DENSITY AND GROWTH RING CHARACTERISTICS OF *PINUS TAEDA* L. FOLLOWING THINNING

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ABSTRACT

Sixteen experimental plots of loblolly pine (*Pinus taeda* L.) grown in plantations in Tennessee, USA, were thinned to basal areas of 13.8 m^2/ha (heavy), 23.0 m^2/ha (moderate), or 32.2 m^2/ha (light) in 1963 at age 23. In 1980 12-mm increment cores were removed at breast height, and sections encompassing 8 years before and after thinning were examined for changes in average wood density, radial growth, earlywood and latewood density, and percent latewood. As expected wood density increased with tree age but was not significantly affected by thinning, even though individual tree growth was considerably improved. Although radial growth usually decreases with age, it actually increased in the heavily thinned plots compared to the less severely thinned or unthinned (control) plots. Trees in the moderately and heavily thinned plots produced wood with lower earlywood density and higher latewood density while percent latewood remained unchanged.

The timber strength and seasoning characteristics related to wood density should not be affected by thinning. However, the shift within growth rings of earlywood and latewood density distributions may adversely affect pulping qualities of wood.

Keywords: Pinus taeda L., thinning, growth-ring characteristics, gamma densitometer.

INTRODUCTION

Silvicultural regimes applied to plantation stands of loblolly pine usually include thinning, which reduces competition and enhances tree growth. The forest manager's objective may be to produce larger diameter sawlogs but preferably not at the expense of wood properties that are closely related to end use.

Results of a thinning study established in 1963 in Hamilton County, Tennessee, USA, in plantations of 23-year-old loblolly pine showed that tree growth was enhanced following thinning, the largest increase in individual tree volume being found on the most heavily thinned plots. However, there was concern about the quality of the wood produced after plots were thinned. Earlier work on loblolly pine (Zahner and Whitmore 1960; Jackson 1968; Burton and Shoulders 1974)

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TABLE 1. *Average stocking of loblolly pine before and after thinning in 1963.*

Treatment level	Basal area (m^2æha)	Stem frequency (no./ha)	Volume (m^3/ha)
	Before thinning		
Heavy	35.8	2,026	264.3
Moderate	36.3	1,992	219.4
Light	35.9	1,641	234.0
Control (no thinning)	37.4	2,125	201.1
	After thinning		
Heavy	13.8	620	88.3
Moderate	23.0	1,109	148.2
Light	32.2	1,305	207.2
Control	37.4	2,125	201.1

found little change in specific gravity following thinning. Smith (1968) showed that thinning and pruning of 9-year old loblolly pine increased both specific gravity and percent latewood. Megraw and Nearn (1972) also observed that intensive silvicultural treatment (thinning and fertilization) of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] increased earlywood density and reduced latewood density; these authors further noted that such a shift in density distribution within growth rings would make this wood more desirable as pulp for producing paper.

The primary forest-management objective in the original Hamilton County thinning and growth study was to produce larger diameter sawlogs. Therefore, decreases in wood density or changes in within-growth-ring characteristics following thinning, which could adversely affect timber strength and seasoning characteristics would be undesirable. The purpose of the experiment reported here was to determine how the original (1963) thinnings affected average wood density, radial growth, earlywood and latewood density, and percent latewood of the loblolly pine over time.

MATERIALS AND METHODS

Original thinning and growth study

In 1940, loblolly pine seedlings were planted at about 2,965 trees/ha in Hamilton County, Tennessee. The study site is located on a moderate (2–12%) southeast slope. The predominant soil is a silty clay loam derived from high-grade dolomitic limestone. Soil internal drainage is medium. When uneroded, the surface soil, reddish brown and friable, is 15–25 cm thick. The subsurface soil, red and firm but friable, is about 1 m deep. The bedrock is generally >6 m deep. The site shows moderate to severe erosion with numerous old, stabilized gullies present. A few chert fragments may be present on the soil surface or throughout the soil profile. Average rainfall for the 8 years before thinning was 140 cm and for the 8 years after thinning was 129 cm.

In 1963, a study was established to examine the effects of thinning on tree growth. Experimental plots of approximately 0.04 ha each were heavily thinned (to a basal area of 13.8 m^2/ha), moderately thinned (to 23.0 m^2/ha), lightly thinned (to 32.2 m^2/ha), or left unthinned (control; basal area of 37.4 m^2/ha) (Table 1). All thinning was from below. The four treatments were incorporated into a randomized complete block design and were replicated four times.

TABLE 2. *Average growth of loblolly pine after thinning in 1963 and in 1972.*

Treatment level	Diameter at breast height	Height	Volume
	1963 (after thinning)		
	(cm)	(m)	(m^3/ha)
Heavy	17.5	16.2	88.3
Moderate	16.5	15.6	148.2
Light	16.2	15.5	207.2
Control (no thinning)	14.7	14.6	201.1
	1972		
Heavy	21.8	20.6	190.7
Moderate	19.3	20.5	274.2
Light	19.1	20.7	325.2
Control	17.5	19.6	308.1
	Increase (1963–1972)		
		%	
Heavy	25	27	116
Moderate	17	31	85
Light	18	34	57
Control	19	34	53

Diameter and height data were collected before and after thinning in 1963 and again in 1972. A volume prediction equation developed by Smalley and Bower (1968) was used for computing individual tree volumes and percent increases in diameter, height, and volume (Table 2). Analysis of the growth data showed that there were some site quality differences that were not totally removed by the block randomization procedure. There was a narrow band of trees in a riparian zone of an impounded river near the lower edge of the study site, resulting in microsites of above average site quality. The result was that plots assigned as controls tended to be of slightly poorer site quality than plots assigned to the thinning treatments.

Wood-quality study

Ten trees, selected to be free from disease and mechanical damage with a minimum of crook or sweep, were chosen for coring near the center of each of the original 16 plots. One 12-mm increment core per tree from pith to bark was extracted at breast height parallel to the land contour. In total, 160 cores were removed (10 trees/plot, 4 treatments, 4 replications).

Moisture content of the cores was equilibrated to laboratory conditions (6–8%). Cores were mounted between two blocks of wood so that strips approximately 1 mm thick could be cut radially from them with two parallel-mounted hollow ground circular saw blades in a fashion similar to that reported by Moschler and Woods (1975).

The 16-year period between 1956 and 1971—8 years before thinning (time 1), and 8 years after thinning (time 2)—was scanned with a gamma densitometer. The density-measurement system employed is a modification of one developed by Woods and Lawhon (1974) and is similar to the one used by Cown and Clement (1983) in New Zealand. Detailed descriptions of the equipment and calibration

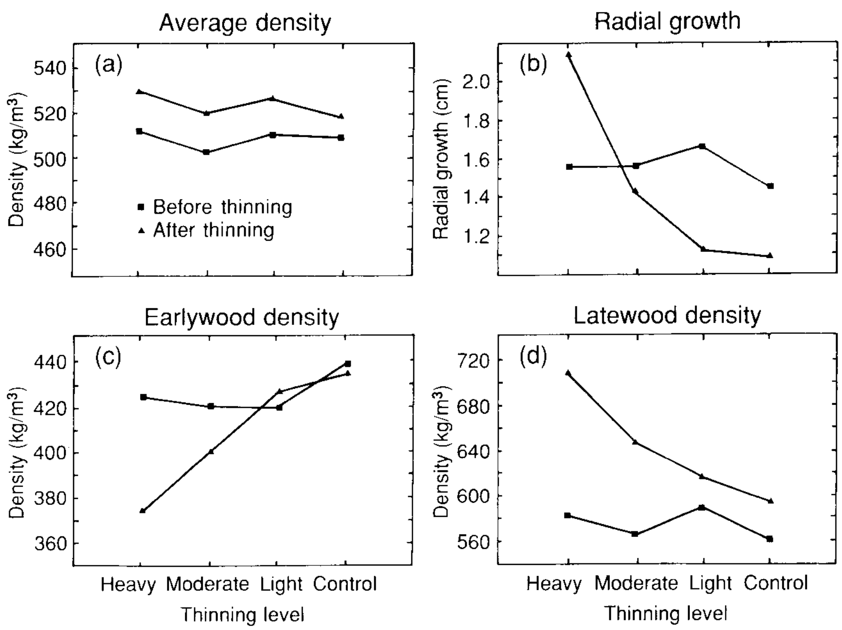

FIG. 1. (a) Average density, (b) radial growth, (c) earlywood density, and (d) latewood density of loblolly pine before and after thinning.

procedures may be found in Moschler and Dougal (1988) and Winistorfer et al. (1986).

For each 8-year period, the average density, radial growth, earlywood density, latewood density, and percent latewood were determined directly from the density scans. Average wood density was defined as the average of all density points from the scan of each 8-year period. Radial growth was defined as the average yearly growth in centimeters for each 8-year period. Earlywood and latewood densities were determined from a point selected in the areas of lowest and highest density, respectively; these values were then averaged for each 8-year period. Percent latewood was defined as the proportion of the growth ring with density values above the midpoint value. The transition zone from earlywood to latewood in loblolly pine is very steep; selecting the midpoint gives a value very close to that obtained from visually locating the latewood zone, as is done in many studies of this kind. Preliminary experiments in our laboratory showed each of the density determination values to give an unbiased estimate of its anatomically defined counterpart.

Analysis of variance was used to determine if the thinning levels significantly affected average density, radial growth, earlywood and latewood density, and percent latewood. F values were computed to test for significance of treatment and time. Where treatment effects were significant, means were compared using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Time significantly affected average wood density ($P < 0.01$, Table 3). Mean density for the 8 years before thinning (age 16–23) was 509 kg/m³, for the 8 years

TABLE 3. *Analysis of variance for growth-ring characteristics of loblolly pine.*[a]

Source of variation	Degrees of freedom	Mean squares[b]				
		Average density	Radial growth	Early-wood density	Late-wood density	% Late wood
Replication (R)	3	3.39	0.59	10.41	7.21	69.46
Treatment (Tr)	3	1.66	4.72*	19.53*	61.89	70.14
(R)(Tr)	9	4.65	0.74	4.48	24.14	92.71
Subsample (S) × (R)(Tr)	144	1.30	0.36	3.22	4.98	44.39
Time (Ti)	1	18.59**	1.83*	22.81**	367.38**	6.67
(Tr)(Ti)	3	0.31	4.54**	12.32**	42.72**	63.78
(R)(Ti) + (R)(Tr)(Ti)	12	0.62	0.17	1.17	3.19	25.10
Residual	144	0.25	0.11	1.00	1.65	15.99

[a] Thinned to three levels (heavy, moderate, light) or left unthinned (control); four replications; randomized complete block design.
[b] Density mean squares presented times 1,000.
* $P < 0.05$.
** $P < 0.01$.

after thinning (age 24–31) 525 kg/m³. This increase in density with age is expected for loblolly pine (Yandle 1956; Ralston and McGinnes 1964). In fact, average density at all thinning levels and for the control was greater for the second than the first 8-year period (Fig. 1a). However, the relation of average density to treatment was not significant (Table 3), indicating that thinning did not significantly change the wood density of loblolly pine. This result, which corresponds to that reported for this species by Jackson (1968), Burton and Shoulders (1974), and Taylor and Burton (1982), suggests that timber strength and seasoning characteristics—wood properties closely related to wood density—should not be adversely affected by thinning.

Time significantly affected radial growth ($P < 0.05$, Table 3). Mean radial growth for the 8 years before thinning was 1.56 cm, for the 8 years after thinning 1.45 cm. This decrease in radial growth with age is normally found in loblolly pine. The effects of treatment on radial growth and the treatment-time interaction also were significant (Table 3). Trees in the control and lightly thinned plots exhibited the expected decrease in radial growth with age (Fig. 1b). In these plots, more trees are competing for available soil moisture, nutrients, and light; therefore, individual tree growth is reduced. Trees in the moderately thinned plots slightly decreased in radial growth from 1.56 cm before thinning to 1.43 cm after thinning. This intermediate level of thinning reduced competition sufficiently to nearly maintain radial growth. Trees in the heavily thinned plots increased substantially in radial growth from 1.56 cm before thinning to 2.14 cm after thinning (Fig. 1b). Moreover, trees in the heavily thinned plots had significantly greater radial growth than did trees less severely thinned. These results are in agreement with those of Zahner and Whitmore (1960), Williston (1967), Jackson (1968), and Taylor and Burton (1982), all of whom found increased radial growth after thinning.

Mean earlywood density for the 8 years before thinning (425 kg/m³) was significantly greater than that for the 8 years after thinning (408 kg/m³), and the effect of treatment on earlywood density and the treatment-time interaction also were significant (Table 3). Earlywood density significantly decreased after heavy and moderate thinning but did not change after light or no thinning (Fig. 1c). In contrast, mean latewood density for the 8 years before thinning (576 kg/m³) was significantly lower than that for the 8 years after thinning (643 kg/m³). Latewood density increased after heavy and moderate thinning but did not change after light or no thinning (Fig. 1d). These results contrast with those reported for Douglas-fir by Megraw and Nearn (1972).

Percent latewood was not significantly affected by time or thinning level (Table 3). Taylor and Burton (1982) also concluded that the relationship between earlywood and latewood percent within a growth ring was not altered in mature wood following thinning. However, the same authors, along with Smith (1968), did find that percent latewood increased in the juvenile or core wood zone following thinning of loblolly pine at a young age in Crossett, Arkansas, USA. Evidence presented by Smith (1968) also suggests that earlywood density increased and latewood density decreased following thinning.

In conclusion, trees remaining after heavy, moderate, and light thinning produced wood whose average density did not differ from that of the control trees. Heavy thinning actually enhanced radial growth. Thus timber strength and seasoning characteristics, which are closely related to wood density, should not be affected by such thinning. Earlywood density decreased following heavy and moderate thinning, whereas latewood density increased—a shift in density distribution within growth rings that could adversely affect pulping qualities of wood. Generally, more uniform wood density across the growth ring is preferred because it yields improved paper properties (Megraw and Nearn 1972).

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REFERENCES

BURTON, J. D., AND E. SHOULDERS. 1974. Fast grown, dense loblolly pine sawlogs: A reality. J. For. 72(10):637–641.

COWN, D. J., AND B. C. CLEMENT. 1983. A wood densitometer using direct scanning with X-rays. Wood Sci. Technol. 17:91–99.

JACKSON, L. W. R. 1968. Effect of thinning on growth and specific gravity of loblolly and slash pine. Res. Pap. Ga. For. Res. Council No. 50. 6 pp.

MEGRAW, R. A., AND W. T. NEARN. 1972. Detailed dbh density profiles of several trees from Douglas-fir fertilizer/thinning plots. Proc. Symp. on the Effect of Growth Acceleration on the Properties of Wood. USDA For. Serv., Madison, WI, USA.

MOSCHLER, W. W., JR., AND E. F. DOUGAL. 1988. A calibration procedure for a direct scanning densitometer using gamma radiation. Wood Fiber Sci. 20(3):297–303.

———, AND F. W. WOODS. 1975. A note on the precision machining of increment cores. Wood Fiber 7(2):149–150.

RALSTON, R. A., AND E. A. MCGINNES, JR. 1964. Shortleaf pine wood density unaffected by ring growth. Southern Lumberman 208(7):17–19.

SMALLEY, G. W., AND D. R. BOWER. 1968. Volume tablets and point sampling factors for loblolly pines in plantations on abandoned fields in Tennessee, Alabama and Georgia highlands. USDA For. Serv. Res. Pap. SO-32.

SMITH, D. M. 1968. Wood quality of loblolly pine after thinning. USDA For. Prod. Lab. Res. Pap. FPL-89.

TAYLOR, F. W., AND J. D. BURTON. 1982. Growth ring characteristics, specific gravity, and fiber length of rapidly grown loblolly pine. Wood Fiber 14(3):204–210.

WILLISTON, H. L. 1967. Thinning desirable in loblolly pine plantations in West Tennessee. USDA For. Serv. Note No. SO-61.

WINISTORFER, P. M., W. G. DAVIS, AND W. W. MOSCHLER, JR. 1986. A direct scanning densitometer to measure density profiles in wood composite products. For. Prod. J. 36(11/12):82–86.

WOODS, F. W., AND W. T. LAWHON. 1974. Gamma densitometry of increment cores. For. Sci. 20(3): 269–271.

YANDLE, D. O. 1956. Statistical evaluation of the effect of age on specific gravity in loblolly pine. USDA For. Prod. Lab. Rep. No. 2049.

ZAHNER, R., AND F. W. WHITMORE. 1960. Early growth of radically thinned loblolly pine. J. For. 58(8):628–634.