Stand Structure and Yield Relationships in A 20-Year-Old Loblolly Pine Spacing Study

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ABSTRACT. A loblolly pine (Pinus taeda *L.) spacing study on a Piedmont site (SI 75, base age 25) had at age 20 a maximum yield of 49 cords per acre with a near maximum basal area of 187 square feet at a spacing of 8 × 8 feet. Comparative yields on the other spacings tested were: 6 × 6, 188 ft² and 43 cords; 10 × 10, 166 ft² and 45 cords; 12 × 12, 152 ft² and 43 cords. Sawtimber volume in trees larger than 9.5 inches in diameter rose from zero at 6 × 6 feet to almost 10,000 board feet per acre at 12 × 12 feet. Survival on the 6 × 6 plots was 71 percent; 8 × 8, 87 percent; 10 by 10, 92 percent; and 12 × 12, 93 percent.*

The effects of tree spacing on growth and yield of planted stands are major and continuing concerns of foresters. Spacing affects planting costs and influences the quantity and quality of wood produced. Choice of initial spacing depends on the number of trees desired at the time of first thinning or at harvest age if thinning is not planned, and the expected survival and the size of trees to be harvested. Economic considerations, management objectives, and biological growth relationships must be applied to these criteria to select the required spacing.

The biological factors that govern the interplay of tree and stand growth in relation to spacing are not well understood, and so empirical studies are still needed to provide comparative data to help guide spacing selection. One such trial of loblolly pine was established in January 1957 on the Calhoun Experimental Forest near Union in the Piedmont of South Carolina. Its purpose was to test the response of unthinned loblolly to different square spacings. A previous paper (Balmer *et al.* 1975) described the growth of the plots through age 15. This report presents data for the twentieth year.

METHODS

The site was a cotton field that had been abandoned the year before planting. The soil is of the Helena series and is characterized by a layer of sandy loam overlaying a compact mottled yellow and red clay. Site index (25-year basis) is approximately 75 (Clutter and Lenhart 1968).

Nursery-run seedlings obtained from the South Carolina Commission of Forestry were planted in 0.6-acre square plots arranged in a randomized block design. Four blocks were established, each consisting of one plot for each of four spacings: 6 × 6, 8 × 8, 10 × 10, and 12 × 12 feet. Trees that died during the first growing season were replaced at the end of the year with seedlings of the same stock that had been set out on the site at the time of planting.

Measurements of diameter at breast height (d.b.h.) were made at the end of the twentieth growing season on all surviving trees in the interior 8 × 8 rows of each plot. In addition, total height, height to base of live crown, and crown width were measured on two randomly selected trees from each 1-inch diameter class on each spacing plot. Cubic-foot volumes were calculated by the equations developed by Bailey and Clutter (1970) for old-field loblolly in the Georgia Piedmont. Board-foot volumes (International ¼ inch rule) were determined for all trees of merchantable size (d.b.h. 9.6 and larger) by the equation of Burkhart *et al.* (1972).

RESULTS

Survival

At age 20, survival on individual plots ranged from 67 to 95 percent. Survival increased markedly from 6 × 6 to 8 × 8 spacing, somewhat less to the 10 × 10, but showed no real increase to the 12 × 12 (Table 1). The cause of most mortality appeared to be natural competition. Although it is possible that fusiform rust also played a part, the overall infection rate has been rather low (Table 1).

Tree Size

Average stand diameter and average and dominant height increased as spacing increased (Table 1). Average diameter on the 12 × 12 plots was 3.6 inches greater (58 percent) than the diameter on the 6 × 6 plots.

Average stand height increased about 2 feet with each increase in spacing from 6 × 6 to 12 × 12 feet. The difference in height between the closest and widest spacings was almost 6 feet. Dominant heights were affected to a lesser extent, the difference between the spacing extremes being about 2 feet (Table 1). Five-year change in average height was about 10 feet for the 6 × 6 and 12 × 12 plots and about 8 feet for the 8 × 8 and 10 × 10 plots (Table 2).

Table 1. Some average stand parameters at age 20.

Stand variable	Planted spacing, ft.			
	6×6	8×8	10×10	12×12
Trees/acre				
Planted	1,210	680	436	302
Surviving	855	590	402	281
Percent	71	87	92	93
Mean d.b.h., in. all trees	6.2	7.5	8.6	9.8
Mean height, ft. all trees	54.6	56.5	58.3	60.5
Dominant height, ft.	61.3	60.8	62.4	63.4
Height to base of crown, ft.	40.8	40.4	40.9	38.6
Crown width, ft.	6.5	7.6	9.8	12.6
Crown length, ft.	13.8	16.1	17.4	21.9
Crown ratio, %	25	29	30	36
Stem fusiform, %	3	6	7	9

Crown length and the ratio of crown length to total tree height increased as spacing widened. Height to the base of the live crown, however, averaged about 40 feet regardless of spacing. This indicates that the increases in crown length and crown ratio with wider spacing are due primarily to the faster height growth in the wider spacings. The magnitude and the uniformity of the height to the base of the crowns across spacings also indicates that effective crown closure had occurred some years earlier on all plots (Table 1).

Crown width also increased as spacing widened. At age 20, average crown width for each spacing approximately equaled the distance between trees at planting.

The diameter distribution by 1-inch classes for each spacing at age 20 is shown in Table 2. Only the 6 × 6 spacing still had an appreciable number of nonmerchantable trees, 71 trees per acre being less than 4.6 inches in d.b.h. All spacings except the 6 × 6 had 40 or more trees of sawtimber size, 9.6 inches in d.b.h. and larger. The 12 × 12 spacing had 29 trees 12 inches and larger in d.b.h.

Yield

Basal area and cubic yields by 1-inch diameter classes for age 20 and totals for ages 15 and 20 are shown in Table 2. Net increment for the period is also given.

Greater basal area was directly associated with closer spacing at age 15. By age 20 however, basal area leveled off as spacing decreased to 6 × 6 feet. This spacing had only 1.5 square feet per acre more than the 8 × 8. The increment in basal area between ages 15 and 20 decreased as spacing decreased, dropping from a high of 27 square feet per acre for the 12 × 12 and 10 × 10 to only 14 square feet per acre for the 6 × 6.

Both total and merchantable volumes showed much the same relation to spacing as did basal area except that maximum values were reached in the 8 × 8 spacing, with amounts falling off at both closer and wider spacings. Merchantable volume was practically the same for the 6 × 6 and 12 × 12 spacings, but only 84 percent of the total volume was merchantable in the 6 × 6 compared to 94 percent in the 12 × 12.

Growth in total volume decreased as spacing decreased, but merchantable volume growth remained about the same over all four spacings. Growth was slightly more than 1,000 cubic feet per acre for the 5-year period, an average of 200 cubic feet (2.8 cords) per acre per year.

At age 15 only the 12 × 12 had sawtimber volume; less than 2,000 board feet per acre (International ¼ inch scale) (Balmer *et al.* 1975). At age 20 all but the 6 × 6 had sawtimber. The 8 × 8 had 1,830 board feet; the 10 × 10, 4,479

Table 2. Stand structure per acre at age 20, by spacing.

1-inch diameter class	Stand characteristic					
	No. of trees	Average height[1] (ft)	Basal area (ft^2)	Total volume[2] (ft^3)	Merch. volume[3] (ft^3)	No. of cords[4]
			Per acre *6 × 6 Spacing*			
3	5	36	0.3	4	0	0
4	66	45	6.2	100	0	0
5	208	51	29.6	541	408	5.6
6	236	54	47.6	925	774	10.7
7	213	57	57.4	1,164	1,028	14.3
8	99	59	34.1	717	654	9.1
9	28	62	13.0	284	265	3.7
10	—	—	—	—	—	—
11	—	—	—	—	—	—
12	—	—	—	—	—	—
13	—	—	—	—	—	—
20-yr total	855	55	188.2	3,734	3,130	43.4
15-yr total	1,011	45	174.3	2,847	2,104	29.2
5-yr growth	−156	10	13.9	887	1,026	14.2
			Per acre *8 × 8 Spacing*			
3	—	—	—	—	—	—
4	5	41	0.6	9	0	0
5	51	48	7.3	128	96	1.3
6	98	53	20.1	380	318	4.4
7	133	57	35.8	718	634	8.8
8	167	59	58.7	1,231	1,124	15.6
9	96	61	42.6	929	868	12.1
10	40	63	21.6	492	466	6.5
11	—	—	—	—	—	—
12	—	—	—	—	—	—
13	—	—	—	—	—	—
20-yr total	590	56	186.7	3,887	3,505	48.7
15-yr total	638	49	165.4	2,901	2,481	34.5
5-yr net growth	−48	7	21.3	986	1,024	14.2

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board feet; and the 12 × 12, 9,725 board feet per acre.

DISCUSSION

The trends among spacings in this study are similar to those reported for other spacing studies for loblolly pine (Campbell and Mann 1974, Shepard 1974, and others): Close spacings favor maximum total cubic-foot volume yield, and wide spacings favor larger diameters and early sawtimber production at the expense of some cubic-volume production. In this study, at age 20 as it was at age 15, the 8 × 8 spacing had the best yield for both total and merchantable cubic-foot volume. The efficiency of volume production may be judged from the percentages of trees and total volume that are merchantable. For the 8 × 8 spacing, 86 percent of the original number of trees planted and 90 percent of the total volume were merchantable at age 20. In contrast, on the 6 × 6 plots only 65 percent of the original number of trees and 85 percent of the total volume were merchantable. Unless a forest manager could reasonably expect a future market for small-tree material (less than 4.6 inches d.b.h.), the 6 × 6 should not be the recommended spacing for loblolly pine under conditions similar to those for this study. Wider spacings such as 8 × 8 or 10 × 10 promote both pulpwood and sawtimber production, utilization of all trees surviving, and an early return from thinning. Although the 12 × 12 is the most favorable spacing for sawtimber growth

Table 2. (*Continued*)

1-inch diameter class	Stand characteristic					
	No. of trees	Average height[1] (ft)	Basal area (ft^2)	Total volume[2] (ft^3)	Merch. volume[3] (ft^3)	No. of cords[4]
	Per acre					
	10 × 10 Spacing					
3	—	—	—	—	—	—
4	—	—	—	—	—	—
5	5	44	0.8	12	9	0.1
6	17	50	3.5	64	53	0.7
7	59	55	16.5	322	284	3.9
8	99	58	35.0	720	657	9.1
9	128	61	57.5	1,236	1,155	16.0
10	75	63	40.2	887	840	11.7
11	17	64	11.0	247	236	3.3
12	0	—	0	0	0	0
13	2	67	1.6	37	36	0.5
20-yr total	402	58	165.9	3,525	3,270	45.3
15-yr total	417	50	139.0	2,506	2,235	31.0
5-yr net growth	−15	8	26.9	1,019	1,035	14.3
	Per acre					
	12 × 12 Spacing					
3	—	—	—	—	—	—
4	1	31	0.1	2	0	0
5	2	41	0.4	5	3	0
6	2	47	0.5	10	8	0.1
7	12	52	3.1	58	52	0.7
8	29	56	10.5	203	184	2.5
9	60	58	27.1	567	529	7.3
10	83	61	45.6	976	923	12.8
11	63	62	41.2	921	881	12.2
12	22	64	17.2	402	388	5.4
13	7	65	6.4	147	143	2.0
20-yr total	281	60	152.1	3,291	3,111	43.0
15-yr total	287	50	124.2	2,246	2,062	28.1
5-yr net growth	−6	10	27.9	1,045	1,049	14.9

[1] *Height average by diameter class.*
[2] *Total volume = Inside bark, all trees.*
[3] *Merchantable volume = Inside bark, all trees 4.6 inches d.b.h. and larger to 4-inch top outside bark.*
[4] *1 cord = 72 cubic feet of solid wood.*

in this study, there is a 12-percent reduction in pulpwood yield at age 20, compared with the 8 × 8. It would seem that the 12 × 12 spacing has not made maximum use of the site up to age 20.

As a practical matter, both the 6 × 6 and 8 × 8 spacings could be profitably thinned to open up the stands to give the small crowns, especially on the 6 × 6, a chance to rebuild and diameter growth to increase. Cutting about one-third of the basal area from both spacings in a low thinning would remove about 45 percent of the trees in 15 cords from the 6 × 6, and about 30 percent of the trees in 16 cords from the 8 × 8. This would leave a residual basal area of 125 square feet. Maximum total volume growth from age 15 to 20 was made by the 12 × 12 spacing with a basal area at age 15 to 124 square feet. The 10 × 10 and 12 × 12 spacings should probably not be thinned yet unless crop trees are to be selected and pruned to promote production of clear wood in anticipation of a sawtimber harvest.

No final judgments leading to a choice of one spacing over another can be made from a single set of plots such as these. However, the data in Table 2 merit close study for they show in considerable detail the relative gains and losses in numbers of trees and in growth and yield that are associated with different spacings. As such, the data should provide a useful basis for planning plantation establishment on similar Piedmont sites.

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Continuing Education Needs Of Foresters

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ABSTRACT. The purpose of the study was to determine the continuing education needs of professional foresters in Georgia. Data were obtained via questionnaires from 257 SAF affiliate foresters concerning their age, level of education, experience, sex, occupation, preferred time of year to attend continuing education activities, and the amount of time available for such activities. Updating needs in silviculture, forest harvesting, forest mensuration/biometrics, forest recreation, forest management, forestry and the law, and communications in forest resources were also solicited. The typical respondent was 25 to 34, male, had more than 10 years' experience, held an undergraduate degree, was employed in private industry or business, and preferred January, February, June, July, and August as times of the year to attend continuing education activities. All topics in the areas of silviculture, forest harvesting, and forestry and the law were high in interest. Topics of least interest were regression-modeling techniques, cruising methods, surveying, fire protection, urban forestry, and designing communications programs. Also of little interest were topics in the area of forest recreation, except wildlife habitat modification.

To be effective in his work, the professional forester, like any other professional, must keep up to date or become obsolete. This requires continuous upgrading in knowledge and skills and the vehicle for accomplishing this is continuing education.

To assist the forester in keeping up to date professionally, the Council on Continuing Education for Foresters was formed at the University of Georgia in 1970. The Council consists of representatives from federal, state, and private forestry organizations and identifies continuing education needs of foresters and develops short courses, seminars, and conferences to meet those needs. This study was conducted under the auspices of the Council.

The purpose of the study was to determine the continuing education needs of professional foresters in Georgia. Part I of the questionnaire used was designed to obtain information about the respondents' age, level of education, experience, occupation, sex, maximum number of consecutive days per year the forester could be away from his work to attend a seminar, and the best time of year to attend such a course. Part II was concerned with information about upgrading needs in selected areas of forestry to include silviculture, forest harvesting, forestry and the law, forest recreation, forest mensuration and biometrics, communications in forest resources, and forest management. Subsumed under each of these broad areas were specific topics to which they were asked to respond in terms of *Don't Need, Would Help, Must Have,* or *Already Have.* Definitions of each of these terms are as follows.

Don't Need—Unnecessary for reaching professional goals
Would Help—Helpful in reaching professional goals
Must Have—Mandatory for reaching professional goals
Already Have—Already have sufficient knowledge

Questionnaires were sent to 755 SAF affiliate foresters in the state. Thirty-four percent returned correctly filled out questionnaires; the respondents