Five-Year Effects from ROW THINNINGS *in Loblolly Pine Plantations of Eastern Maryland*

by S. Little and J. J. Mohr

U. S. FOREST SERVICE RESEARCH PAPER NE-12
1963

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

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YOUNG stands of loblolly and pond pine on Maryland's Eastern Shore ordinarily grow rapidly for the first 15 to 20 years, but then slow down as competition among the dominant trees increases. Similar decreases in growth apparently occur in both plantations and well-stocked natural stands.

Conventional thinnings, removing scattered stems, are not very practicable in such 15- to 20-year-old stands. Too much time is required to select crop trees and mark other trees for cutting. Since many of the trees that should be cut either are unmerchantable or contain only one to three sticks of pulpwood, marking costs must be held down if thinning operations are to break even financially. Moreover, the stand densities of 800 to 1,000 pines per acre make conventional thinnings difficult because many of the cut trees lodge, and the merchantable ones, when down, still are difficult to remove.

Cutting all the trees in selected rows in plantations, or in lanes through natural thickets, would bypass most of these difficulties. Once the appropriate interval between cut rows or lanes was determined, supervision costs would be greatly reduced. Even if each plantation or stand had to be considered separately for deciding upon interval widths, marking costs still would be far less than in conventional thinnings. Felling and removal costs would also be appreciably less: trees could be felled progressively in the row so that there would be little lodging, and unmerchantable trees and slash could be rolled or dragged to one side, thus opening lanes for removing the pulpwood.

However, there are several questions besides economic feasibility that need to be answered before row thinning can be recommended for loblolly pine stands. These include:

- Will automatic spacing remove too many of the better trees and leave too few good-quality crop trees?
- Will row thinning result in significant increases in wind or snow damage?
- What effect will row thinning have on growth and yield? What row interval is best from the standpoint of (1) quality and number of crop trees left, and (2) growth of these trees and of the stand as a whole? Will such thinning result in the development of trees that are suitable only for sawtimber, but not suitable for piling?

To answer these questions, the Maryland Department of Forests and Parks and the Northeastern Forest Experiment Station of the U.S. Forest Service started a study of row thinnings in 1954. The first 5-year results are described in this report.

The Study

The study areas were in four similar adjoining stands, ranging from 3.0 to 5.2 acres each, in the Wicomico State Forest. The overstory of each stand was composed chiefly of loblolly pines planted at 6- by 6-foot spacing about 1938, plus varying numbers of volunteer pines.

Four treatments were tried: cutting (1) every other row of trees, (2) every third row, (3) every fourth row, and (4) every fifth row. In some places (mostly in the plots where the first and last treatments above were applied), volunteer pines were so numerous that rows could not be distinguished, and the treatment specifications had to be modified. The following procedures gave a fairly close approximation to the desired degrees of stand opening: for the first treatment, strips 6 feet wide were cut and alternate strips of equal width were left uncut; for the last (every-fifth-row) treatment, strips 10 feet wide were cut and the alternate uncut strips were 20 feet wide.

One of the treatments was applied in each of the four stands. Areas actually treated ranged from 1.5 to 2.6 acres, or about half of the total stand in each instance. The remaining half of each stand served as a check or control area. The specified cutting, including removal of the products, was done between late July 1954 and January 1955.

In studying treatment effects, two approaches were used: (1) comparison of individual tree responses, and (2) comparison of overall stand responses.

Primary emphasis was placed on the responses of individual trees by crown classes. In each of the four check areas, 20 trees of each of three crown classes (dominant, codominant, and intermediate) were selected and tagged, and a like number was similarly selected in each crown class from the released stems in each stand. Also, in the two treatments where every fourth or every fifth row was cut, 20 additional trees were selected in each crown class from the center one or two rows that, for all practical purposes, remained unreleased. Thus, in all, 600 trees were selected and tagged: 240 trees in check areas, 240 trees definitely released by the treatments, and 120 unreleased trees in the treated areas. For each tagged tree, diameter (b.h.) to the nearest 1/10 inch, total height, and length of living crown were measured.

To obtain some stand data, five 0.5-acre plots were established, one under each treatment, and one in a check area. In these plots all stems larger than 0.5 inch d.b.h. were tallied by 1-inch diameter classes and species. In addition, 75 pine crop trees were selected in each plot, marked with paint, and tallied separately. Crop trees were selected on the basis of both tree quality (dominance, form, and vigor) and spacing.

Results

MORTALITY

Row thinning had relatively little effect on mortality during the first 5 years. Both among sample trees and in entire stands, somewhat fewer pines died in most of the treated areas than in the check areas; moreover, somewhat fewer trees died under the heavier thinnings than under the lighter ones. However, the differences were rather small: from 18 percent mortality among all residual pines in the every-other-row treatment up to 30 percent where every fifth row had been removed. Average mortality in the check plot where stand data were taken was 25 percent.

Among sample trees the mortality was considerably lower—only 4.5 percent—because this group did not include overtopped stems. Most of the deaths occurred in the intermediate crown class. A somewhat higher proportion of unreleased intermediate trees died in plots where every fourth or fifth row was cut than in check areas or among released trees.

Table 1.—*Effect of row thinning on average 5-year diameter growth per tree, by crown classes*[1]

Treatment, row cut	Area	Dominant trees	Codominant trees	Intermediate trees
		Inches	*Inches*	*Inches*
Every other row	Treated	1.4	1.2	0.6
	Check	1.0	0.9	0.2
Every third row	Treated	1.3	1.0	0.6
	Check	1.1	0.8	0.3
Every fourth row	Treated: released	1.2	0.7	0.4
	Treated: unreleased[2]	1.1	0.6	0.4
	Check	0.9	0.6	0.2
Every fifth row	Treated: released	1.2	0.9	0.4
	Treated: unreleased[2]	1.1	0.7	0.4
	Check	1.1	0.7	0.4

[1] Crown classes before thinning.

[2] Trees in center of uncut strips, hence not released.

Wind and snow damage did not affect mortality in these plots, even though wet snows during the winter of 1957-58 injured trees in younger plantations (2). And although Hurricane Hazel in October 1954 and Hurricanes Connie and Diane in August 1955 occurred soon after the thinning, the accompanying high winds did not appreciably affect the thinned stands—possibly because the plots are on a flat site and are surrounded by other forest stands.

BASAL-AREA AND DIAMETER GROWTH

Sample-Tree Data

Cutting every other row caused the greatest stimulation of growth among the residual sample trees—0.3 to 0.4 inch more diameter growth in thinned than in check trees in all crown classes during the 5-year period (table 1). Among the sample trees released by cutting every third row, the increased growth was 0.2 to 0.3 inch; by cutting every fourth row, 0.1 to 0.3 inch; and by cutting every fifth row, 0.0 to 0.2 inch.

Although diameter-growth increases were not markedly different among crown classes, growth increases in terms of basal area were considerably greater in the larger, dominant trees than in the smaller codominants and intermediates. Where every other row was cut, the basal-area increases were 0.0488, 0.0249, and 0.0243 square feet for the three crown classes, respectively (table 2).

In the strips left after cutting every fourth or fifth row, the interior unreleased trees showed hardly any response to thinning (tables 1 and 2).

The statistical analysis began with isolation of the important independent variables affecting diameter increment. First considered were the continuous independent variables—that is, the independent variables other than thinning treatment and crown class. These were: original (1954) stem diameter, original crown length, original stem length to base of live crown, original crown ratio (live-crown length as percent of total height, expressed as a whole number), squared values of each of the above variables, and simple interactions among them.

Table 2.—*Effect of row thinning on average basal area growth per tree, by crown classes*

Treatment, row cut	Area	Dominant trees	Codominant trees	Intermediate trees
		Square Feet	*Square Feet*	*Square Feet*
Every other row	Treated	0.1357	0.0925	0.0402
	Check	.0869	.0676	.0159
Every third row	Treated	.1144	.0798	.0317
	Check	.0962	.0697	.0184
Every fourth row	Treated: released	.0994	.0552	.0268
	Treated: unreleased	.1025	.0464	.0215
	Check	.0803	.0494	.0126
Every fifth row	Treated: released	.1105	.0687	.0243
	Treated: unreleased	.1022	.0584	.0268
	Check	.1077	.0604	.0184

Data for all sample trees in terms of the above variables were subjected to regression analysis. Original diameter, crown ratio, and their interaction proved to be most significant. The equation obtained from this analysis was:

Diameter increment (inches) = 0.312 (d.b.h.) + 0.049 (crown ratio) — 0.0043 (d.b.h. × crown ratio) — 2.00

For this equation, the standard error was 0.28, and the coefficient of multiple correlation was 0.74. The first two terms in the equation simply indicate that diameter increment is positively related to d.b.h. and crown ratio. However, the minus interaction term reveals that diameter increment tends to level off as d.b.h. and crown ratio get larger and larger.

In preparation for an overall covariance analysis, the sample tree data were divided into 7 thinning-treatment classes and 3 crown classes—a total of 21 treatment-crown class combinations. The 7 treatment classes include separate listings for released and interior trees in the every-fourth- and every-fifth-row thinnings. Of the continuous variables tested as covariates, only d.b.h. and crown ratio were important. The interaction term, which had proved significant in the regression for all sample trees, dropped out of the picture when the data were subdivided into treatments and crown classes. The regression coefficients did not differ significantly among treatment-crown class groups. However, the elevation terms or treatment-crown class values did differ. Thus, the following equation was derived:

Diameter increment (inches) = 0.0756 (d.b.h.) + 0.0126 (crown ratio) + (treatment-crown class value)

The treatment-crown class values for the above equation were as follows:

Treatment	*Dominant trees*	*Codominant trees*	*Intermediate trees*
Thinned every other row	+0.34	+0.19	—0.08
Thinned every 3rd row	+0.24	+0.05	—0.29
Thinned every 4th row	+0.07	—0.17	—0.33
Thinned every 5th row	+0.08	—0.16	—0.45
Unreleased in thinning:			
Every 4th row	—0.01	—0.27	—0.50
Every 5th row	—0.03	—0.21	—0.58
Check trees	—0.09	—0.22	—0.53

For this equation, the standard error was 0.22 inch, and the coefficient of multiple correlation was 0.86. Note that this equation is somewhat more precise than the one developed without consideration of thinning treatment and crown class.

The treatment-crown class values indicate the relative position of the curve of diameter increment over d.b.h. and crown ratio for each combination of thinning treatment and crown class. Note that the position of the curve drops rather consistently with decreasing thinning intensity and with decreasing tree dominance. To predict diameter increment for a tree, it is only necessary to insert the appropriate d.b.h., crown ratio, and treatment-crown class value into the equation and make the necessary computations. This procedure will illustrate that the treatment-crown class values are measures of the differences among treatments and crown classes in predicted diameter increment. For example, for any given d.b.h. and crown ratio, the predicted increment of released dominant trees is 0.10 inch greater under every-other-row thinning than under every-third-row thinning: it is 0.17 inch greater under the latter treatment than where every fourth row was removed, and so on.

Adjusted means were computed for each treatment-crown class combination. This technique eliminates the effects of initial differences among trees in d.b.h. and crown ratio. Comparisons of adjusted means among crown classes were not considered realistic because trees in the upper crown classes naturally have larger diameters and higher crown ratios than trees in the lower crown classes. However, comparisons of adjusted means among thinning treatments revealed some meaningful differences that were not evident in table 1. Of most importance, the difference in average growth of released trees between every-other-row and every-third-row treatments became 0.10 inch for dominants, 0.14 inch for codominants, and 0.21 inch for intermediates, as compared to the 0.1-, 0.2-, and 0.0-inch respective differences between means in table 1. Thus, every-other-row thinning favored the intermediate crown class more than the unadjusted means in table 1 indicate. In the unadjusted means, this effect of the more intensive thinning is obscured by differences among treatment plots in average d.b.h. and crown ratio of the intermediate trees.

An analysis of variance and orthogonal comparisons of unadjusted means were used to determine the significant differences among crown classes and treatments. The results show that:

- Diameter increment differed significantly among crown classes.
- The thinnings increased diameter increment significantly.
- Release on two sides of a tree, or every-other-row thinning, increased this increment significantly more than when trees were released on one side.
- Trees released on one side by cutting every third row grew significantly more than those released by cutting every fourth or fifth row. There was no significant difference between the last two treatments.
- The diameter increment of unreleased trees in the strips left after cutting every fourth or fifth row did not differ significantly from that of trees in the control plots.

A separate analysis indicated a significant difference between the growth of released trees from cutting every fourth or fifth row and that of trees in the control plots. All significant differences mentioned above were at the 1-percent level.

Stand Data

Stand records indicated treatment responses similar to those shown by the individual sample trees. Cutting every other row resulted in by far the greatest net gain in basal area—double that from cutting every third row (table 3). The control and the other two treatments had small net losses, that is, less basal area in 1959 than in 1954. However, their 1954 basal-area values were comparatively high—113 to 171 square feet per acre.

If mortality and the slow growth of small pines are ignored, the differences among treatments are smaller. For example, crop trees in the every-other-row cutting did grow the fastest in basal

Table 3.—***Basal areas per acre for all pines and for crop trees only, by treatments***

Treatment, row cut	All pines			Crop trees		
	1954	1959	Change	1954	1959	Change
	Sq.Ft.	*Sq.Ft.*	*Sq.Ft.*	*Sq.Ft.*	*Sq.Ft.*	*Sq.Ft.*
Every other row	76.2	89.5	+13.3	36.2	49.9	+13.7
Every third row	108.0	114.6	+ 6.6	35.1	48.0	+12.9
Every fourth row	121.7	118.9	− 2.8	38.3	47.2	+ 8.9
Every fifth row	112.8	109.2	− 3.6	42.0	50.8	+ 8.8
None (check)	171.1	169.8	− 1.3	40.2	50.0	+ 9.8

area (table 3), but were followed so closely by those in the every-third-row cutting that diameter growth computed to the nearest 1/10 inch was the same (table 4). In the other two treatments, crop trees grew somewhat more slowly than in the check area (tables 3 and 4).

Table 4.—*Average diameter of all pines and of crop trees only, by treatments*

Treatment, row cut	All pines			Crop trees		
	1954	1959	Change	1954	1959	Change
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Every other row	5.5	6.6	+1.1	6.6	7.8	+1.2
Every third row	5.6	6.5	+0.9	6.6	7.8	+1.2
Every fourth row	5.8	6.7	+0.9	6.8	7.7	+0.9
Every fifth row	5.7	6.7	+1.0	7.2	7.9	+0.7
None (check)	6.0	6.9	+0.9	7.0	7.9	+0.9

When all pines are considered, the 5-year changes in average diameter were similar in all treatments—between 0.9 and 1.1 inches (table 4). However, among crop trees, the most drastic treatments produced about 0.3 inch more diameter growth in the 5-year period than occurred in the check plot—a response comparable to that shown by the sample trees.

CROWN RATIOS

Original live-crown ratios in 1954 ranged from 39 percent (of total height) for dominants, to 35 percent for codominants, to 29 percent for intermediates. Average lengths of live crown were 17.7, 15.1, and 11.1 feet, respectively.

Crown ratios of sample trees in the check areas decreased slightly—by an average of 2 percentage points—during the 5-year study period. Crown ratios of the interior unreleased trees in the strips left after cutting every fourth or fifth row underwent practically no change during this period.

For all released sample trees collectively, crown ratios increased by an average of 2 percentage points. Increases were greater among dominant stems than among intermediates, and they were appreciably greater in the every-other-row cutting than in the other treatments. Dominants in the every-other-row treatment increased their live-crown ratio by an average of 8 points—from 37 to 45 percent. The original differences in crown ratios between dominants and other trees became even greater during the 5-year period in all treatments because of the greater response of the dominants to release.

CROWN CLASS

Except in the every-other-row treatment, the trees underwent little change in crown class in the 5-year period other than minor shifts both up and down. However, in the every-other-row treatment, 35 percent of the trees classed as codominant in 1954 were classed as dominant in 1959.

VOLUMES AND VOLUME GROWTH

Because of initial differences in stand conditions, the volumes left after treatment did not decrease uniformly from the check plot to the heaviest thinning (table 5). The check plot, incidentally, had more volume than any of the treated ones before thinning.

Even so, the check area grew the most volume in the 5-year period, 6.8 cords per acre, followed closely by the two more heavily thinned plots. Under the two lighter thinnings, growth was 4.3 and 4.6 cords per acre.

Of course, in terms of growth percent on residual volume, the

Table 5.—*Volumes and 5-year growth per acre, by treatments*

Treatment row cut	Volume[1] per acre After thinning	5 years later	5-year growth	
	Cords	*Cords*	*Cords*	*Percent*
None	30.7	37.5	6.8	22
Every fifth row	19.9	24.2	4.3	22
Every fourth row	21.4	26.0	4.6	21
Every third row	18.5	24.8	6.3	34
Every second row	13.1	19.6	6.5	50

[1] Volumes in cords of rough wood above a 1-foot stump to a top diameter (i.b.) of 3 inches. Table values were computed using field measurements and table 3 of U. S. Dept. Agr. Misc. Pub. 50 (6).

two more drastic treatments gave the highest values—50 percent for the every-other-row cutting and 34 percent for the every-third-row cutting. The other two treatments and the check plot produced values of 21 or 22 percent.

Discussion

Some investigators of thinning loblolly pine or other species have already reported results comparable to those obtained in this study. For example, Staebler (*4*) found that the diameter growth of individual Douglas-firs was affected by crown class, diameter (b.h.), and degree of release. In his study the largest trees made the greatest response—much as in the present study.

Crown ratio has also proved in certain studies to have a significant relationship with diameter growth as, for example, in a study of jack pine by Stoeckeler and Olsen (*5*). In view of a recent article that condemned crown ratio as being a less valuable index than crown length (*3*), the results of the present study, in which crown ratio was found to be the better index, are particularly interesting.

Most of the questions raised earlier about the effects of row thinning have been satisfactorily answered by this study and other experience with row thinning on the Eastern Shore:

- In typical plantations, cutting every third row (or at wider intervals) does not remove too many of the best trees. Cutting every other row may, in some spots, leave an insufficient number of desirable crop trees.
- Row thinnings can be a commercial operation in areas that have a market for pulpwood. In the Pocomoke State Forest, all the plantations comparable in age to our study plantation have been row-thinned, mostly by cutting every third row, and most of this thinning has been accomplished through stumpage sales to commercial operators.
- No evidence that row thinning results in any immediate increase in wind or snow damage has appeared in our study plots or in the Pocomoke Forest plantations. However, some

damage by *Fomes annosus* is now noticeable, especially in the Pocomoke Forest. In the study plantation, fruiting bodies of *F. annosus* were found in 1961 on most of the residual trees in the thinned plots, but on very few trees in the unthinned plots.

- One question that cannot yet be answered is the effect of row thinning on the production of piling. This and other long-term effects that may develop could modify present conclusions.

Unthinned stands about 20 years old on the Eastern Shore usually are still growing at a rapid rate: in our check plot, dominants added an inch in diameter in the 5-year study period (from ages 17 to 22), and stand growth was 6.8 cords per acre. However, crown ratios were diminishing: at 17 years the ratios of even the dominant trees were dropping below the 40 percent that Chapman (*1*) recommends, and some further decline occurred during the study period. The next 5 years almost certainly will accentuate the differences between the check and the treated stands in both crown ratio and growth rate. So, unless *Fomes annosus* infection after cuttings proves to be a determining factor, dense young loblolly pine plantations on the Eastern Shore apparently should be thinned at about 20 years of age.

If the row method of thinning is chosen, we recommend removing every third row. Although cutting every other row results in greater response in diameter growth and crown development, it may leave too few desirable stems. On the other hand, cutting only every fourth or fifth row is too light a treatment; some of the residual trees are not released, and the overall benefits are considerably less than when every third row is cut.

Summary

In 1954, four thinning treatments were tried in a 17-year-old loblolly pine plantation in the Eastern Shore section of Maryland. The four treatments involved cutting all the trees in: (1) every other row, (2) every third row, (3) every fourth

row, and (4) every fifth row. Row thinning was investigated because pulpwood operators will pay a fair stumpage price for the thinnings when this method is used, whereas removal of scattered stems is not commercially feasible in such plantations.

Statistical analyses of 5-year data (1954-59) indicated that diameter increment after thinning was related to original diameter (b.h.), crown class, crown ratio, and degree of release.

Cutting every other row of trees caused the greatest stimulation of growth in diameter and basal-area increment per tree, in basal-area growth per acre, in volume-growth percent of the stand, and in crown development of the remaining trees. However, in spots this drastic treatment left an insufficient number of desirable crop trees.

Cutting every fourth or fifth row produced so little stimulation of growth that in some respects, as in diameter growth of the crop trees or in volume-growth percent of the stand, results were about the same as in untreated areas.

Consequently, for thinning plantations similar to the one that was studied, removal of every third row is recommended. While this did not stimulate growth per tree in the study plots quite as much as cutting every other row, it did increase average diameter growth by 0.2 to 0.3 inch in the 5-year period. It also favored greater crown ratios, and increased stand volume growth by 12 percent, as compared to an unthinned control.

Fruiting bodies of *Fomes annosus* were present in 1961 on many of the residual trees in the thinned plots. How serious the damage from *Fomes* infections will become in thinned plantations on the Eastern Shore is still an open question. It is possible that, because of the *Fomes* threat, the above thinning recommendation may later have to be modified.

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The Authors...

SILAS LITTLE *is a graduate of Massachusetts State College, and has Master of Forestry and Ph.D. degrees from Yale University. A member of the U.S. Forest Service since 1936, he is now in charge of the Northeastern Forest Experiment Station's research unit at New Lisbon, N.J. Dr. Little has worked chiefly on forest-management research in southern New Jersey and eastern Maryland.*

JOHN J. MOHR *received his B.S. degree in Forestry from Pennsylvania State University in 1939. Since military service in World War II, he has held the position of District Forester with the Maryland Department of Forests and Parks.*