Reprinted from: PROCEEDINGS: SYMPOSIUM ON EASTERN COTTONWOOD AND RELATED SPECIES, p. 20-30. 1976.

NATURAL COTTONWOOD STANDS--PAST MANAGEMENT AND IMPLICATIONS FOR PLANTATIONS

R. L. Johnson [1/] and E. C. Burkhardt [2/]

Abstract.--This paper reviews literature and presents the results of a survey of natural stands along the Mississippi River from Cairo, Illinois, to Vicksburg, Mississippi. Natural stand development, growth, and silviculture are described, and stocking suggestions for plantations are made based on measurements of natural stands.

Additional keywords: *Populus deltoides*, growth, natural regeneration, spacing, thinning, increment.

Since the first commercial plantings of cottonwood (*Populus deltoides* Bartr.) in the early 1960's, the species has become well known for being the fastest-growing tree native to North America and for the farming techniques developed for establishing and growing it. Early growth estimates from plantation-grown cottonwood are indeed gratifying, and select stock developed at the Southern Hardwoods Laboratory should lead to even better growth (Mohn, Randall, and McKnight 1970). As impressive as man-planned cottonwood stands appear, are they really an improvement on those that nature has provided for centuries? Since the plantation era is still relatively young, perhaps now is an appropriate time to examine nature's efforts at growing cottonwood. Therefore, this paper summarizes the characteristics of natural cottonwood trees and stands in the lower Mississippi River Valley. The information presented is based on published reports, personal observations, and a recent survey of cottonwood stands near the Mississippi River. The survey, which included both fully stocked uncut stands and cut stands, was made on good cottonwood sites sampled near Cairo, Illinois; Ripley, Tennessee; McGehee, Arkansas; and Tunica, Rosedale, and Vicksburg, Mississippi.

Cottonwood grows naturally throughout much of the United States from the Great Plains eastward (McKnight 1971). Although it grows in many northern States, cottonwood performs best in the southern United States along the Mississippi River and its major tributaries from Cairo, Illinois, to Baton Rouge, Louisiana. Most extensive stands are enclosed within protection levees--land often referred to as the batture.

Cottonwood can reach a height of over 175 feet and a dbh of more than 6 feet. In stands of the lower Mississippi Valley there are several trees about 100 years old. One that was harvested in 1975 near Vicksburg, Mississippi, was 64 inches dbh, 136 feet tall, and contained over 5,000 board feet Doyle in the bole and top. It grew about 0.8 inch in diameter annually for the first 60 years and was still growing at 0.4 inch per year when cut.

1/ Principal Silviculturist, Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, Forest Service--USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

2/ Chief Forester, Anderson-Tully Co., Vicksburg, Mississippi.

STAND DEVELOPMENT

After Williamson (1913) published his comprehensive document on development of natural stands, other researchers also reported how cottonwood becomes established on new land (Shelford 1954; Switzer 1948; McKnight 1969; Putnam, Furnival and McKnight 1960). Cottonwood stands begin with thousands of trees per acre but start eliminating weaker individuals almost immediately. Although it is known that early height and diameter growth of cottonwood are usually greater than those of most other species, there is little information published on stand conditions during the first 5 years.

One of the locations visited during our survey was a 3-year-old stand north of Vicksburg, Mississippi, which became established in an open area that had been largely cottonwood before cutting and clearing. After taking a random sample of five .006-acre plots, we estimated stocking at between 5,000 and 6,000 trees per acre. Largest trees were 2 to 3 inches dbh and 25 to 30 feet tall. Because trees with dominant growth characteristics are recognizable, selection of rapid growing clones from this stand was possible after only 2 or 3 years (Mohn and Randall 1971). Dominants were spaced about 6 to 8 feet apart. Although they were only slightly taller than obviously weaker trees, dominants had diameters one-third to one-half greater than those of other trees; they also had wider crowns (6 to 8 feet in diameter) and a higher live crown length to total height ratio--usually 50 to 60 percent.

Near Cairo, Illinois, we visited three stands growing side-by-side. They were 5, 10, and 15 years old. The 5-year-old stand had developed in an open area after high water flooded the location in 1971. Stocking was not typical because of mechanical thinning the second year, when all cottonwoods in 10-foot-wide strips were cut with a bush hog in two directions, leaving groups of trees in a 5- to 6-foot-square area. We sampled at random 10 of these groups, each of which contained about 15 to 25 trees with one or two dominants. Average height and diameter of dominants (one per group) were 30 feet and 3.2 inches, respectively. The largest tree observed in the area was 6.7 inches dbh and 39 feet tall. Dominants in each sample group were slightly taller and much larger in diameter than the other trees and had larger and usually longer crowns. By year 5, Williamson's (1913) average tree was 2.0 inches dbh and 22 feet tall (table 1).

The average tree in the fully stocked 10-year-old stand was smaller than Williamson's average. Measurements in four 1/40-acre plots located at random indicated stocking of about 1,300 trees per acre, a basal area of about 100 square feet per acre, and an average tree size of 3-1/2 inches dbh. Eighty to 85 percent of the trees were less than 5 inches dbh. Largest trees were between 8 and 9 inches dbh and 50 to 60 feet tall. About one tree in three--400 trees per acre--was considered dominant or codominant. Live crowns of dominants covered about 60 percent of total height; crown diameters were 9 to 12 feet. Based on a height-diameter curve generated from our sample trees, we used the Mohn and Krinard formula (1971) to estimate a total stem volume (outside bark from ground to tip) of about 2,200 cubic feet per acre. On the basis of tree size however, the stand would be considered too small for a normal pulpwood thinning.

Table 1.--Growth and yield of cottonwood (Populus deltoides Marsh) in pure, fully stocked stands in the Mississippi Valley (Williamson 1913)

Age	Number of trees per acre		Average size		Yield per acre			Average annual yield per acre		
	14 inches and over	All trees	Diameter breast high	Height	Stem wood	Scribner decimal	Doyle	Stem wood	Scribner decimal	Doyle
Years			Inches	Feet	Cu. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Bd. ft.
5	--	--	2.0	22	650	--	--	130	--	--
6	--	--	2.8	29	875	--	--	146	--	--
7	--	1,450	3.5	36	1,025	--	--	146	--	--
8	--	1,163	4.2	43	1,250	--	--	156	--	--
9	--	900	5.0	49	1,500	--	--	167	--	--
10	--	699	5.7	56	1,800	--	--	180	--	--
11	--	558	6.4	61	2,175	--	--	198	--	--
12	3	452	7.1	67	2,600	--	200	217	--	17
13	8	375	7.8	72	3,050	800	700	235	62	54
14	15	320	8.5	76	3,500	1,600	1,300	250	114	93
15	22	276	9.2	81	3,850	2,400	1,900	257	160	127
16	29	243	9.8	85	4,150	3,200	2,600	259	200	163
17	34	217	10.5	88	4,400	4,000	3,300	259	235	194
18	37	195	11.1	92	4,575	4,900	4,100	254	272	228
19	40	178	11.7	95	4,750	5,800	4,900	250	305	258
20	43	163	12.3	97	4,900	6,600	5,700	245	330	285
21	45	150	12.8	100	5,025	7,600	6,500	239	362	310
22	47	140	13.4	102	5,125	8,600	7,500	233	391	341
23	49	130	13.9	104	5,250	9,600	8,400	228	417	365
24	50	121	14.5	106	5,350	10,700	9,500	223	446	396
25	52	114	15.0	108	5,450	11,900	10,700	218	476	428
26	53	106	15.5	109	5,525	13,200	12,000	213	508	462
27	54	99	16.0	111	5,600	14,700	13,400	207	544	496
28	55	92	16.5	112	5,675	16,300	15,100	203	582	540
29	55	86	16.9	114	5,750	18,100	17,100	198	624	590
30	55	80	17.4	115	5,825	20,300	19,200	194	677	640
31	55	75	17.9	116	5,875	22,700	21,400	190	732	690
32	55	70	18.3	117	5,950	24,900	23,500	186	778	734
33	55	66	18.8	119	6,025	26,800	25,300	183	812	767
34	54	62	19.3	120	6,075	28,300	26,600	179	832	782
35	53	59	19.7	121	6,150	29,400	27,500	176	840	786
36	52	57	20.2	123	6,200	30,100	28,200	172	836	783
37	51	53	20.6	124	6,275	30,400	28,700	170	822	776
38	50	51	21.1	125	6,325	30,700	29,100	166	808	766
39	49	50	21.5	126	6,375	30,900	29,300	163	792	751
40	48	49	22.0	127	6,425	31,000	29,300	161	775	733
41	46	48	22.4	128	6,475	31,000	29,400	158	756	717
42	45	45	22.9	129	6,525	31,100	29,500	155	740	702
43	44	44	23.4	130	6,575	31,000	29,500	153	721	686
44	43	43	23.8	131	6,625	31,000	29,500	151	705	670
45	42	42	24.2	132	6,675	30,900	29,500	148	687	656
46	40	40	24.7	133	6,725	30,800	29,500	146	670	641
47	38	38	25.1	134	6,775	30,700	29,500	144	653	628
48	37	37	25.6	135	6,825	30,600	29,500	142	638	615
49	34	34	26.0	136	6,875	30,500	29,300	140	622	602
50	32	32	26.5	136	6,900	30,300	29,400	138	606	588

The 15-year-old stand had more trees and a smaller average diameter than that shown in table 1. Our sample of one 1/5-acre plot and two 1/20-acre plots indicated about 385 trees and 112 square feet of basal area per acre. Average dbh was 6.8 inches. About 25 trees per acre were classified as dominants and about 80 as codominants; about one out of every 3.7 trees was a dominant or codominant. Dominants were 12.2 to 15.2 inches dbh and 85 to 92 feet tall and codominants, 7.2 to 10.9 inches dbh and 70 to 85 feet tall. Live crowns of dominants were about 50 percent of total heights and 14 to 18 feet in diameter. Volumes amounted to about 3,400 cubic feet per acre--similar to the 14-year-old stand in table 1. The authors felt that a commercial thinning was practical in this stand.

Most references report average height growth of 4 to 5 feet annually to age 15. Height growth of dominant trees in the stands we surveyed averaged about 6 feet per year during the first 15 years; height growth appeared to decrease with age almost from the beginning, but about 8 to 9 feet of annual height growth during the first 5 years is typical. The range of annual diameter increments of our dominants during the first 15 years was similar to those of Bull (1945) and Broadfoot (1970), who reported 0.5 to 1.0 inch.

Current annual cubic foot increment (CAI) in natural stands may peak between ages 12 and 15 years and mean annual increment (MAI) between ages 15 and 22 years (Walker 1967, Walker 1969, Williamson 1913). Range reported for CAI was 190 to 500 cubic feet per acre and for MAI, 140 to 255 cubic feet per acre.

Williamson (1913) predicted that stands would peak in board foot MAI at age 35 to 45 years. Depending on site, stands might produce 700 to 800 board feet per acre per year and contain 30 to 35 thousand board feet per acre (McKnight 1950, Efferson 1965, Bull 1945). Our survey gathered data from three fully stocked, unthinned sawtimber stands ranging in age from 27 to 35 years (table 2). Of the 60 trees per acre in the 35-year-old stand (Driver Bar), 10 were dominant and 30 codominant. Of the dominants, average dbh was 26.4 inches, average height was 139 feet, and average crown diameter was 41 feet. Codominants averaged 22.0 inches in dbh, 132 feet in height, and 29 feet in crown diameter. About 50 percent of the total height in dominants and 40 percent in codominants was crown.

The 27-year-old stand (Upper Bottom Bar) supported 10 dominants and 35 codominants among the 75 trees per acre. Dominants averaged 22.5 inches in dbh, 128 feet in height, and 37 feet in crown diameter. Codominants averaged 18.8 inches dbh, 129 feet in height, and 24 feet in crown diameter (one sample). Live crown was about 50 percent of total height of dominants and 40 percent of codominants.

At Indian Point, Mississippi, we sampled a two-tiered stand. Of the 32-year-old cottonwoods in the overstory, 15 were dominant and 20 codominant. Dominants averaged 27.8 inches in dbh, 138 feet in height, and 42 feet in crown diameter. Crowns were about 50 percent of total height. Codominants averaged 19.9 inches dbh. Under the cottonwood were 205 trees per acre of sycamore, boxelder, ash, and sugarberry. The understory stand averaged 31 square feet of basal area; projected plot total was 190 square feet per acre. Average dbh of all living understory, noncottonwoods was 5.1 inches.

Table 2.--Stocking and volumes in pure, unthinned, fully stocked natural stands

Location	Age	Average dbh	Number of trees	Sq. ft. basal area	Board feet [a/]			
					Total		MAI	
					Doyle	Int.	Doyle	Int.
	Years	Inches	Per acre					
Ripley, Tenn. (Driver Bar)	35	20.8	60	148	26,390	33,830	754	967
Ripley, Tenn. (Upper Bottom)	27	17.6	80	138	16,980	23,700	629	878
Rosedale, Miss. (Indian Point)	32	19.0	60	159	22,995	27,985	719	875

[a/] Based on Girard's volume tables (to a 10-inch minimum log through grade 3).

Williamson's data does not go beyond age 50, and we found no records on older stands. During our survey we did not locate any uncut stands older than 35 years.

MANAGEMENT

In the last 20 years, most cottonwood stands have been managed by thinning from below followed by a final harvest; time of first thinning, degree of thinnings, and the interval between cuts have varied.

If a pulpwood market is available, the first thinning may begin when the stand is 15 to 20 years old. If sawtimber is the only market, the first thinning may not occur until ages 20 to 25. Time of the first thinning has been governed by economics and the practical problems of harvesting and marketing.

The intensity of thinning from below is usually determined according to the general guidelines suggested by Obye (1958): (1) first mark suppressed trees; (2) next take those obviously in poor condition from wounds, rot, or poor form; and (3) last start marking crowded trees to create a space (in feet) between crowns no greater than half the diameter (in inches) and to leave the best trees as crop trees. Although the primary objective in thinning is to forestall mortality and improve the residual stand, no other documented guides exist to determine the degree of thinning necessary to meet these objectives; most foresters therefore judge according to their experience. Although recommended thinning frequency is between 3 to 7 years, most commercial operators thin at about 5- to 10-year intervals.

What is to be gained from thinning? Much of the research with thinning, spacing, and growth has been with 10- to 15-year-old stands. None has been reported with stands over 30 years old. Usually, the work has been of short duration and covers only one phase of stand development. In most thinning studies, stands have been selectively thinned from below to a specified basal area level and the results compared to an unthinned check. Variation in the results among studies has been largely due to differences in age, stand conditions, site, or growing conditions, but benefits from thinning have been strikingly similar (U.S. Department of Agriculture, Forest Service 1959, Neebe and Fletcher 1960). One of the main benefits of thinning is recovery of a large percentage of gross volume produced, which means that trees are utilized that would otherwise die. Another benefit is that total growth is distributed among a few high-quality trees. Thinning does not increase gross volume production nor does it significantly improve the growth of individual dominant and codominant trees.

During our survey, we visited several stands in the Mississippi River Valley that have been selectively cut one or more times. In a 50-year-old stand near Cairo, Illinois, we remeasured three 1/5-acre growth plots that had been established for 21 years. [3/] Plots were cut for the first time when trees were 45 years old. Estimated removal was 12,113 board feet (Doyle). Five years later, the stand still supported 20,000 board feet (Doyle). Thus, utilized and available production was about 32,000 board feet in 50 years or 640 board feet per acre annually. Dominant trees averaged 34.2 inches dbh, 146 feet in height, and 50 feet in crown diameter. Live crowns were about 50 percent of the total height. From ages 40 to 50, dominants were still growing from 0.5 to 0.7 inch annually and other trees from 0.2 to 0.5 inch annually. About 70 percent of the volume was in grade one logs. Although most trees had adventitious branches after the cut 5 years earlier, only about 2 percent degrade resulted. Trees with small crowns produced the most branches.

Near McGehee, Arkansas, and Tunica, Mississippi, we measured large trees that had survived several thinnings. At McGehee, a residual 70 to 75 years old was 47.4 inches dbh and 156 feet tall. It had 90 feet of merchantable height; 42 percent of the total height was in live crown; crown diameter was 47 feet. The tree contained six logs, all No. 1, and 3,285 board feet (Doyle). There were other trees of similar size in the area as well as several recent stumps. From ring counts on the stumps, we found diameter growth to be rapid--up to 1 inch annually--for the first 10 years. Good growth--0.3 to 0.5 inch per year--continued to age 40 and then dropped to 0.2 to 0.3 annually to age 70. There was variation, however, as average growth of one tree was 0.5 inch per year from age 60 to 70. There was no indication that these 70- to 75-year-old trees would soon break up and die.

The Tunica trees were about 70 years old and healthy. Six that we measured were from 31 to 43 inches dbh. All were about 150 feet tall. Live crowns were 50 to 60 percent of total height. Crown diameters were approximately 50 to 60 feet. Individual tree volumes ranged from about 1,500 to 2,500 board feet in from four to eight logs. Over 90 percent of the volume was grade one.

One important aspect of successful management is frequent observation of the stand. Growing conditions may be excellent one year but may change enough to cause widespread mortality the next. Periods of drought--either natural or man-made--can be quite detrimental to stands on sandy soils. Man-made droughts

---

3/ Heavrin, C. A. 1968 Poplar Council Tour for the International Poplar Commission, Stop 2.

may occur as a result of excessive drainage caused by channeling or from revetments that cut off lateral movement of underground water (Broadfoot 1960); on the other hand, trapped, standing water can also kill the trees (Broadfoot 1973) as can sudden and deep sedimentation, which is especially bad for older trees. Insects and diseases associated with cottonwood (Morris et al. 1975) can cause degrade, deformity, or a loss in growth; some diseases can even lead to mortality (Toole 1962). Ordinarily, however, vigorous trees are not affected greatly by insects and diseases.

Natural cottonwoods are shallow rooted and subject to windthrow, which is particularly prone to occur when high winds follow an overflow that has thoroughly saturated the soil.

In older stands on most sites, vines, grape (*Vitis* spp.), and poison-ivy (*Toxicodendron radicans*) grow up the boles and into the tops. Vines 4 or 5 inches in diameter are not uncommon. Although some foresters believe that vines hinder diameter growth, Krinard (1960) refutes this theory.

Cottonwood normally does not reproduce naturally. Even in fully-stocked, unthinned stands the shade from cottonwood is not dense enough to prevent establishment of other tree species in the understory. Thinning promotes understory development by increasing the sunlight available. The two most common species invading cottonwood stands are silver maple (*Acer saccharinum* L.), which predominates north of Memphis, Tennessee, and boxelder (*Acer negundo* L.) to the south. Others include sycamore (*Platanus occidentalis* L.) sweet pecan (*Carya illinoensis* (Wangenh.) K. Koch), sugarberry (*Celtis laevigata* Willd.), and green ash (*Fraxinus pennsylvanica* Marsh.). To prevent these species from taking over the site after the cottonwoods are cut and to create a seedbed of bare mineral soil conducive to natural cottonwood regeneration, foresters once recommended that thinnings be kept very light to prevent opening the canopy (McKnight 1950, Switzer 1948). Later experience, however, indicated the unlikelihood of reproducing cottonwood without drastic site preparation (Hosner and Minckler 1960).

We reported a method of site preparation to promote natural regeneration of cottonwood by simulating natural conditions (Johnson 1965). With the method, the overstory is cleared completely; then, ditches 6 to 7 feet wide and 8 to 10 inches deep are created near or adjacent to seed trees (within 1,000 feet) during the seedfall period. Seedlings become established in the ditches, which provide a relatively open, weed-free environment. Although the treatment is successful when used properly, it requires a thorough knowledge of soils as well as adequate but not excessive seedbed moisture. Very sandy soils and soils with a clay cap are unsuitable. One stand established by the technique on Commerce silt loam soil near Vicksburg, Mississippi, contained several trees 12 to 14 inches dbh after 16 years. One open-grown tree was 20.7 inches dbh and 97 feet tall.

IMPLICATIONS FOR PLANTATION COTTONWOOD

Apparently homogeneity caused by constant spacing in plantations can cause a stagnation that does not occur in natural stands. This problem will probably become increasingly important in plantings of select clones. For example, at some age, depending on initial spacing, plantation trees from run-of-the-bar cuttings drop significantly in diameter growth over a wide range in spacings

(Krinard and Johnson 1975). Once stagnated, the trees do not appear to respond to release. Thus, thinnings to create proper spacing appear critical. Since natural stands begin with many more trees per acre than planted ones, one would expect them to stagnate quite early, although their inherent diversity apparently prevents this occurrence. At age 3 and possibly earlier, above average growers are obvious throughout the natural stand. They stand out because of their comparatively large diameters and correspondingly large crowns, a probable result of genetic make-up, proximity to other dominants or codominants, spacing, and perhaps micro-site. Early in a stand's development, there is enough space for both codominants and dominants. Later, only dominants prevail. Our observations of 27- to 35-year-old stands revealed only about 10 to 15 dominants per acre.

Dominants are usually slightly taller and larger in diameter than codominants and have fuller crowns that constitute about 50 percent of their total height. Codominants have close to 40 percent of their total height in crown but often have more merchantable height than dominants, which tend to fork. Table 3 summarizes the dominant and codominant trees by stands found in our survey. The figures are based on only a small sample (one to four plots and less than six sample trees per location); although not conclusive, the data indicate the stocking and spacing to aim for in our plantations.

The preceding discussion suggests certain advantages of natural stands over plantations: the cost of maintaining a natural stand is less, gross fiber production is higher, natural pruning is better, and delayed thinning is not so detrimental to residual trees as for plantations. Advantages of plantations are fast early growth from use of select stock, ease in mechanical harvesting, and, most important, predictability--a key point. Not only is it impossible to predict the start of natural stands, but it is becoming increasingly less likely that new stands will be established at all. Efforts to control the Mississippi River have effectively curtailed the establishment of cottonwood on new land (Dutrow, McKnight, and Guttenberg 1970; McKnight and Biesterfeldt 1968). No longer is the meandering river likely to cut banks and build up new bars over a large area because of channel straightening, dredging, and the installation of miles of revetments. Thus, in reality we probably have no choice other than plantations if we are to continue growing cottonwood on a large scale.

LITERATURE CITED

Broadfoot, W. M. 1960. Soil-water shortages and a means of alleviating resulting influences on southern hardwoods. In Southern forest soils, Proc. La. State Univ., 8th Annu. For. Symp. p. 115-119.

Broadfoot, W. M. 1970. Tree-character relations in southern hardwood stands. USDA For. Serv. Res. Note SO-98, 7 p. South. For. Exp. Stn., New Orleans, La.

Broadfoot, W. M. 1973. Water table depth and growth of young cottonwood. USDA For. Serv. Res. Note SO-167, 4 p. South. For. Exp. Stn., New Orleans, La.

Bull, H. 1945. Cottonwood--a promising tree for intensive management. Chemurg. Dig. 4: 53-55.

Dutrow, G. F., McKnight, J. S., and Guttenberg, S. 1970. Investment guide for cottonwood planters. USDA For. Serv. Res. Pap. SO-59, 15 p. South. For. Exp. Stn., New Orleans, La.

Efferson, J. N. 1965. Wanted--bottomland. The Unit, No. 106: 15-17.

Hosner, J. F., and Minckler, L. S. 1960. Hardwood reproduction in the river bottoms of southern Illinois. For. Sci. 6: 67-77.

Johnson, R. L. 1965. Regenerating cottonwood from natural seedfall. J. For. 63: 33-36.

Krinard, R. M. 1960. Deadening vines fails to improve cottonwood growth. Miss. Farm Res. 23(5): 3, 5.

Krinard, R. M., and Johnson, R. L. 1975. Ten-year results in a cottonwood plantation spacing study. USDA For. Serv. Res. Pap. SO-106. South. For. Exp. Stn., New Orleans, La.

McKnight, J. S. 1950. Forest management by Old Man River. South. Lumberman 181(2273): 233-235.

McKnight, J. S. 1969. Ecology of four hardwood species. *In* The ecology of southern forests, Proc. La. State Univ. 17th Annu. For. Symp. p. 99-116.

McKnight, J. S. 1971. Cottonwood. USDA Am. Woods FS-231, 8 p.

McKnight, J. S., and Biesterfeldt, R. C. 1968. Commercial cottonwood planting in the southern United States. J. For. 66: 670-675.

Mohn, C. A., and Krinard, R. M. 1971. Volume tables for small cottonwoods in plantations. USDA For. Serv. Res. Note SO-113, 4 p. South. For. Exp. Stn., New Orleans, La.

Mohn, C. A., and Randall, W. K. 1971. Inheritance and correlation of growth characters in *Populus deltoides*. Silvae Genet. 20: 182-184.

Mohn, C. A., Randall, W. K., and McKnight, J. S. 1970. Fourteen cottonwood clones selected for Midsouth timber production. USDA For. Serv. Res. Pap. SO-62, 17 p. South. For. Exp. Stn., New Orleans, La.

Morris, R. C., Filer, T. H., Solomon, J. D., et al. 1975. USDA For. Serv. Gen. Tech. Rep. SO-8, 37 p. South. For. Exp. Stn., New Orleans, La.

Neebe, D. J., and Fletcher, P. W. 1960. Thinning of eastern cottonwood in Missouri. Univ. Mo. Agric. Exp. Stn. Res. Bull. 733, 20 p.

Obye, K. D. 1958. Thinning cottonwood and willow. *In* Management of bottomland forests, Proc. La. State Univ. 7th Annu. For. Symp. p. 35-41.

Putnam, J. A., Furnival, G. M., and McKnight, J. S. 1960. Management and inventory of southern hardwoods. USDA, Agric. Handb. 181, 102 p.

Shelford, V. E. 1954. Some lower Mississippi Valley flood plain biotic communities; their age and elevation. Ecology 35: 126-142.

Switzer, H. D. 1948. The management of cottonwood in the bottomlands of southern Illinois. South. Lumberman 177(2225): 153-157.

Toole, E. R. 1962. Cottonwood canker. South. Lumberman 204(2539): 42, 44.

U.S. Department of Agriculture, Forest Service. 1959. Eastern cottonwood responds to thinning. Annu. Rep. 1958, p. 42-43. USDA For. Serv., Cent. States For. Exp. Stn., Columbus, Ohio.

Walker, N. 1967. Growth and yield of cottonwood in central Oklahoma. Okla. Agric. Exp. Stn. Bull. B-656, 20 p.

Walker, N. 1969. Economic and management models for cottonwood in central Oklahoma. Okla. State Univ. Agric. Exp. Stn. Bull. B-664, 18 p.

Williamson, A. W. 1913. Cottonwood in the Mississippi Valley. USDA Bull. 24, 62 p.

Table 3.--Dominant and codominant component [a] of pure, fully stocked stands

Location	Dbh		Average height	Sq. ft. basal area	Number of trees	Average spacing [b]	Average crown diameter	
	Average	Range					Dominants	Codominants
	---- Inches ----		Feet	--- Per acre ---		Feet	-------- Feet ----------	
Cairo, Ill.	5.1	3.1- 7.9	56	67	420	10X10	12	9
McGehee, Ark.	9.4	7.1-13.9	80	80	160	16X16	21	18
Cairo, Ill.	10.2	7.2-15.2	88	62	100	21X21	15	--
McGehee, Ark.	12.6	10.7-16.7	110	71	80	23X23	27	25
Ripley, Tenn.	19.7	16.5-23.0	129	96	45	31X31	37	24
Rosedale, Miss.	22.5	18.8-29.6	138	128	45	31X31	42	--
Ripley, Tenn.	23.1	17.7-28.3	134	119	40	33X33	41	29

a/ Trees considered intermediate or suppressed not included.

b/ Indicates possible plantation spacing for number of trees and average dbh for each stand.