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# Growth of *PLANTED SLASH PINE* Under Several Thinning Regimes

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# Growth of Planted Slash Pine Under Several Thinning Regimes

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Three intensities of thinning, each started at 10, 13, and 16 years, were applied to slash pine planted on a highly productive, cutover site in central Louisiana. Over a 9-year period, early and heavy thinnings increased diameter growth but reduced volume growth. The longer initial thinnings were deferred, the slower was the response in diameter growth. Growth on unthinned plots was good.

Slash pine (*Pinus elliottii* Engelm. var. elliottii) has been planted on about 10 million acres across the South--or on more acreage than all other species combined. It has been planted extensively west of the Mississippi River, beyond its natural range.

Many of the plantations have reached or are approaching merchantable size. Consequently, it is timely to summarize early results of a study that is comparing growth of stands in which thinnings were initiated at ages 10, 13, and 16 years. Three intensities of thinning were applied at each stand age. The plantation is on a cutover site in central Louisiana, where slash pine is an introduced species.

First thinnings removed a high proportion of poor-risk trees, chiefly those with large fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.) cankers on the trunk. Subsequent thinnings concentrated on release of better sterns.

## MEASUREMENTS

Measurements were made at 3-year intervals from age 10 to 19 years. They included a complete tally of diameters to the nearest 0.1 inch to obtain basal area. Moreover, volume and basal area of individual sample trees were determined on each plot, and merchantable volume per plot was calculated by multiplying the volume/basal-area ratio of the sample trees by basal area of all trees 4 inches d.b.h. and larger. Volume:; of individual trees were taken by height-

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accumulation' in 2-inch taper steps to a top diameter of 4 inches outside bark. Diameter points and heights were determined with a Spiegelrelaskop.[3]

At ages 10 and 13 years, three sample trees before and after cutting were measured on each plot to provide a common volume/basal-area ratio for a treatment. At ages 16 and 19 years, 12 sample trees were measured to obtain a ratio for each plot. In the larger sample, the number of trees representing each diameter class was in proportion to the total number in that class. Volume removed was calculated by subtracting residual volume from that present before cutting.

Volumes reported here are cubic feet of rough wood (including bark).

## THE STUDY

The site is about 25 miles southwest of Alexandria, Louisiana. After the virgin timber was cut in the 1920's, the land remained idle until it was planted in 194849. As frequent wildfires had kept hardwoods in check, native grasses were the main vegetation.

Soils are Arcadia and Beauregard silt loams and Bowie fine sandy loam-all excellent for pine growth. Terrain is flat to gently rolling. Site index (age 50 years) averages 98 feet, and ranges from 93 to 103 feet.

The site was burned before planting. Slash pine seedlings were hand-planted at a spacing of approximately 6 by 7 feet. Initial survival apparently was high, and at age 10 years stocking on individual plots ranged from 670 to 960 stems per acre.

Forty plots were established, selected for high, uniform stocking. Each is square and 0.4 acre in size. Measurements were taken only on the central O.l-acre. Ten treatments are replicated four times in a randomized block design. They include all combinations of three cutting intensities and three stand ages for the first thinning:

Intensity: Plots cut back to 70, 85, or 100 square feet of basal area per acre at each thinning.

Starting age: thinnings begun at ages 10, 13, or 16 years.

The tenth treatment is an uncut check. Thinnings were repeated at 3-year intervals, but now that the stands are past 19 years of age the cycle will be extended to 5 years.

Table 1 summarizes some of the important stand and stock data during the period covered in this report.

[2] Grosenbaugh, L. R. New tree-measurement concepts: height accumulation, giant tree, taper and shape. USDA Forest Serv. South. Forest Exp Stn. Occas. Pap. 134. 32 p. 1954.

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

Table l.-Average stand and stock data ***per acre*** [1] before cutting ***at 3-year*** intervals from age *10* to 19 years

| Age at first cut, and stocking level | Site index | Age 10 | | | Age 13 | | Age 16 | | Age 19 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Trees | Basal area | Volume | Basal area | Volume | Basal area | Volume | Basal area | Volume |
| | Feet | No. | *sq. ft.* | *Cu. ft.* | *sq. ft.* | *cu. ft* | *Sq. ft.* | *Cu ft.* | *Sq.ft.* | *cu. ft.* |
| 10 years | | | | | | | | | | |
| B.A. '70 | 98 | 81'7 | 104 | 1,325 | 103 | 1,838 | 88 | 1,966 | 91 | 2,362 |
| B.A. 85 | 100 | 775 | 106 | 1,515 | 117 | 2,088 | 104 | 2,341 | 105 | 2,741 |
| B.A. 100 | 100 | 888 | 124 | 1,853 | 135 | 2,513 | 122 | 2,856 | 123 | 3,298 |
| 13 years | | | | | | | | | | |
| B.A. 70 | 98 | 830 | 103 | 1,295 | 138 | 2,386 | 88 | 1,955 | 92 | 2,332 |
| B.A. 85 | 98 | 862 | 114 | 1,507 | 151 | 2,474 | 106 | 2,306 | 104 | 2,722 |
| B.A. 100 | 96 | 845 | 112 | 1,530 | 148 | 2,538 | 118 | 2,638 | 123 | 3,124 |
| 16 years | | | | | | | | | | |
| B.A. 70 | 95 | 795 | 102 | 1,304 | 138 | 2,306 | 156 | 3,159 | 88 | 2,159 |
| B.A. 85 | 96 | 810 | 107 | 1,434 | 143 | 2,478 | 160 | 3,386 | 104 | 2,521 |
| B.A. 100 | 98 | 818 | 115 | 1,676 | 151 | 2,492 | 164 | 3,462 | 117 | 3,016 |
| Unthinned check | 96 | 793 | 103 | 1,386 | 139 | 2,282 | 153 | 3,117 | 173 | 4,045 |

[1] Number of trees and basal area of trees 1 inch d.b.h. and larger; volumes of trees 3.6 inches d.b.h. and larger outside bark to a 4-inch top.

Mortality, which ranged from 9 to 114 cubic feet per acre by treatments over the 9 years, was included in all growth and yield data. This approach was chosen for two reasons. First, special precautions were taken to minimize insect damage following thinning, and consequently the mortality was unrepresentative of that encountered in normal operations. Second, losses from suppression and trunk cankers were negligible on all plots, including the unthinned checks.

# RESULTS

## Periodic Annual Volume Growth

Table 2 summarizes volume growth during each of the 3-year measurement periods and the entire 9 years of study. Comparisons between the short periods must be made with caution, for growth is influenced by spring and summer rainfall, which tends to vary considerably in this region.

**Table** *2.-Periodic annual volume growth*[1] *per acre from ages 10 to 19 years*

| Age at first cut, and stocking level | 10-13 years | 13-16 years | 16-19 years | 10-19 years |
|---|---|---|---|---|
| | | *Cubic feet* | | |
| **10 years** | | | | |
| **B.A. 70** | **292** | **251** | **250** | **264** |
| **B.A. 85** | **280** | **277** | **284** | **281** |
| **B.A. 100** | **325** | **315** | **310** | **317** |
| 13 years | | | | |
| **B.A. 70** | **367** | **230** | **256** | **284** |
| **B.A. 85** | **324** | **275** | **281** | **293** |
| **B.A. 100** | **339** | **269** | **310** | **306** |
| **16 years** | | | | |
| **B.A. 70** | **339** | **303** | **220** | **287** |
| **B.A. 85** | **351** | **324** | **241** | **305** |
| **B.A. 100** | **275** | **348** | **262** | **295** |
| **Unthinned** check | 300 | 297 | 323 | 306 |

[1] **Trees 3.6 inches d.b.h. and larger, with volumes outside bark.**

Periodic annual volume growth from age 10 to 13 years averaged about 9 percent less on thinned plots than on the checks or on plots where thinning was deferred to ages 13 and 16. The reduction was

greatest on plots cut back to 70 and 85 square feet of basal area per acre; it was negligible on plots with 100 square feet.

Plots first thinned at age 13 also grew less from age 13 to 16 years than unthinncd plots. While the overall difference averaged 20 Percent, heavy thinning reduced growth more than medium and light thinning.

The same overall trend of decreased growth following thinning occurred when the first cut was deferred until age 16. The average reduction was 82 cubic feet per acre, or about 25 percent. Decreases ranged from 61 to 103 cubic feet, with the greatest drop on the heavily thinned plots.

Within the range of basal areas on the plots, volume growth was directly related to stand density. Differences in basal areas between thinned and unthinned plots increased as the age of the first thinning advanced. As a consequence, growth differences also became greater.

Average annual volume growth for the 9-year period from age 10 to 19 years reflects the differences discussed for individual 3-year periods. Overall, growth was least when moderate and heavy thinnings were made at 10 years. It was best when thinnings were deferred, because then the plots were uncut for 13 or 16 years. The unthinned checks grew well over the 9-year span.

Covariance analysis was used to adjust for the effects of site index and initial differences in stocking. The 9-year adjusted means were then analyzed statistically, and the findings supported the conclusions above.

One of the noteworthy features on this study so far is the good growth on all plots. Average annual volume growth for 9 years ranged from 264 to 317 cubic feet per acre-undoubtedly a response to the good site.

**Total Yield**

Total yields through age 19 were also excellent, ranging from 3,703 to 4,705 cubic feet per acre (table 3). However, they cannot be used to appraise treatments, for there were substantial disparities in volume at the start of the study. The largest initinl difference, 558 cubic feet per acre, exceeded any that developed between thinning regimes.

The proportion of total growth that was harvested by age 19 ranged from 49 to 53 percent for heavy thinning, 44 to 46 percent for medium, and 37 to 40 percent for light thinning. Time of initial thinning had only a slight effect on the proportion of total growth that was cut.

**Table 3.-Total *yield and mean annual growth* [1] *per acre to age 19 years***

| Age at first cut, and stocking level | Volume at age 10, before cutting | Age 10 to 19 | | Total yield, age 19 | Mean annual growth to age 19 | Proportion of cut to total yield |
|---|---|---|---|---|---|---|
| | | cut | Mortality | | | |
| | *Cubic feet, outside bark* | | | | | *Percent* |
| 10 years | | | | | | |
| **B.A. 70** | **1,325** | **1,831** | **9** | **3,703** | **195** | **49.4** |
| **B.A. 85** | **1,515** | **1,773** | **13** | **4,041** | **213** | **43.9** |
| **B.A. 100** | **1,853** | **1,900** | **19** | **4,705** | **248** | **40.4** |
| **13** years | | | | | | |
| **B.A. 70** | **1,295** | **1,964** | **9** | **3,852** | **203** | **51.0** |
| **B.A. 85** | **1,507** | **1,839** | **71** | **4,147** | **218** | **44.3** |
| **B.A. 100** | **1,530** | **1,644** | **22** | **4,284** | **226** | **38.4** |
| **16** years | | | | | | |
| **B.A. 70** | **1,304** | **2,060** | **71** | **3,890** | **205** | **53.0** |
| **B.A. 85** | **1,434** | **1,912** | **103** | **4,184** | **220** | **45.7** |
| B.A. 100 | 1,676 | 1,602 | 114 | 4,330 | 228 | 37.0 |
| Unthinned check | 1,386 | 0 | 103 | 4,148 | 218 | .0 |

[1] **Trees 3.6 inches d.b.h. and larger.**

## Diameter Growth

*All* trees.-Thinning at age 10 stimulated average diameter growth of the entire stand over the following 3 years, and the increase was directly related to the degree of cutting (table 4). Diameter growth from age 10 to 13 years on the unthinned plots (including those scheduled for later cutting) was uniform, averaging 0.26 inch yearly. On thinned plots, it ranged from 0.27 inch on plots cut back to 100 square feet of basal area per acre to 0.33 inch on those reduced to 70 square feet.

From age 13 to 16, two dry summers caused diameter growth to decline substantially in all treatments. It was highest on plots first thinned at age 10, and next best on those initially cut at age 13. The difference between these two treatments was 0.024 inch annually, or about 10 percent. Evidently stands thinned for the first time at age 13 could not respond as well as those thinned at age 10 and again at 13 years. Annual diameter growth on unthinned plots during this period averaged 0.13 inch, or 24 to 41 percent less than on plots thinned initially at age 13.

Diameter growth on all plots, including the checks, was higher from age 16 to 19 than in the previous 3 years, presumably because rainfall was ample. It was greatest on plots thinned earliest and heaviest. With one exception, plots thinned at age 10 and every 3 years thereafter had better diameter growth than those thinned to

**Table 4.-Periodic annual diameter growth of all trees and of 50 largest trees per acre**

| Age at first cut, and stocking level | All trees | | | | 50 largest trees per acre | | | |
|---|---|---|---|---|---|---|---|---|
| | 10-13 years | 13-16 years | 16-19 years | 10-19 years | 10-13 years | 13-16 years | 16-19 years | 10-19 years |
| | *Inch* | | | | | | | |
| **10 years** | | | | | | | | |
| **B.A. 70** | **0.33** | **0.25** | **0.33** | **0.30** | **0.42** | **0.32** | **0.40** | **0.38** |
| **B.A. 85** | .30 | .22 | .26 | .26 | .44 | .30 | .36 | .37 |
| **B.A. 100** | .27 | .21 | .24 | .24 | .43 | .29 | .32 | .35 |
| **13 years** | | | | | | | | |
| **B.A. 70** | .26 | .22 | .31 | .27 | .43 | .32 | .42 | .39 |
| **B.A. 85** | .26 | .22 | .28 | .25 | .40 | .29 | .35 | .35 |
| **B.A. 100** | .26 | .17 | .23 | .22 | .38 | .25 | .32 | .32 |
| **16 years** | | | | | | | | |
| **B.A. 70** | .27 | .15 | .24 | .22 | .40 | .25 | .32 | .32 |
| **B.A. 85** | .26 | .14 | .23 | .21 | .40 | .26 | .32 | .32 |
| **B.A. 100** | .25 | .12 | .19 | .19 | .39 | .25 | .30 | .32 |
| **Unthinned check** | .26 | .12 | .15 | .18 | .41 | .22 | .27 | .30 |

comparable basal areas at later ages. Similarly, diameter increment was higher when thinning began at age 13 rather than at age 16; differences averaged about 25 precent. Differences between high and low basal areas were 0.09, 0.08, and 0.05 for thinnings initiated at 10, 13, and 16 years.

For the 9-year period, diameter growth was best on plots thinned heavily at age 10, averaging 0.30 inch annually. It was progressively lower as thinning was deferred and residual basal areas were higher. For all residual basal areas combined, delay of the first thinning to age 13 reduced diameter growth by about 7 percent, and a 6-year delay reduced it by 22 percent. Differences between light and heavy thinning averaged about 18 percent for all times of first thinning. As expected, differences due to stocking levels decreased as the first thinning was delayed. Growth on the check plots averaged 0.18 inch annually, or 40 percent less than on plots thinned heavily at age 10.

***Fifty largest*** trees.-Most of the same trends in diameter growth were also evident for the 50 largest trees per acre, although somewhat less pronounced. The most obvious deviation was that thinning intensity had no effect on growth from age 10 to 13, probably because the biggest trees were free of severe competition for crown space. Thereafter, degree of thinning influenced growth of dominants nearly as much as with all trees. Thinned stands outgrew unthinned ones, regardless of the age of first thinning.

It is noteworthy that diameter growth of the large trees on the check plots averaged 0.30 inch annually over the 9 years. This is 67 percent more than tbe growth of all trees on these plots and only 21 percent less than growth of the large trees on plots thinned heavily starting at age 10.

## Average Diameter

Average diameters for all trees at age 10 ranged from 4.7 to 5.1 inches (table 5). Nine years later the range was considerably greater, with the highest averages on plots cut earliest. No consistent differences occurred between stocking levels, however, because average d.b.h. at age 19 was influenced by cutting and mortality, as well as by d.b.h. at age 10. Increment alone accounted for 79 to 91 percent of the increase over the 9 years.

Table 5 — *Average d.b.h of all trees at ages 10 and 19 years, and umount of increase due to growth*

| Age at first cut. and stocking level | Average d.b.h. before cutting | | Diameter increase due to growth, 10 to 19 yrs. |
|---|---|---|---|
| | Age 10 | Age 19 | |
| | — — Inches — — — — | | |
| **10 years** | | | |
| **B.A. 70** | **4.8** | **8.0** | **2.7** |
| **B.A. 85** | **5.0** | **7.6** | **2.3** |
| **B.A. 100** | **5.0** | **7.6** | **2.2** |
| **13 years** | | | |
| **B.A. 70** | **4.7** | **7.6** | **2.4** |
| **B.A. 85** | **4.9** | **7.6** | **2.2** |
| **B.A. 100** | **5.0** | **7.2** | **2.0** |
| **16 years** | | | |
| **B.A. 70** | **4.8** | **7.1** | **2.0** |
| **B.A. 85** | **4.9** | **7.3** | **1.9** |
| **B.A. 100** | **5.1** | **7.1** | **1.7** |
| **Unthinned check** | **4.9** | **6.7** | **1.6** |

## Diameter Distributions

**While** average d.b.h. serves many useful purposes in appraising stand growth, distribution of trees by diameter classes is of greater importance. From table 6, it can be seen that stands thinned initially at age 10 had about twice as many 9- and lo-inch trees as those in which the first thinning was deferred for 6 years. For thinnings started at age 13, stocking in these two large diameter classes was

Table 6.--*Cumulative* number of *trees per acre by* 1-inch d.b.h. *classes, before cutting at age 19*

| Age at first cut, and stocking level | <4 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|
| | Number | | | | | | | |
| 10 years | | | | | | | | |
| B.A. 70 | 262 | 260 | 258 | 258 | 236 | 181 | 83 | 5 |
| B.A. 85 | 332 | 327 | 322 | 300 | 265 | 165 | 67 | 15 |
| B.A. 100 | 390 | 380 | 378 | 348 | 313 | 210 | 95 | 10 |
| 13 years | | | | | | | | |
| B.A. 70 | 295 | 287 | 277 | 257 | 225 | 153 | 60 | 10 |
| B.A. 85 | 328 | 323 | 311 | 301 | 276 | 178 | 73 | 8 |
| B.A. 100 | 435 | 417 | 407 | 385 | 300 | 175 | 50 | 8 |
| 16 years | | | | | | | | |
| B.A. 70 | 320 | 310 | 302 | 280 | 215 | 115 | 35 | 2 |
| B.A. 85 | 365 | 363 | 351 | 319 | 266 | 143 | 43 | 8 |
| B.A. 100 | 428 | 418 | 410 | 368 | 270 | 145 | 40 | 10 |
| Unthinned check | 698 | 690 | 638 | 536 | 381 | 176 | 43 | 8 |

intermediate. Early thinning retained a slight superiority down to the 'I-inch class, but when all trees 6 inches d.b.h. and larger were totaled, thinning initially at age 16 ranked first and thinning at age 10 ranked last.

The effect of thinning intensity on number of trees in the largest diameter classes is not clear, even where thinning started at age 10. Trends are evident for stocking of trees 7 inches d.b.h. and larger, with light thinning having more trees per acre than heavier thinnings. In terms of trees 6 inches d.b.h. and larger, plots thinned to 70 square feet of basal area had 24 to 33 percent fewer than plots cut to 100 square feet.

The unthinned checks had fewer 9- and lo-inch trees than did plots thinned at ages 10 and 13 years, but they equalled plots cut first at 16 years. For trees 8 inches and over, the checks were surpassed only by thinnings started at age 10. They excelled all thinning regimes in number of trees 7 inches and more in d.b.h.

Cutting records show that time and severity of thinning had no important influence on the number of larger trees removed (table 7). In d.b.h. classes of 6 inches and larger, deferred thinning and heavy cutting both removed more large trees per acre than light cuts made at earlier ages.

Table 7.—*Cumulative* number of ***trees*** harvested ***per acre between ages 10 to 16 years, by 1 -inch d.b.h. classes***

| **Age** at first cut, and stocking level | <4 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| | | | | *Number* | | | |
| **10 years** | | | | | | | |
| **B.A. 70** | **544** | **504** | **373** | **200** | **66** | **16** | |
| **B.A. 85** | **420** | **403** | **372** | **195** | **85** | **18** | **3** |
| **B.A. 100** | **475** | **450** | **362** | **204** | **74** | **12** | **2** |
| **13 years** | | | | | | | |
| **B.A. 70** | **490** | **475** | **405** | **248** | **65** | **25** | **5** |
| **B.A. 85** | **478** | **468** | **411** | **247** | **76** | **23** | |
| **B.A. 100** | **368** | **360** | **315** | **190** | **62** | **10** | |
| **16 years** | | | | | | | |
| **B.A. 70** | **428** | **428** | **393** | **271** | **128** | **23** | **5** |
| **B.A. 85** | **375** | **373** | **345** | **235** | **85** | **27** | **12** |
| **B.A. 100** | **310** | **305** | **287** | **190** | **95** | **35** | **8** |
| **Check** | | | | | | | |

# DISCUSSION

This study gives important information on the consequences of thinning slash pine plantations at various ages.

Age 10 years seems too early. Even though maximum diameter growth was obtained, many small trees-unprofitable to harvest—had to be removed. In addition, volume growth was reduced.

The choice between initiating thinning at age 13 or age 16 depends on the importance of stimulating diameter growth at the earliest practical age. Trees cut at age 13 will be larger than those removed at age 10, but only marginally profitable to harvest. And the value of added diameter growth must be weighed against a reduction in volume. Deferral to age 16 will sacrifice some diameter growth, but this will be offset by higher volume growth and by increases in sizes of trees cut.

For short pulpwood rotations there seems to be merit in leaving stands unthinned. Volume growth is good, no costs are incurred for marking, there are fewer small trees to harvest, and stand disturbances that may attract bark beetles are avoided.

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Three intensities of thinning, each started at 10, 13, and 16 years, were applied to slash pine planted on a highly productive, cutover site in central Louisiana. Over a 9-year period, early and heavy thinnings increased diameter growth but reduced volume growth. The longer initial thinnings were deferred, the slower was the response in diameter growth. Growth on unthinned plots was good.