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TEN-YEAR GROWTH OF PLANTED SLASH PINE AFTER EARLY THINNINGS

Hans G. Enghardt and W. F. Mann, Jr.[1]

Volume growth of slash pine between ages 17 and 27 years was directly related to residual basal area per acre after thinning. Diameter growth was inversely related to stand density, and very heavy cutting was required to attain a rate of 3 inches in 10 years.

This paper summarizes 10-year volume and diameter growth of planted slash pine *(Pinus elliottii* Engelm. var. *elliottii)* that was thinned at age 17 years to a broad array of residual densities. The site, which has never been in cultivation, is highly productive and typical of large acreages in the flatwoods region of the West Gulf Coastal Plain.

Information on growth and yield of slash pine in this region is limited. It is known, however, that data from slash pine plantations in the Southeast, whether on old-field or cutover sites, are not applicable here. Differences in soils and climate probably account for the variations.

The Plantation

The plantation is about 14 miles west of Kinder, Louisiana. The old-growth longleaf pine was removed from the site in the 1920's, and when the slash pines were planted the land supported only a dense stand of native grasses.

The soil is mostly a Beauregard silt loam, slowly permeable. Since topography is almost flat, surface drainage is also slow. Site index for slash pine is 91 to 102 feet (age 50 years), a range that is typical for large areas of central and southwest Louisiana.

The plantation was established in the winter of 1941-42. Seedlings were hand-planted in the grass sod at an approximate spacing

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of 6 by 7 feet. No record of early survival is available, but average stocking of 690 trees per acre at age 17 years indicates that it was reasonably good.

In 1957, 1 year before the study was started, a thinning was made to remove an average of 72 small trees per acre whose trunks were cankered by fusiform rust *(Cronartium fusiforme* Hedgc. & Hunt ex Cumm.). Volumes of these trees have been added to cut volumes at age 17 and to mean annual growth. Of the remaining trees, 20 percent had cankers on the trunk.

Description of Study

Eight thinning regimes plus an unthinned check are under test, with four block replications of each treatment. Thinnings, all started at age 17 years, are as follows:

BA 70: Thin to 70 square feet of basal area per acre every 5 years.

BA 85: Thin to 85 square feet every 5 years.

BA 85-10: Thin to 85 square feet every 10 years.

BA 100: Thin to 100 square feet every 5 years.

BA 95/55: Thin to 95 square feet at age 17, and to 55 square feet at age 22 and every 5 years thereafter. Reduction of stocking in two steps was to avoid a heavy release that would leave trees vulnerable to wind and ice damage.

BA 95/115: Thin to 95 square feet at age 17, and to 115 square feet at age 22 and every 5 years thereafter. The first thinning was heaviest, since the aim was to remove badly diseased trees.

Increasing BA: Thin to progressively higher basal areas on a 5-year cycle, starting with 85 square feet and reaching 120 square feet at 52 years.

D+: D+ (X) thinning *(8)*, advocated by the USDA Soil Conservation Service. D is the average diameter (b.h.) of the stand, and in this study X is equal to 4 plus the expected diameter growth in 5 years (in inches). The sum of D + X is expressed in feet for an average spacing between trees after cutting. SCS personnel marked the plots to insure that the system was applied correctly.

Check: No thinning.

Plots are 200 feet square or 0.92 acre in size, but measurements were confined to the central 0.25 acre.

Average stocking at age 17 years was comparable for individual treatments (table 1). Variations from the means of number of

Table 1.—*Average stand per acre of trees 3.6 inches d.b.h. and larger before thinning at age 17 years, by treatments*

Thinning treatment	Site index	Trees	Basal area	D.b.h.	Volume, inside bark
	Feet	*Number*	*Sq. ft.*	*Inches*	*Cu. ft.*
BA 70	97	619	112	6.0	1,746
BA 85	97	622	118	6.0	1,739
BA 85-10	96	650	119	6.0	1,685
BA 100	98	596	116	6.2	1,942
BA 95/55	96	645	120	6.0	1,867
BA 95/115	98	648	122	6.0	1,923
Increasing BA	96	640	120	6.0	1,828
D+	95	639	117	6.0	1,717
Check	95	625	114	5.9	1,707

trees, basal area, and d.b.h. were less than 5 percent. Cubic volumes differed slightly more, ranging from 1,685 to 1,942 cubic feet of peeled wood (i.b.) per acre.

Mean annual growth was rapid during the initial 17 years, a consequence of the good site. It averaged 106 cubic feet (i.b.) per acre and 0.35 inch of diameter for all trees 3.6 inches d.b.h. and larger.

Diameter of all trees 3.6 inches and larger was measured before each thinning. To determine volumes, stand basal areas were multiplied by a volume/basal-area ratio computed from measurements on sample trees. In 1959 and 1964, cut and leave volumes were added to obtain initial volume; in 1969 cut volume was derived by subtracting leave from initial volume.

Sample-tree volumes were obtained by height accumulation *(2, 6)* in 2-inch taper steps to a top diameter of 4 inches outside bark. Diameter points and heights were determined with a Spiegelrelaskop.[1] To calculate cubic-foot volumes inside and outside bark, bark thickness was measured at breast height, at the midpoint of each merchantable stem, and at the 4-inch top of 100 felled trees distributed over the study plots. Ratios of d.i.b./d.o.b. averaged 0.87, 0.87, and 0.88 in 1959, 1964, and 1969, respectively. Volumes and volume growth reported here are in cubic feet of peeled wood. Approximate values outside bark can be calculated by multiplying inside bark data by 1.306.

Ten well-spaced dominant and codominant trees of good quality were selected on each 0.25-acre plot and numbered as potential crop trees. Measurements on these trees included total height, length

[1] Mention of trade names is for information only, and does not imply endorsement by the U.S. Department of Agriculture.

to the base of the live crown, and length of bole clear of branches and branch stubs.

Mortality, which ranged from 5 to 240 cubic feet (i.b.) per acre over the 10-year study period, was included in growth data because it was unrelated to treatment and because losses from suppression were negligible even on the controls. Moreover, losses due to factors like lightning are distorted on small plots. Special measures were taken to control bark beetles, and hence the data offer no information on possible relations between thinning and insect attack.

Site indices are for a base age of 50 years. They were determined from average heights of dominant and codominant trees measured at 27 years and from curves for slash pine in figure 4 of USDA Miscellaneous Publication 50 *(10)*.

Results

Periodic Annual Volume Growth

Periodic annual volume growth from age 17 to 22 years ranged from 195 to 283 cubic feet (i.b.) per acre (table 2). Poorest growth was on plots thinned by the D+ rule, which left the least basal area (67 square feet per acre) after the first thinning. The best growth was on the unthinned check plots, which had 114 square feet of basal area per acre at the start of the period. In general, volume growth during the first 5 years was related directly to residual basal area at age 17 years.

In all but three treatments, residual basal areas at the start

Table 2.—*Periodic annual cubic volume growth*[1] *(inside bark) from age 17 to 27 years*

Thinning treatment	17-22 years	22-27 years	17-27 years
		Cubic feet	
BA 70	201	222	211bc[2]
BA 85	242	197	219bc
BA 85-10	226	289	258a
BA 100	250	266	258a
BA 95/55	243	194	218bc
BA 95/115	236	238	237abc
Increasing BA	233	257	245ab
D+	195	208	201c
Check	283	261	272a

[1] Trees 3.6 inches d.b.h. and larger to a 4-inch top outside bark.
[2] Values followed by the same letter are not significantly different at the 0.05 level.

of the second 5-year period differed from those at the start of the first period. From 22 to 27 years, volume growth on plots with constant residual basal areas averaged about the same as in the preceding period. Rankings changed somewhat, however, and the relationship of volume growth to density was not as strong as initially.

Plots thinned to 85 square feet of basal area per acre on a 10-year cycle had the best growth, averaging 289 cubic feet annually. Growth on the checks ranked third with 261 cubic feet, although these plots had the highest basal area. Least growth was on plots thinned to 55 square feet of basal area per acre (BA 95/55) at age 22 years. Sharp declines on BA 85 and check plots may have been due to sampling errors that inflated volumes at age 22. Such errors would increase calculated volume growth from 17 to 22 years, but decrease it from 22 to 27 years.

Site index, age, number of trees per acre, basal area per acre, and various interactions between these factors were examined by regression analysis *(3)* for their effect on annual volume growth in both 5-year periods. The best regression contained five of the nine variables tested and accounted for 45 percent of the variation. Because data for only two growth periods were available and some of the treatments had caused large differences in density between periods, the decision was made not to compute prediction equations.

Growth over the 10 years probably offers the best comparison, as it tends to average out weather influences and other unavoidable factors. However, treatments like BA 95/55 are difficult to characterize except with an average residual basal area.

Ten-year annual growth excelled on the unthinned checks, averaging 272 cubic feet per acre. Average basal area during this period increased from 114 to 170 square feet per acre. In contrast, increment was least—201 cubic feet annually—on plots thinned by the D+ rule. On these plots, average basal area per acre left after cutting was 67 square feet at 17 years and 78 square feet at 22 years. Between these two extremes, volume growth increased directly with basal area.

In treatments with a constant residual basal area after each cut, growth increased by about 25 cubic feet for each additional 15 square feet of basal area per acre. This trend is consistent with findings in other studies *(7)*.

Covariance analysis was applied to adjust periodic annual volume growth for differences in site index. Adjusted treatment means differed from actual ones by only a few cubic feet, and rankings were unchanged. Since differences were small, adjusted values are not reported here.

Total Yield and Mean Annual Growth

Mean annual growth to age 27 years ranged from 138 to 167 cubic feet per acre (table 3). These data should not be used to compare thinning treatments, for differences in volumes at the start of the study were larger than differences in growth after treatments. They are given primarily to permit comparison with periodic annual growth and because they may be helpful in certain management decisions.

Table 3.—*Volume cut, mortality, total yield, and mean annual growth per acre to age 27 years*

Thinning treatment	Initial volume—age 17	Cut—age 17 to 27	Mortality—age 17 to 27	Gross yield—age 27	Mean annual growth—to age 27
	Cubic feet (i. b.)				
BA 70	1,746	1,889	8	3,860	143
BA 85	1,739	1,662	43	3,933	146
BA 85-10	1,685	1,844	50	4,261	158
BA 100	1,942	1,751	31	4,517	167
BA 95/55	1,867	2,406	36	4,052	150
BA 95/115	1,923	1,237	37	4,293	159
Increasing BA	1,828	1,580	55	4,276	158
D+	1,717	1,304	5	3,731	138
Check	1,707	[1] 49	240	4,427	164

[1] Cut at age 16 years for fence posts.

Cut volumes amounted to 30 to 60 percent of total yield. Generally, they were highest with heavier thinnings, but initial volume at age 17 also influenced the proportion of total growth that was cut.

Mortality was negligible—less than 60 cubic feet—in all treatments except the check, where it totaled 240 cubic feet from age 1 to 27 years. The loss on check plots was caused by annosus root rot (*Fomes annosus* (Fr.) Cke.) on two of the replicates and not by suppression. It is not known why root rot was heaviest on control plots, which were only thinned lightly in 1957.

Saw Log Volumes

Information on saw-log-size trees is given in table 4 to show what might be expected at age 27 years, rather than to compare the performance of treatments. Because of the variation in volumes prior to the first thinning, no significance can be attributed to any of the differences. Moreover, many trees were just below saw log size at age 27, and ingrowth will be substantial during the next 5 to 10 years.

Table 4.—*Number and volume of saw-log-size trees per acre before cutting at age 27 years*

Thinning treatment	Merchantable trees [1]	Saw-log-size trees [2]	Saw log volume	Avg. volume per tree
	-- *Number* --		- *Board feet* [3] -	
BA 70	207	93	6,562	71
BA 85	245	103	6,611	64
BA 85-10	375	95	5,502	58
BA 100	320	97	6,258	65
BA 95/55	162	78	5,385	69
BA 95/115	355	97	6,148	63
Increasing BA	274	91	6,522	72
D+	233	77	5,092	66
Check	491	83	4,850	58

[1] Trees 3.6 inches and larger.
[2] Trees 9.6 inches d.b.h. and larger.
[3] Int. ¼-inch rule, to 8-inch top (o.b.).

Diameter Growth

All merchantable trees.—From 17 to 22 years, diameter growth of trees 3.6 inches d.b.h. and larger varied from a high of 0.26 inch annually on plots thinned to 70 square feet of basal area to a low of 0.20 inch on the unthinned checks (table 5). On the D+ plots,

Table 5.—*Periodic annual diameter growth of all merchantable-size and selected crop trees*

Thinning treatment	Merchantable trees			Crop trees [1]		
	17-22 yrs.	22-27 yrs.	17-27 yrs.	18-22 yrs.	22-27 yrs.	18-27 yrs.
	---------- *Inch* ----------					
BA 70	0.26	0.30	0.28a [2]	0.30	0.30	0.30
BA 85	.24	.26	.25bc	.28	.29	.28
BA 85-10	.22	.21	.21de	.26	.25	.26
BA 100	.22	.22	.22de	.24	.24	.24
BA 95/55	.21	.34	.28ab	.27	.33	.30
BA 95/115	.22	.21	.22de	.28	.25	.26
Increasing BA	.23	.24	.24cd	.28	.25	.26
D+	.24	.27	.25abc	.30	.27	.28
Check	.20	.19	.20e	.26	.22	.23

[1] First measurement made at age 18 years.
[2] Values followed by the same letter are not significantly different at the 0.05 level.

which had an initial basal area of 67 square feet, diameter growth averaged 0.24 inch yearly. It was 0.04 inch greater on plots thinned to 70 square feet of basal area than on those thinned to 100 square feet.

In the second 5-year period, growth either remained unchanged or increased in treatments where a constant basal area was maintained on a 5-year cutting cycle. It decreased on checks, BA 85-10 plots, and BA 95/115 plots. On plots cut by the D+ rule, it increased from 0.24 to 0.27 inch. The greatest change occurred on BA 95/55 plots, where the average rose from 0.21 to 0.34 inch.

Averages over the entire 10 years were also inversely related to basal area per acre, ranging from 0.20 to 0.28 inch annually. Thinning back to 70 square feet of basal area stimulated diameter growth 0.06 inch more than light thinning to 100 square feet—a difference of about 27 percent, or an average of 0.03 inch for each 15 square feet of residual basal area.

Covariance analysis was applied to adjust treatment means for differences in site index, but only negligible changes in values were obtained.

Selected sample trees.—Diameter growth of the best, well-spaced crop trees followed the same general trends as for all merchantable trees (table 5). From age 18 to 27 years, averages ranged from 0.23 to 0.30 inch yearly, or 7 to 24 percent more than those for all trees over 3.5 inches d.b.h. Only two of the treatments, BA 70 and BA 95/55, resulted in a growth rate of 3 inches in 10 years.

Average diameter.—Increases of average diameters for all merchantable trees over the 10-year period varied from 2.1 to 3.6 inches, with the largest gains in plots thinned heaviest. Parts of these increases are due to cutting and mortality. On all thinned plots, increment alone accounted for 78 to 92 percent of the increase. On the checks, 95 percent was due to growth and the remainder was from mortality of small trees.

Diameter Distributions

To the land manager, diameter distributions are more informative than average diameters. From the number of trees in each diameter class he can estimate volumes available for various products and appraise the value of the stand.

Table 6 gives the cumulative number of trees per acre in and above each 1-inch d.b.h. class for each treatment. There were more trees 11 inches and larger on thinned than on unthinned plots, and heavy thinnings seemed to have a slight superiority over light thinnings. Most differences in stocking of trees 10 inches d.b.h. and larger were small. In trees 9 inches and larger, BA 95/115 and the unthinned check ranked first and second, and light thinnings excelled heavy thinnings. With each successively lower threshold diameter, unthinned checks attained a greater superiority over other treatments.

Table 6.—*Cumulative number of trees per acre before cutting at age 27, by 1-inch d.b.h. classes*

Thinning treatment	D.b.h.—inches											
	<4	4	5	6	7	8	9	10	11	12	13	14
	Number											
BA 70	222	207	203	201	191	169	141	93	40	12	1	...
BA 85	253	245	239	234	220	191	143	103	49	13	2	1
BA 85-10	392	375	361	344	316	262	171	95	31	7	...	...
BA 100	329	320	306	292	269	230	169	97	32	10	3	1
BA 95/55	171	162	159	158	156	145	123	78	34	11	...	...
BA 95/115	364	355	342	324	300	253	179	97	44	14	4	...
Increasing BA	285	274	270	258	247	210	152	91	39	14	4	1
D+	237	233	233	232	227	198	145	77	39	9	2	...
Check	507	491	472	424	352	270	173	83	24	6	1	1

Some trees in the upper crown classes were removed by all thinnings at age 17 and 22 years, although cutting was primarily from below. To achieve the desired stocking levels, 179 to 332 trees per acre were cut in the 4-, 5-, and 6-inch d.b.h. classes, with the greatest number in the heavy thinnings. In contrast, there were only 139 trees per acre in these three size classes on the unthinned checks at 27 years. Obviously, harvest costs will not be adversely affected by an excessive number of small trees when unthinned stands are clearcut at age 27.

Discussion

The actual growth and yield values summarized in this paper are probably of greater value to the land manager than are the relationships of growth to stocking. Similar research has already shown that heavy thinning stimulates diameter growth and lowers volume growth *(1, 4, 5, 7)*. In this study, within a range of 70 to 100 square feet of basal area per acre, an increase of 15 square feet resulted in a decline of 11 percent in diameter growth and a gain of equal magnitude in cubic volume growth.

Earlier studies have also shown the difficulty of obtaining an average diameter growth rate of 0.30 inch on all merchantable stems. This high rate is achieved only by reducing stocking to about 60 square feet of basal area per acre.

Much more difficult to decipher are the total economics, including logging costs, of thinning versus no thinning on a short rotation primarily for pulpwood. A frequent criticism of unthinned stands is that many small trees have to be handled, with resulting high costs per cord for cutting, limbing, and bucking. This study showed that more small trees may be cut when early thinnings are made than when stands are left unthinned until clearcut at age 27.

At age 27, thinned plots had more trees 10 inches d.b.h. and larger than the checks. A saving in cost of final harvest could therefore be expected, but this advantage might be offset by the higher cost of cutting the small trees in the intermediate thinnings. While logging costs decrease slowly in diameters beyond 8 or 9 inches, they rise rapidly in sizes typically removed in thinnings (table 7). A rough appraisal with Tufts' *(9)* data indicates there would be little difference in total logging costs between plots thinned heavily at age 17 and 22 years and clearcut at age 27, in comparison to no thinning and clearcutting at age 27.

Table 7.—*Trees per acre removed in thinnings through age 22*

Thinning treatment	D.b.h.—inches									
	<4	4	5	6	7	8	9	10	11	12
	Number									
BA 70	39	87	105	86	65	48	17	3		
BA 85	15	86	92	82	56	30	16	1	1	
BA 85-10	11	70	86	67	31	5				
BA 100	32	56	57	66	49	37	10	4	2	
BA 95/55	29	84	98	94	108	65	24	5	0	1
BA 95/115	17	74	83	73	34	15	4	1		
Increasing BA	12	75	101	89	48	29	12	2		
D+	11	83	137	112	56	23	4	3		
Check	0	21	18	5						

Results now available should not influence decisions about plantations from which larger trees are desired. The study was designed to run at least until the trees are 50 years old. The interim findings given here thus apply mostly to pulpwood production. Undoubtedly, thinnings will prove beneficial in rotations where veneer and saw logs are the main product goal.

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