IMPACT OF EARLY PRUNING AND THINNING ON LUMBER GRADE YIELD FROM LOBLOLLY PINE

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Abstract—The Sudden Sawlog Study was established in 1954 near Crossett, AR, in a 9-year-old loblolly pine plantation to test the hypothesis that loblolly plantations can produce sawtimber in 30 years. To stimulate diameter and height growth and clear wood production, study plots were heavily thinned, trees pruned to 33 feet by age 24 years, understory mowed, and growth of intensively managed trees compared with control trees. The study was officially closed at age 33 when it was reported that, with intensive management on good sites, loblolly pine can produce sawtimber-size trees in 30 years. The intensively managed and unpruned control trees were harvested in 2001 and the butt two logs of each tree sawn into lumber. At harvest, average diameter at breast height was 22.4 inches on plots receiving intensive treatments compared with 16.1 inches for controls. A portion of the intensively managed and control trees were sawn at a dimension sawmill and a portion sawn at a shop sawmill. Starting at age 9, trees were pruned every 3 years to one-half total height; by age 15 they were pruned to 20 feet and thinned to 100 trees per acre or less. These practices significantly increased the yield of high-grade lumber from butt logs sawn at the dimension and shop sawmills. Pruning every 3 years to one-half total height to 33 feet by age 24 and continued thinning resulted in a large-diameter knotty core in the second log that significantly reduced lumber grade. To reduce the diameter of this knotty core, when loblolly pine is thinned to < 100 trees per acre by age 15, crop trees should be aggressively pruned to 34 feet, either by frequent pruning or pruning to a shorter live crown of 33 to 40 percent with a minimum stem diameter of 2 inches at base of crown. To maximize lumber value, pruned logs should be sawn into shop lumber.

INTRODUCTION

To test the hypothesis that loblolly pine (*Pinus taeda* L.) plantations can produce sawtimber in 30 years, the Sudden Sawlog Study was established in 1954 near Crossett, AR (Burton 1982). The study was established in a 9-year-old loblolly pine plantation hand-planted in 1945 on an old cotton field at a spacing of 6 feet by 6 feet [1,210 trees per acre (TPA)]. The site index for the plantation was projected to be between 90 and 100 feet at age 50 years, and in 1954 average stocking was 1,100 TPA. The original objective of the study was "to determine whether a plantation on a good site (SI = 90) could be managed to produce good quality sawtimber on a short rotation by combining early thinning, understory vegetation control and pruning" (Baker and Bishop 1986).

To stimulate diameter growth, height growth, and clear wood production, researchers thinned study plots, controlled understory growth, pruned trees, and compared growth to control plots. The study imposed the following treatments.

- Sawtimber-only: all noncrop trees and all but 100 crop TPA were cut at age 9. Stands were thinned every 3 years thereafter to 76 TPA by age 19 and to 41 TPA at age 30
- Sawtimber-pulpwood: thinnings at age 9 and 12 removed noncrop trees with crowns within 5 feet of crowns of 100 crop trees. The last noncrop trees were removed at age 15. Continued thinnings at 3-year intervals left 80 TPA at age 19 and 52 TPA at age 30
- Sawtimber-delayed: stands were thinned to 100 crop TPA at age 12 and thinned every 3 years thereafter until 45 TPA remained at age 30
- Control: plots were thinned, mainly from below, to a basal area of 85 square feet per acre at age 12 and every 3 years afterward though age 30. The thinnings reduced stand density from 712 stems per acre at age 12 to 116 stems per acre at age 30.

The four treatments were installed on 0.25-acre plots and replicated three times in randomized blocks. Crop trees in the intensively managed sawtimber only, sawtimber pulpwood, and sawtimber-delayed plots were pruned from the ground to about one-half total height after the first thinning at age 9 and every 3 years afterward until clear length averaged 33 feet at age 24. The severity and timing of later thinnings were based on periodic growth in diameter at breast height (d.b.h.). Beginning at age 19, the woody understory was mowed every 2 years in the intensively managed plots.

Numerous researchers have published findings based on the Sudden Sawlog Study. Burton and Shoulders (1974) reported that at age 21 the saw log-only treatment produced the greatest sawtimber volume and lowest returns from thinnings. They also reported that the sawtimber-delay treatment produced the largest early return from thinnings and largest yield of sawtimber at age 27. However, if maximum fiber production was the objective, the control treatment would produce 35 to 66 percent more merchantable cubic volume through age 27 than any of the

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intensive treatments. At age 33, average d.b.h. was 17.1 to 18.0 inches in the intensive treatments compared with 12.3 in the controls; therefore, loblolly pine plantations can produce sawtimber on good sites in 30 years (Burton 1982). Burton (1982) also found that the intensive treatments' advantages over control in sawtimber yield to an 8-inch top rapidly diminished after age 30. Conventional saw-log yield from intensive treatments was six times that of control at age 24, 2.4 times at age 27, 2.3 times at age 30, and only 1.5 times at age 33.

The study was officially closed at age 33; however, thestands were never cut, and the trees were remeasured at ages 36, 39, and 45. At age 45, average Doyle board-foot volume per acre for all treatments was not significantly different (Baldwin and others 1998). However, the average d.b.h. of the trees that received the intense treatments (20.4 inches) was 38 percent larger than that of the control trees (14.9 inches). Baldwin and others (1998) reported that after 33 years, the control treatments led all other treatments in predicted financial returns, and throughout the study the controls produced the greatest cubic-foot volume. At age 45, basal area of the control trees was about 30 square feet per acre more than the sawtimber-pulp treatment (109 square feet) and 40 square feet per acre more than the sawtimber-only (98 square feet) and sawtimber-delay (102 square feet) treatments. At age 48, five trees were harvested from the saw log-only plots to examine the effect of intensive treatments on yield and quality of veneer (Groom and others 2002). Their results show the intensive plantation trees produced the lowest quality veneer, both in terms of visual and ultrasonic grade, when compared with veneer produced from 48-year conventional plantations, natural regeneration, and uneven-aged stands.

The objective of this study was to determine the impact of the sawtimber-only, sawtimber-pulp, sawtimber-delay, and control treatments on dimension and shop lumber grade yields produced from the Sudden Sawlog Study trees.

METHODS

In October 2001, at plantation age of 57, we harvested the remaining 167 Sudden Sawlog Study trees (table 1). The trees were felled using a saw-head feller buncher. A stratified random sample of seven trees per d.b.h. class from 12 to 20 inches for controls and from 20 to 26 inches for intensively managed trees were measured in detail. After felling, taper measurements were collected at 2-foot intervals from the butt to the tip on 8 sawtimber-only, 10 sawtimber-pulp, 12 sawtimber-delay, and 34 control trees. On trees measured in detail, diameter and location of dead and live branches were recorded for the butt 50 feet up the stem. Taper measurements were also collected at 2-foot intervals on the butt 33 feet on all trees not measured in detail.

Table 1—Average tree characteristics by treatment for 57-year sudden saw log loblolly pine harvested

	Treatment			
	Sawtimber			
Tree characteristics	Only	Pulp	Decay	Control
Trees harvested	23	34	33	77
D.b.h. (*inches*)	22.9	21.5	21.8	16.1
Total height (*feet*)	99	101	103	103
Form class	82	82	83	83
Sawlog volume (*cubic feet*)[a]	67.2	59.6	61.7	34.0

[a] Butt two saw logs only.

Two 16.4-foot saw logs were cut from the butt of each tree and identified by tree number and log number. The ends of each log were painted with a color-and-pattern combination to identify each log to tree and log position. A subsample, stratified by d.b.h. class of 30 trees harvested from intensively managed plots and 47 trees harvested from control plots, were sawn into dimension lumber at a conventional pine-band-dimension sawmill. The dimension mill produced 8 by 4 dimension lumber and 4 by 4 boards. A second subsample of 60 trees from intensively managed plots and 30 trees from control plots were sawn into shop lumber at a shop sawmill equipped with a band-head rig. The shop sawmill produced 5 by 4 shop or factory lumber, 4 by 4 boards, and 8 by 4 dimension lumber. After kiln drying and planning, the lumber was graded by certified lumber graders using rules of the Southern Pine Inspection Bureau (1994). Lumber was pencil-trimmed during grading to retain paint on the ends of each board in order to identify the tree and log from which the piece was sawn. The wholesale value of lumber produced from each tree was determined based on southern pine November 2002 average Random Lengths (Elmore 2002) prices. Lumber prices for radiata pine were used for southern pine molding grades. The value of each board was calculated based on its size, length, and lumber grade.

On the intensively managed crop trees, the d.b.h. and total height data collected every 3 years from age 9 through age 24 was used to estimate diameter of the knotty core. It was assumed that each tree was pruned to one-half of its total height every 3 years starting at age 9. Based on this assumption, taper functions were used to estimate the diameter outside bark at the base of the crown after each pruning lift using d.b.h. and total height as independent variables.

RESULTS

The d.b.h. of trees harvested from the intensively managed plots was 37 percent larger than that of the trees harvested from the control plots (table 1). Total height did not vary significantly among treatments and averaged 101 feet. Girard form class averaged 82 and did not vary significantly with treatment. The average small-end diameter of the logs processed in the dimension sawmill was similar to that of the logs processed in the shop sawmill (table 2). Board-foot volume of lumber produced per cubic foot of saw log input [lumber recovery factor (LRF)] for the dimension mill (8.4 board feet per cubic foot) was on average 18 percent higher than that of the shop mill (7.1 board feet per cubic foot). The shop sawmill had a lower LRF because it produced 57 percent 4 by 4 and 5 by 4 lumber, requiring more saw cuts and resulting in a higher proportion of each log being processed into sawdust (table 3). The dimension sawmill

Table 2—Average saw log small end diameter, cubic volume, board feet of lumber produced, and lumber recovery factor by treatment and log position for trees sawn in dimension and shop sawmills

	Intensively managed		Control	
Log characteristic	Butt log	Second log	Butt log	Second log
	Dimension sawmill			
Logs sawn (*no.*)	30	30	47	47
SED (*inches*)	18.5	17.3	13.4	12.4
Volume (*cubic feet*)	21.2	16.2	10.3	8.8
Lumber (*bf*)[a]	311	239	151	129
LRF (*bf/cubic foot*)	8.7	8.3	8.2	8.4
	Shop sawmill			
Logs sawn (*no.*)	60	60	30	30
SED (*inches*)	17.9	16.7	13.4	12.4
Volume (*cubic feet*)	18.9	16.2	11.1	9.0
Lumber (*bf*)[a]	220	199	136	114
LRF (*bf/cubic foot*)	6.5	7.3	7.1	7.4

SED = small end diameter; LRF = lumber recovery factor.
[a] Mill tally.

Table 3—Proportion of lumber produced by lumber thickness by treatment and log position for 57-year sudden saw log loblolly pine sawn at a dimension sawmill compared to a shop sawmill

Lumber	Intensively managed		Control	
thickness	Butt log	Second log	Butt log	Second log
inches	*percent*			
	Dimension sawmill			
4 by 4	3	1	1	0
5 by 4	0	0	0	0
8 by 4	97	99	99	100
	Shop sawmill			
4 by 4	7	7	29	26
5 by 4	65	47	28	18
8 by 4	28	46	43	56

averaged 99 percent 8 by 4 lumber and 1 percent 4 by 4 lumber. From the intensively managed trees sawn in the shop sawmill, the average LRF for butt logs was lower than that of the other logs because they produced 72 percent of their lumber in 4 by 4 and 5 by 4 boards.

The proportion of dimension lumber sawn into different lumber widths differed significantly between the intensively managed and control trees because of the significant difference in small-end diameter between treatments (table 4). The intensively managed trees sawn at the dimension sawmill produced on average 67 percent 2 by 12s and only 19 percent 2 by 10s, compared with the control trees that produced only 16 percent 2 by 12s and 53 percent 2 by 10s.

Table 4—Average distribution of lumber by lumber width by treatment and log position for 57-year loblolly sawn at a dimension sawmill

	Lumber width (*inches*)									
	Butt log					Second log				
Treatment	4	6	8	10	12	4	6	8	10	12
	percent									
Sawtimber only	1	3	8	24	64	5	2	9	27	57
Sawtimber pulp	3	2	7	16	72	6	1	6	19	68
Sawtimber delay	1	5	9	24	61	6	1	6	5	82
Control	4	7	17	56	16	3	10	21	50	16

Pruning to one-half of total height by age 15 resulted in the butt logs from intensively managed trees sawn in the dimension sawmill yielding a higher proportion of No. 1 & Btr and a lower proportion of No. 2 lumber than that of controls (table 5). Pruning to 33 feet by age 24, however, did not result in an increase in proportion of No. 1 & Btr lumber produced from the second log of intensively managed trees sawn in the dimension sawmill compared to that of controls. In fact, thinning the stand and pruning the second log yielded a significant decrease in proportion of No. 1 & Btr and increase in the proportion of No. 3 lumber compared with that of the unpruned controls. Pruning the second log at later ages after thinning resulted in a large-diameter knotty core in the second log (fig. 1). The average diameter of the knotty core was generally < 6.0 inches in the butt pruned log compared with 9.5 inches at the top of the second log. Thinning the intensively managed stands to < 100 TPA at

Table 5—Proportion of lumber produced by lumber grade by treatment and log position for 57-year sudden saw log loblolly pine sawn at a dimension sawmill

	Treatment			
	Sawtimber			
Lumber grade	Only	Pulp	Decay	Control
	- - - - - - - - - *percent* - - - - - - - - -			
Butt log				
C & D	3	3	2	1
No. 1 & Btr	56	72	62	54
No. 2	37	20	32	40
No. 3	4	4	3	3
No. 4	0	1	2	2
Second log				
C & D	0	0	0	0
No. 1 & Btr	7	8	11	16
No. 2	58	74	61	71
No. 3	35	15	26	10
No. 4	0	4	2	3

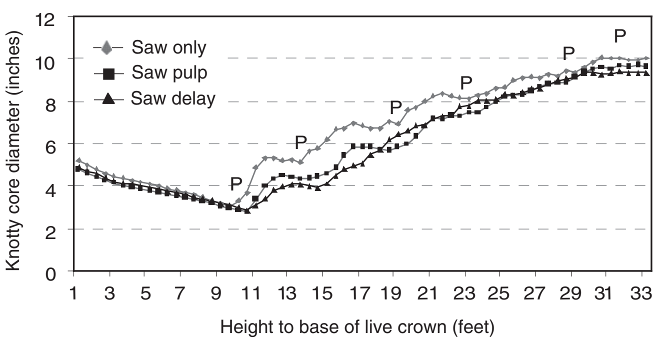

Figure 1—Average diameter of knotty core at base of live crown after pruning lift (P) by treatment for loblolly pine Sudden Sawlog Study trees.

age 15 and pruning to one-half of total height in 3-year intervals delayed crown closure and stimulated stem diameter and branch growth at the base of the crown, resulting in lower grade lumber in the second log.

Based on the literature, loblolly pine will respond well to release if the trees have a minimum diameter of 2 inches at the base of the live crown and > 20 percent live crown (McLemore 1987). Thus, to reduce the diameter of the knotty core, it appears that loblolly pine should be pruned as early as possible to 17 feet in the first lift and to 34 feet in the second lift. Pruning should occur as soon as the trees are large enough to maintain 33 to 40 percent live crown and have a diameter at the base of the live crown > 2 inches.

Although the objective of the Sudden Sawlog Study was to prune to a height of two 16-foot saw logs plus trim (Burton 1982), a few of the trees were apparently not pruned up to 33 feet on the intensively managed plots. Based on the live and dead branch data collected on 31 intensively managed trees, 13 of the trees had live branches at 31 feet (table 6). The average diameter of the knots in the second log was larger than the average diameter of the knots in control trees. The wide spacing of crop trees on the intensively managed plots stimulated branch growth in the third log. On average the third log of the intensively managed trees contained twice as many branches as that of the controls, and the branches were on average 50 percent larger in diameter. The average maximum size knot on the third log was > 70 percent larger on the intensively managed trees compared with the control trees.

The butt logs of intensively managed trees, sawn in the shop sawmill, produced on average 190 percent more of their lumber in molding-grade boards compared with the butt log of the controls (table 7). However, the control butt logs sawn in the shop sawmill yielded significantly more 4 by 4 C&D boards than the intensively managed trees. The butt logs of the intensively managed and control trees both yielded very little No. 3 or No. 4 lumber.

Table 6—Summary of live and dead knots by treatment and log position for 57-year sudden saw log loblolly pine trees

Log position	Logs sampled	Logs with knots	Knots per log	Average knot diameter	Average maximum knot diameter	Average height of knot
	- - - - - - - - - - - *no.*	- - - - - - - - - - -		- - - - - - *inches*	- - - - - -	*feet*
Intensively managed						
Butt	31	0	0	—	—	—
Second	31	13	2	2.3	2.4	31
Third	31	31	15	2.7	4.1	42
Control						
Butt	34	1	2	1.0	1.0	7
Second	34	8	1	1.5	1.5	31
Third	34	32	7	1.8	2.4	45

Table 7—Proportion of lumber produced by lumber grade by treatment and log position for 57-year sudden saw log loblolly pine sawn at a shop sawmill

Lumber grade	Treatment			
	Sawtimber			
	Only	Pulp	Decay	Control
	percent			
Butt log				
Molding	60	56	60	20
C & D	3	5	6	25
No. 1	8	20	11	16
No. 2	26	15	20	38
No. 3	3	4	3	1
No. 4	0	0	0	0
Second log				
Molding	15	10	16	7
C & D	6	5	6	13
No. 1	30	32	30	16
No. 2	19	26	28	53
No. 3	28	25	18	10
No. 4	2	2	2	1

Table 8—Average value of lumber per 1,000 board feet mill tally and 100 cubic feet of saw log by treatment and log position for 57-year sudden saw log and 57-year loblolly pine sawn at dimension and shop sawmills

Log position	Treatment			
	Sawtimber			
	Only	Pulp	Delay	Control
Dimension sawmill (*dollars per 1,000 board feet*)				
Butt	378 (14)[a]	386 (17)	371 (12)	331
Second	313 (1)	336 (9)	337 (9)	309
Shop *sawmill (dollars per 1,000 board feet*)				
Butt	816 (36)	806 (34)	818 (36)	600
Second	582 (28	544 (20)	591 (30)	455
Dimension sawmill (*dollars per 100 cubic feet*)				
Butt	338 (24)	337 (23)	320 (18)	272
Second	249 (-5)	282 (8)	284 (8)	262
Shop sawmill (*dollars per 100 cubic feet*)				
Butt	530 (24)	522 (22)	530 (24)	427
Second	428 (27)	409 (21)	414 (23)	337

[a] Percent difference from control.

The proportion of lumber sawn in the shop sawmill from the second log of intensively managed trees that graded molding or No. 1 was on average twice that of controls (table 7). However, the second log of intensively managed trees yielded on average only 24 percent in No. 2 compared with 53 percent for the controls and 24 percent in No. 3 compared with 10 percent for the controls. The significant reduction in proportion of No. 2 and significant increase in No. 3 lumber produced from the second log of intensively managed trees is the direct result of the large knotty core (fig. 1) and a few large unpruned branches at the top of the second log (table 6).

The wholesale value of lumber per 100 cubic feet of log input for butt logs from intensively managed trees sawn at the dimension mill was on average 22 percent higher than that of the controls (table 8). However, the lumber value per 100 cubic feet of log input for the second logs from the intensively managed trees increased an average of only 4 percent over that of the controls. The value of lumber per 100 cubic feet of log input was 13 percent lower for the second logs compared with that of the butt logs for the intensively managed trees sawn at the dimension sawmill. The value of lumber per 100 cubic feet for the second log was reduced because the large diameter of the knotty core increased production of No. 3 lumber from the second log.

The value of lumber produced per 100 cubic feet of log input for the intensively managed trees sawn at the shop mill was on average 23 percent higher than that of the controls for both the butt and second logs (table 8). The large knotty core in the second log of the intensively managed trees, however, reduced the value of lumber per 100 cubic feet of log input by 19 percent in the second log compared with the butt log.

The value of lumber per 100 cubic feet of tree input averaged $305 per 100 cubic feet for intensively managed trees sawn at the dimension sawmill or 14 percent higher than for the control trees ($267 per 100 cubic feet). The value of lumber per 100 cubic feet of tree input for intensively managed trees sawn at the shop sawmill averaged $477 per 100 cubic feet or 23 percent higher than the control trees ($388 per 100 cubic feet). The value of lumber per 100 cubic feet of tree input averaged 56 percent higher for intensively managed trees sawn at the shop sawmill compared with intensively managed trees sawn at the dimension sawmill.

SUMMARY AND CONCLUSIONS

Pruning every 3 years to one-half total height starting at age 9, to 20 feet by age 15, and thinning to 100 TPA or less by age 15 significantly increased the yield of high-grade lumber from butt logs. The intensively managed butt logs sawn at the shop sawmill produced 59 percent molding lumber compared with only 20 percent for that of the controls. The intensively managed butt logs sawn at the dimension sawmill yielded 63 percent No. 1 & Btr compared with 54 percent for the controls. The value of lumber per 100 cubic feet of log input was 23 percent higher for intensively managed butt logs sawn at the shop sawmill compared to controls and 22 higher for intensively managed butt logs sawn at the dimension sawmill compared to controls.

The Sudden Sawlog Study intensive treatments resulted in the greatest increase in lumber value when intensively managed butt logs were sawn at the shop sawmill. The average value of lumber from intensively managed butt logs sawn at the shop sawmill was $813 per 1,000 board feet or 115 percent higher than intensively managed butt logs ($378 per 1,000 board feet) sawn at the dimension sawmill.

Pruning every 3 years to one-half total height to 33 feet by age 24 and continued thinning resulted in a large-diameter knotty core in the second log that reduced lumber grade. The average value of lumber per 100 cubic feet of log input for intensively managed second logs sawn at the shop sawmill was 24 percent higher compared with controls. However, the value of lumber per 1,000 board feet from second logs was 42 percent less than that from the intensively managed butt logs. The average value of lumber per 100 cubic feet of log input for intensively managed second logs sawn at the dimension mill was only 4 percent higher than that of the controls, and the value of lumber per 1,000 board feet from second logs was 15 percent less than that of the intensively managed butt logs. Thinning to 53 TPA or less by age 30 and pruning to 33 feet by age 24 slowed crown closure and stimulated branch growth in the third log. Therefore, pruning only the butt 17 feet would probably stimulate growth of large branches in the second log and reduce lumber grade yield.

When loblolly pine is thinned to < 100 TPA by age 15, crop trees should be aggressively pruned to 34 feet either by frequent pruning or pruning to a shorter live crown of 33 to 40 percent with a minimum stem diameter of 2 inches at base of crown to reduce the diameter of the knotty core in the second log. To maximize lumber value, pruned logs should be sawn into shop lumber.

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