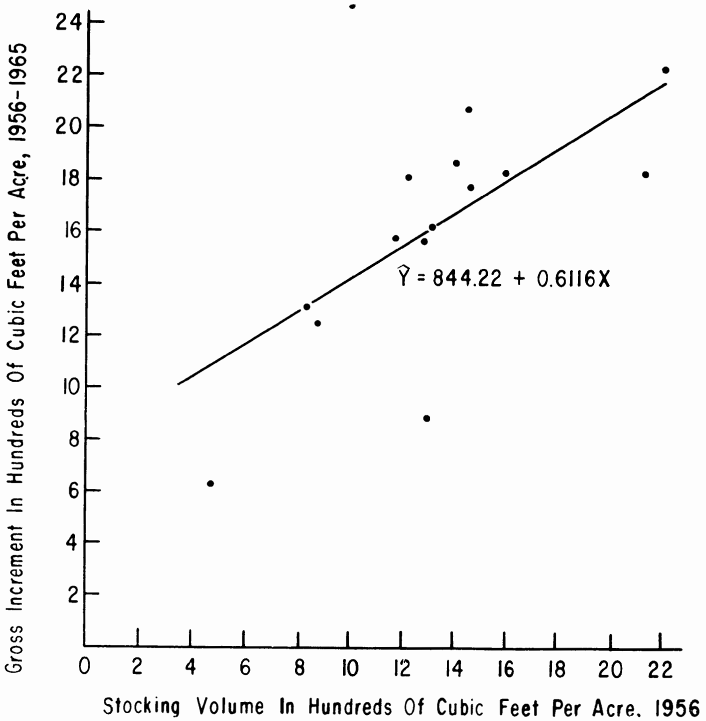

Figure 6. Gross Volume Increment, 1956-65, Related to 1956 Stocking Volume, Cottonwood Stands, Lincoln County, Oklahoma.

MEAN ANNUAL AND CURRENT ANNUAL GROSS INCREMENT

Current gross increment in cubic feet culminated approximately at age 15, then began to decline. Mean gross increment leveled off at age 20 and 21. The shapes of the two curves suggest culmination of mean gross growth at age 22 or 23, and intersection of the curves of mean and current growth at that point. (Figure 7 and Table 9) . A technical rotation of 22 years should produce about 140 cubic feet (approximately 2 cords) per acre per year. In order to recover all this volume, mortality

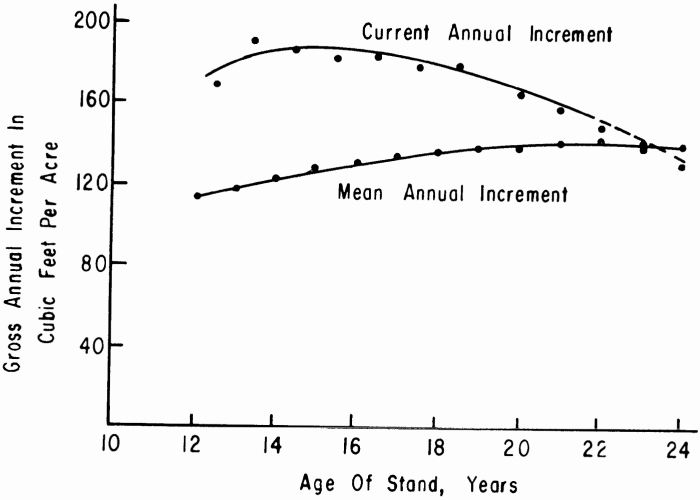

Figure 7. Mean Annual and Current Annual Gross Increment in Cubic Feet Per Acre, Cottonwood Stands, Lincoln County, Oklahoma.

Table 9. Means Annual and Current Annual Gross Increment in Cubic Feet

Age	Mean annual growth per acre cubic feet	Current annual growth per acre cubic feet
12	114.2	
13	118.5	170.1
14	123.7	191.7
15	128.3	187.2
16	131.7	183.5
17	134.9	186.3
18	137.4	178.7
19	139.6	178.7
20	139.2	131.7
21	141.7	192.7

would have to be forestalled by frequent light cuts (from below) after age 10. Any trees dying in spite of the thinnings would have to be cut before they began to deteriorate. Any volume lost would constitute a reduction in total volume obtained from the stand.

Summary and Conclusions

A natural stand of cottonwood (seed origin) on Port silt-loam soil in west-central Lincoln County, Oklahoma, was studied from time of stand establishment until stand age 21. The juvenile development until age 12 was studied on one plot only. In 1956, at stand age 12, three additional plots were established in the same stand. Two of the four plots were thinned lightly from below, removing about 30 percent of the stems, 15 percent of the basal area, and 8 percent of the merchantable volume. Trees removed were mostly in the 2-inch to 5-inch classes.

Trees lost to competition in the first decade were nearly all in non-merchantable sizes, and therefore such losses were of no economic significance. After stand age 12, competition losses became significant. Thinning was effective in forestalling much of the loss, and it was indicated that additional frequent light thinnings could have prevented further losses of volume.

Immediately following the thinning, two significantly different populations existed. The thinned stand had a higher average diameter, less basal area and volume, and a higher volume-basal area ratio. At age 21, the significance of these differences had disappeared. Competition over this period removed the trees that would have been cut in a thinning. Surviving trees in the untreated plots responded very much the same as the surviving trees in thinned plots.

Thinning had no significant effect upon gross production over the 21-year period, or upon gross production in the second decade. It likewise had no effect on diameter increment or basal area increment of trees surviving throughout the second decade. Thinning was instrumental in lengthening the period of survival for trees 4 inches to 7 inches in diameter, thus permitting trees of these sizes to produce more basal area and volume before they succumbed to competition. The benefits of thinning, therefore, were centered about a greater percentage recovery of the gross volume produced.

Total gross production in the second decade was positively correlated with the density of stocking at the beginning of the period. This finding suggests that a heavy thinning at age 12 might cause a decline in gross production. There must be a break-even intensity for the initial thinning beyond which the increasing recovery in the thinning is more than offset by a future decline in gross yield. This level of thinning has not been identified, but it seems clear that if repeated thinnings are designed only to forestall competition mortality the result will be one of increasing the net recovery of wood volume over a rotation period.

Although the technical rotation for pulpwood production has not been identified positively, the leveling off of mean annual gross production at age 20 and the trend of the curve of current growth suggest that culmination of mean gross growth in cubic feet (technical rotation) will occur at age 22 or 23. Whether stands should be held any longer would be dependent upon increasing unit values for larger timber and in declining unit costs in converting standing trees to pulp. In other words, the net stumpage value (above costs of production and carrying costs) would determine whether stands should be held past the technical rotation age.

Natural stands of cottonwood in the Central Oklahoma area evidently cannot produce the volumes obtainable from stands in the more humid regions farther east. The climate is undoubtedly responsible for a major portion of the difference. It is not known how much of the difference may be due to heredity. A tree improvement program for cottonwood may pay off handsomely.

Literature Cited

1. Broadfoot, W. M. Field guide for evaluating cottonwood sites. Occasional Paper 178, So. For. Exp. Sta., U.S.D.A. 1960.
2. Cope, J. A. Fruit to fibre. American Forests 53:233, May, 1947.
3. McDonald, G. B. Growth, returns and uses of planted cottonwood. Iowa Agriculture Experiment Bulletin 223: 169-201.
4. Maisenhelder, Louis C. Planting and growing cottonwood on bottomlands. Mississippi Agr. Exp. Sta. Bulletin 485. October, 1951.
5. Neebe, David J., and Peter W. Fletcher. Thinning of Eastern cottonwood in Missouri. Missouri Ag. Exp. Sta. Research Bulletin 733. April, 1960.

6. Swenning, K. A. Management studies on cottonwood and silver maple. Jour. of Forestry, 22:178-183, February, 1924.

7. U.S.D.A. Circular 77 (Forest Service) (1907).

8. Vincent, Gustav. Propagation of poplars as a part of planned increase in timber production. Bulletin of the Czechoslovakia Academy of Agriculture, 22:172-177. (Reviewed by S. A. Wilde in Jour. For 46:616, August, 1948).

9. Williamson, A. W. Cottonwood in the Mississippi Valley, U.S.D.A. Bulletin 24.

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