United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Paper
NE-576

1986

Changes in Stem Quality on Young Thinned Hardwoods

David L. Sonderman

The Author

David L. Sonderman, research forest product technologist, joined the Northeastern Forest Experiment Station in June 1962, and was on the staff of the Eastern Softwood Timber Quality project until June 1972. He is currently stationed in Delaware, Ohio, with the Station's project on management and utilization alternatives for nonindustrial private forests.

Manuscript received for publication 6 June 1985.

Abstract

Describes changes in limb-related defects on 18-year-old, even-aged hardwoods 6 years after thinning. Stocking levels of 30, 45, and 60 percent were studied. There were fewer defects per square foot of surface area in the higher stocking plots than in the lower stocking plots. The average number of live limbs decreased by 83 percent in the unthinned plots and increased slightly in the heavily thinned plots. The results show that the frequency and size of limb-related defects are affected by stand density over a short period of time.

Introduction

Manipulating stand density is one way to improve the quality of young hardwood stems. Various thinning schemes have successfully improved the quality of some hardwood stems by reducing the number of defects that normally occur. Although some trees inherently develop fewer defects than others, the majority of the commercial species do not fall into this category. Sometimes, trees develop poor stem quantity when extensive thinning methods are used to improve volume growth. However, moderate stand density reduces the adverse effects. For example, Godman and Brooks (1971) found that northern hardwood stem quality of pole-size trees improved after 15 years of treatment at 85 square feet of basal area per acre. This provided a compromise between good quality improvement and a substantial growth rate. In a more recent study on young white oak crop trees by Dale and Sonderman (1984), similar effects were found on thinning methods above C-level stocking where tree quality was not markedly affected, and in some instances, did improve with increased stand density. Sonderman (1984) found that in mixed central hardwoods, the number of limb-related defects per square foot of surface area increased by 6 percent over the control in plots thinned to 30 percent in only 6 years. Limb-related defects are one of the greatest deterrents to stem quality and should be an important consideration in the management of a stand.

In this study, changes in limb-related characteristics were analyzed over a 6-year period after initial thinning. Species, age, site, and stocking levels are the most important factors that affect potential stem quality. Limb-related defects that are measured on each tree, such as live limbs, dead limbs, and epicormic branches, should be considered simultaneously when interpreting the results because a progression of biological events is taking place. That is, epicormic branches grow into live limbs that die and become dead limbs. After dropping-off, the dead limbs form overgrowths. The length of the cycle depends on the stocking levels and ages of the trees.

The Stand

The study plots are located on the Vinton Furnace Experimental Forest in southern Ohio. The 18-year-old even-aged stand had its origin as a result of a circular clearcut made as part of a "size of opening" study established in 1959. It is 5 acres in size, a good cove hardwood site, a northeast facing slope, and approximately a 75 to 80 site index for northern red oak.

The study consisted of twenty 1/10-acre plots, representing three thinning treatments of 30, 45, and 60 percent stocking. A control was established plus a 1/2-chain-wide isolation strip that surrounded each treatment boundary. Stocking was determined by the tree area ratio equation for mixed oaks developed by Gingrich (1967). A stratified sample of 154 trees, randomly selected, came from four species groups: oaks, yellow-poplar, red maple, and a miscellaneous group. The last group consisted of hickory, ash, black cherry, blackgum, and red elm. An aspen group was eliminated from the analysis because of an inadequate number of sample trees.

Methods

External tree characteristics were systematically measured by the quality classification system (Sonderman 1979) on sample trees 3.6 inches or larger in diameter at breast height (d.b.h.). The measurements of limb-related surface characteristics were recorded from the first and second 8-foot section of the butt 16-foot log on each tree at initial thinning in 1977 and again in 1983. These surface characteristics include:

- d.b.h.
- total height
- crown ratio
- number of live limbs on the first and second 8-foot section of the butt 16-foot log
- number of dead limbs on the first and second 8-foot section of the butt 16-foot log
- diameter of the largest live limb on the first and second 8-foot section of the butt 16-foot log
- diameter of the largest dead limb on the first and second 8-foot section of the butt 16-foot log
- number of epicormic branches on the first and second 8-foot section of the butt 16-foot log

In this study, epicormic branches were grouped to facilitate counting: 0 = No epicormic branches, 1 = 1 to 6 epicormic branches, and 2 = 7 or more epicormic branches.

The branch had to be 0.3 inch or more diameter at the base to qualify as a measurable live or dead limb; otherwise, it was considered an epicormic branch. All stem defects were summarized by species, plot, and stocking level. Covariance analysis was used to test the limb-related variables; the value of the variable at initial time was used as the covariate.

Results and Discussion

Diameter Growth

Thinning hardwood stands to different density levels affects the diameter growth of the residual trees. The data in Figure 1 show a decrease in the average diameter growth as the stocking increases. When analyzed for all species combined, the change from 1977 to 1983 in average diameter growth was: 3.5 inches in the 30 percent stocking, 2.5 inches in the 45 percent stocking, 2.3 inches in the 60 percent stocking, and only 2.0 inches in the control. Yellow-poplar was the single fastest growing species, increasing 3.8 inches in diameter in the 30 percent stocking plots and only 2.8 inches in the control. The next fastest growing species was red maple, followed last by the oak group.

Height Growth

After thinning, the average total height for all species combined decreased as the stocking level increased (Fig. 2). From 61.5 feet in the 30 percent stocking, average height decreased to 61.0 feet in the 45 percent stocking, 57.5 feet in the 60 percent stocking, and 55.2 feet in the control. The largest change in height growth for all species combined from 1977 to 1983 was in the 45 percent stocking plots, averaging over 3 feet per year. The trend was similar for individual species. One of these, yellow-poplar, outgrew all other species, in the 45 percent stocking plots. Other studies on tree quality (Sonderman 1985) involving tree heights in relation to stocking have shown similar trends resulting in maximum height growth change in the 45 to 70 percent stocking.

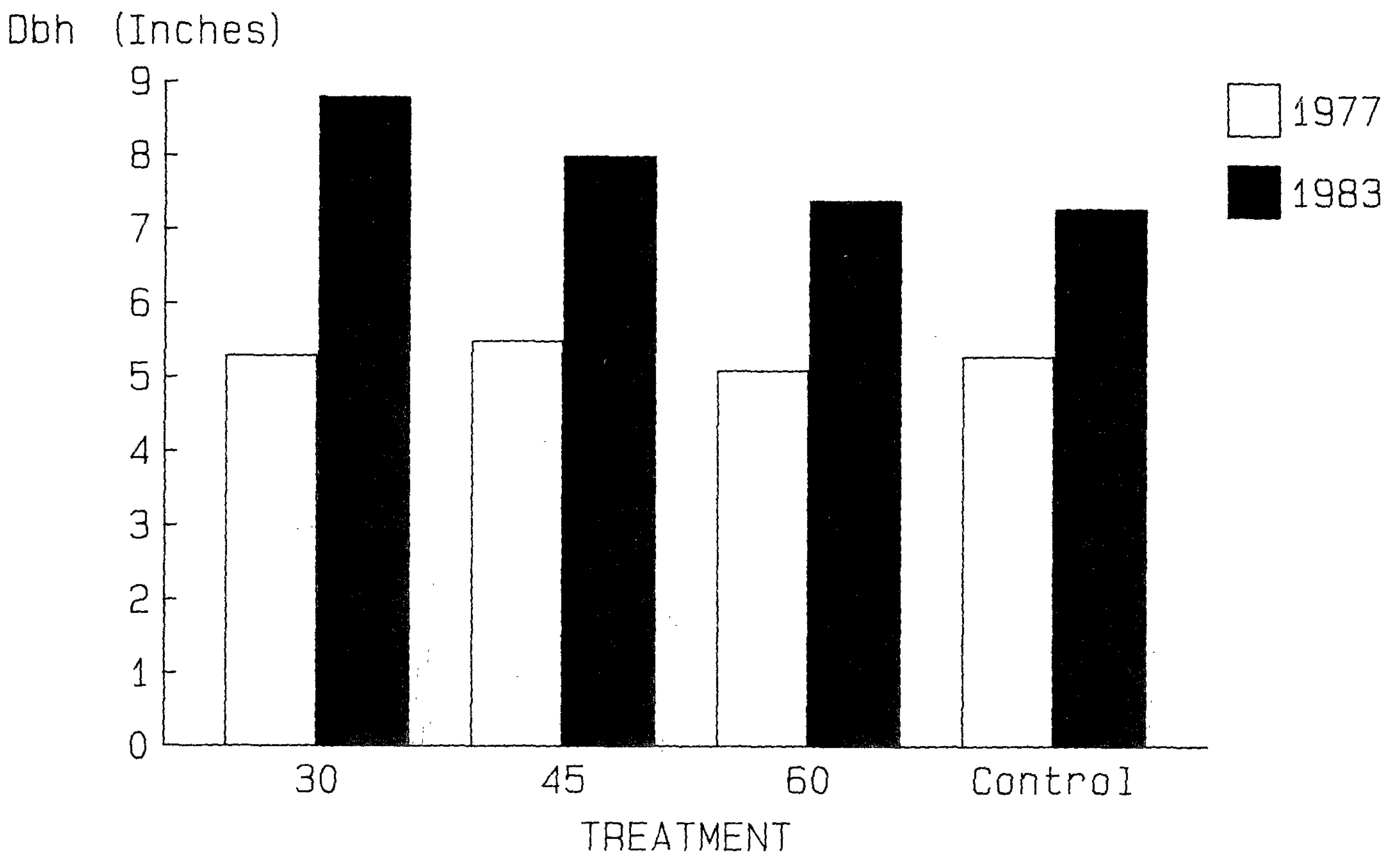

Figure 1.—Average d.b.h. for all species combined by treatment—1977-83.

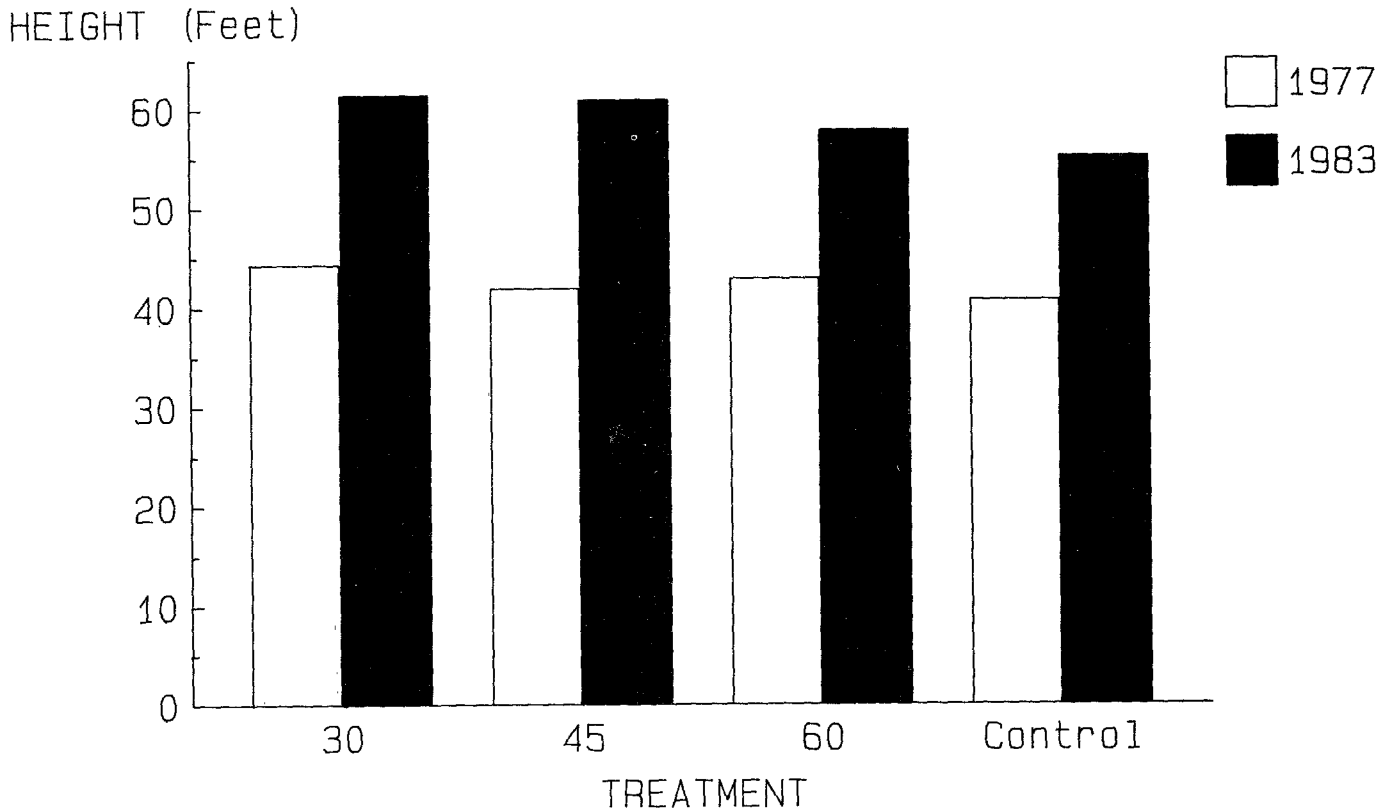

Figure 2.—Average height for all species combined by treatment—1977-83.

Crown Ratio

Crown ratio is the ratio of live crown length to total height of the tree. It is usually one of the best indicators of the effects of stand density on stem quality. For all species combined, the average crown ratio increased slightly in the plots with 30 and 45 percent stocking from 1977 to 1983, and remained about the same in the 60 percent and control plots (Fig. 3). During those 6 years, the heavily thinned plots with open crown canopies and much light from above influenced the crown ratios of many study trees. In many instances, there was a downard extension of the crown that resulted in an increase in epicormic branching and live limb development.

Live and Dead Limb Defects per Square Foot of Surface Area

As tree d.b.h. expands, so does the surface area. Live and dead limb defects per square foot of surface area generally decrease as the tree grows and the surface area expands—if no new defects develop. In this study, the heavily thinned plots showed an increase in the number of defects per square foot of surface area even though surface area greatly increased. Therefore, these plots developed many new limb-related stem defects in only 6 years.

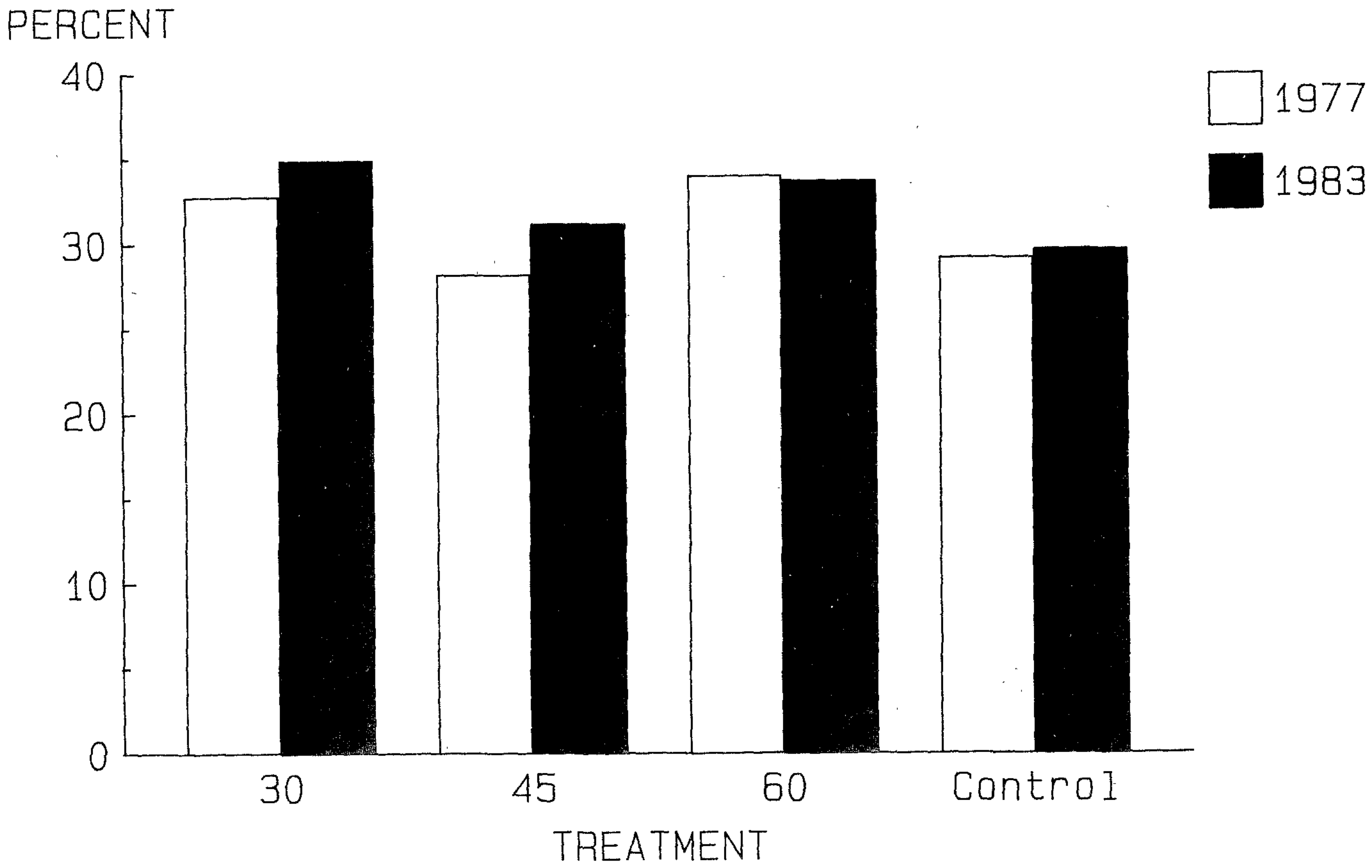

Figure 3.—Average crown ratio, in percent, for all species combined by treatment—1977-83.

The analysis showed that surface area increases for all species combined between 1977 and 1983 from lowest to highest stocking levels were 64, 45, 47, and 39 percent, respectively. In comparison, the number of defects per square foot of surface area for all species combined between 1977 and 1983 is:

Stocking Treatment (%)

Year	*30*	*45*	*60*	*Control*
1977	0.201	0.169	0.264	0.264
1983	0.109	0.060	0.079	0.104

Comparison of live and dead limb defects per square foot of surface area (butt 16-foot section) for all species combined after 6 years showed that the 30 percent stocking plots had a significantly greater number of defects than the other stocking plots ($P<0.12$) when tested by covariance analysis.

Epicormic Branches

Thinning a stand heavily often opens the crown canopy to light which stimulates suppressed buds that may develop into epicormic branches on some tree species. In many instances, these branches will continue to grow into small live limbs so long as light is abundant.

In this study, few of the trees had epicormic branches when first measured in 1977. Six years after thinning, however, the percentage of trees with epicormic branches had increased in all stocking plots (Fig. 4). The 60 percent stocking level had the largest increase in the number of epicormic branches found in the butt 16-foot log. This large change resulted partially from a high proportion of red maple trees in this stocking level. Red maples are prolific sprouters, and almost half of them in the plots with 60 percent stocking had seven or more epicormic branches when meas-

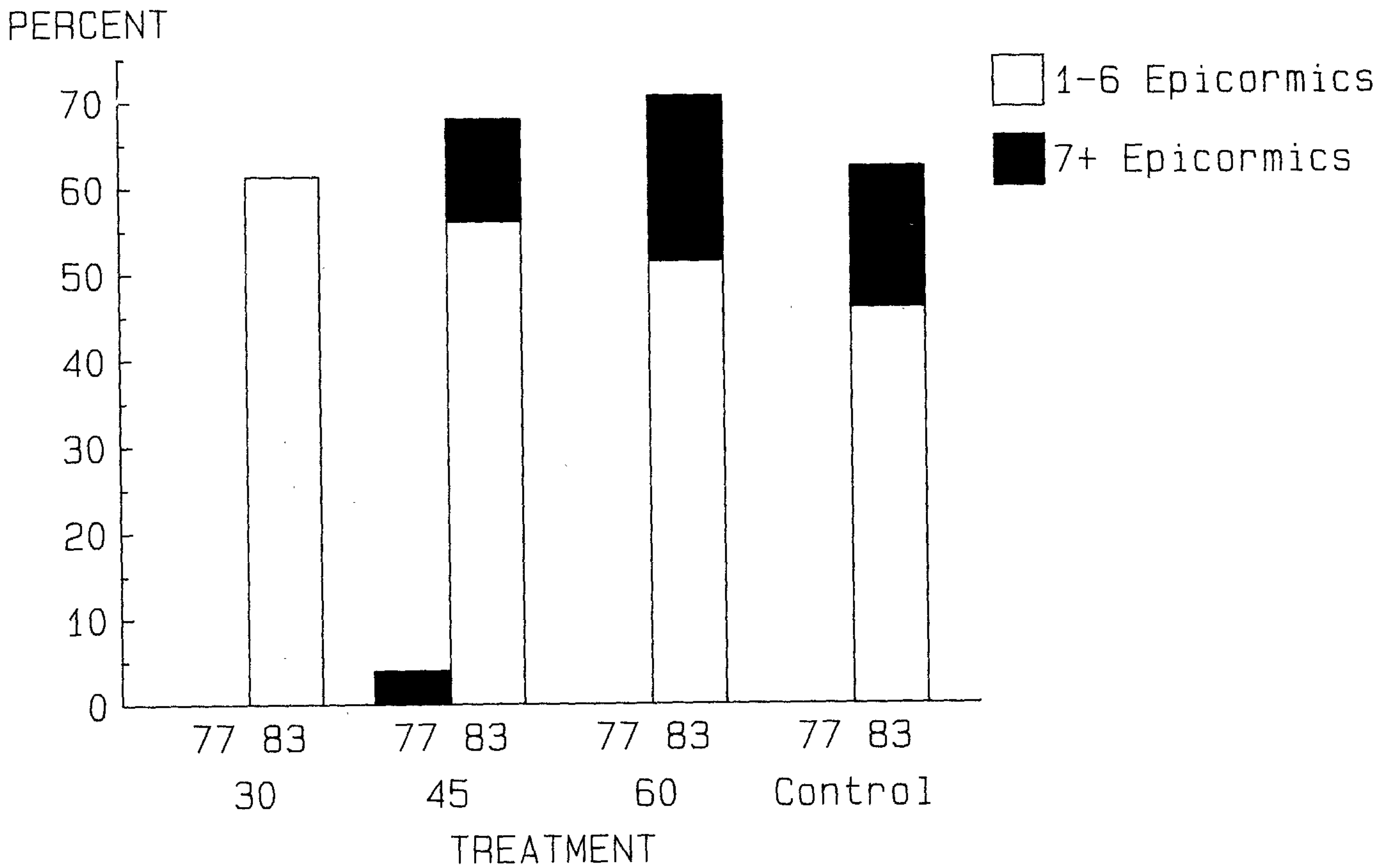

Figure 4.—Percentage of trees with epicormic branches for all species combined (butt 16-foot section) by treatment—1977-83.

ured in 1983 (Table 1). Similarly, more than one-half of the red maples in the control plots had seven or more epicormic branches in the same amount of time. In comparison, yellow-poplar in the 60 percent stocking plots made up less than 10 percent of the trees having seven or more epicormic branches and had none in the control.

Live Limbs

None of the trees in any of the stocking plots had live limbs in 1977 when the butt 8-foot section was analyzed. However, by 1983 many trees in the 30 percent stocking plots had grown new live limbs, but the control plots remained free.

For all species combined, the average number of live limbs (Table 2) in the second 8-foot section increased the most in the 30 percent stocking plots and decreased by 83 percent in the control plots. The size of the live limbs (Table 3) for all species combined in the 30 percent stocking plots decreased by 23 percent from 1977 to 1983, but increased only 1 percent in the control. As a rule, the second 8-foot section of the butt 16-foot log usually will contain more and larger live limbs than the butt 8-foot section.

Treatment differences for live limbs in the butt 16-foot section for all species were significant ($P<0.01$). In the butt 16-foot section, the 30 percent stocking plots had an increase of 0.7 live limbs, and the control plots had a loss of 0.6 live limbs.

Table 1.—Percent of trees with epicormic branches in the butt 16-foot section, 1977-83, by species

Number of epicormic branches	Stocking level (%) 30		45		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				OAK				
0	100.0	—	100.0	—	(No Trees)		100.0	—
1-6	—	100.0	—	—	—	—	—	50.0
7+	—	—	—	100.0	—	—	—	50.0
				YELLOW-POPLAR				
0	100.0	41.4	100.0	40.0	100.0	9.2	100.0	46.2
1-6	—	58.6	—	60.0	—	81.8	—	53.8
7+	—	—	—	—	—	9.0	—	—
				RED MAPLE				
0	100.0	33.4	80.0	20.0	100.0	15.9	100.0	14.4
1-6	—	66.6	—	60.0	—	36.8	—	28.5
7+	—	—	20.0	20.0	—	47.3	—	57.1
				MISCELLANEOUS[a]				
0	100.0	16.7	100.0	33.4	100.0	70.6	100.0	50.0
1-6	—	83.3	—	55.5	—	29.4	—	50.0
7+	—	—	—	11.1	—	—	—	—
				ALL				
0	100.0	35.9	96.0	32.0	100.0	29.4	100.0	37.6
1-6	—	64.1	—	56.0	—	51.7	—	46.8
7+	—	—	4.0	12.0	—	18.9	—	15.6

[a]Miscellaneous group includes hickory, ash, black cherry, blackgum, and red elm.

Table 2.—Average number of live limbs in the butt and second 8-foot sections, 1977-83, by species group

Species group	Stocking level (%) 30		45		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				BUTT 8-FOOT SECTION				
Oaks	—	1.76	—	—	(No trees)		—	—
Yellow-poplar	—	.44	—	0.21	—	0.09	—	—
Red maple	—	1.47	—	—	—	.14	—	—
Miscellaneous[a]	—	—	—	.29	—	—	—	—
All	—	.47	—	.20	—	.08	—	—
				SECOND 8-FOOT SECTION				
Oaks	—	6.79	—	—	(No trees)		6.93	—
Yellow-poplar	2.04	2.88	0.99	0.57	1.95	0.23	.86	0.16
Red maple	6.90	5.51	.87	2.06	2.51	1.67	4.90	—
Miscellaneous[a]	.46	.45	.83	.74	.40	.60	1.63	.98
All	2.18	2.79	.87	1.03	1.75	.87	2.52	.42

[a]Miscellaneous group includes hickory, ash, black cherry, blackgum, and red elm.

Table 3.—Average diameter, in inches, of the largest live limbs in the butt and second 8-foot sections, 1977-83, by species group

Species group	30		45		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				BUTT 8-FOOT SECTION				
Oak	—	0.75	—	—	(No trees)		—	—
Yellow-poplar	—	.55	—	1.25	—	3.00	—	—
Red maple	—	1.00	—	—	—	.50	—	—
Miscellaneous[a]	—	—	—	.50	—	—	—	—
All	—	.64	—	.87	—	1.75	—	—
				SECOND 8-FOOT SECTION				
Oak	—	0.75	—	—	(No trees)		1.00	—
Yellow-poplar	1.00	.64	0.87	1.00	0.92	1.00	1.91	2.00
Red maple	1.37	1.62	2.00	1.16	1.05	1.09	.87	—
Miscellaneous[a]	1.75	2.50	.87	.62	1.41	.50	1.35	1.06
All	1.15	.89	1.10	.95	1.06	.97	1.23	1.25

Stocking level (%)

[a]Miscellaneous group includes hickory, ash, black cherry, blackgum, and red elm.

Dead Limbs

The average number of dead limbs (Table 4) for all species combined in the second 8-foot section decreased in all stocking plots from 1977 to 1983. However, the numbers of dead limbs in the control plots did not decrease as much as those in the other stocking plots. This was due partially to the larger average size of the dead limbs in the control plots. In fact, the average size of the largest dead limbs for all species combined (Table 5) occurred in the control plots where they increased by 49 percent as opposed to a 22 percent decrease in size in the 30 percent stocking plots. Large dead limbs, when they reach a certain size, do not prune-off easily even in the unthinned plots.

Summary and Conclusion

Limb-related defects are the major cause of degrading stem quality in young hardwood trees. It is improbable that all defects can be prevented; so, the results of this study may provide the land manager with enough information on stand density choices to reduce stem-defect occurrence and numbers. To do this, forest management decisions should be based on the best residual stand densities needed to grow high-quality trees at fast volume growth. The results of these data show that the heavily thinned stands usually have good diameter growth, large numbers of stem defects, and big crowns. Therefore, stand densities should be held above C-level stocking to maintain tree quality.

Table 4.—Average number of dead limbs in the butt and second 8-foot sections, 1977-83, by species group

Species group	Stocking level (%)							
	30		45		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
	BUTT 8-FOOT SECTION							
Oak	—	—	—	—	(No trees)		3.60	0.94
Yellow-poplar	0.12	0.94	—	0.36	0.85	0.09	.28	.19
Red maple	4.01	—	1.22	—	1.27	.28	1.28	—
Miscellaneous[a]	1.28	.84	.66	—	2.03	1.19	2.06	.50
All	.53	.81	.55	.11	1.31	.48	1.39	.34
	SECOND 8-FOOT SECTION							
Oak	18.41	6.79	2.26	—	(No trees)		6.55	4.54
Yellow-poplar	4.34	2.75	4.05	2.98	2.61	1.49	2.16	1.91
Red maple	9.09	2.74	6.88	.83	10.16	2.42	7.40	5.98
Miscellaneous[a]	11.34	5.73	7.37	3.10	10.67	5.75	10.29	7.75
All	5.84	3.32	5.99	2.48	7.36	3.12	6.60	5.32

[a]Miscellaneous group includes hickory, ash, black cherry, blackgum, and red elm.

Table 5.—Average diameter in inches of the largest dead limbs in the butt and second 8-foot sections, 1977-83, by species group

Species group	Stocking level (%)							
	30		45		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
	BUTT 8-FOOT SECTION							
Oak	—	—	—	—	(No trees)		0.75	0.50
Yellow-poplar	0.62	0.50	—	0.50	0.95	0.50	1.00	1.00
Red maple	1.00	—	0.75	—	.68	1.00	.62	—
Miscellaneous[a]	1.00	.87	.75	—	.85	.92	1.00	.66
All	.89	.55	.75	.50	.81	.90	.85	.70
	SECOND 8-FOOT SECTION							
Oak	1.00	0.75	0.75	—	(No trees)		1.25	1.25
Yellow-poplar	.72	.61	.84	0.82	0.82	0.86	.91	1.66
Red maple	1.25	.87	.62	1.37	.81	1.02	.85	1.10
Miscellaneous[a]	1.41	.95	.78	1.18	1.08	1.35	.77	1.15
All	.92	.72	.77	1.01	.91	1.11	.85	1.27

[a]Miscellaneous group includes hickory, ash, black cherry, blackgum, and red elm.

Other important results are:

- Diameter (d.b.h) growth increased as the growing space increased.
- Average crown ratio for all species combined increased only in the 30 and 45 percent stocking plots.
- Limb defects per square foot of surface area increased the most in the 30 and 45 percent stocking plots when average surface area was considered.
- The average number of live limbs in the second 8-foot section of the butt 16-foot log decreased as the percent stocking increased.
- Average size of live limbs in the second 8-foot section of the butt 16-foot log was smaller in the lower stocking plots and increased as stocking increased.
- The number of dead limbs in the second 8-foot section of the butt 16-foot log of the control plots did not decrease as much as the dead limbs in the same section of the other stocking plots.
- Average size of dead limbs in the second 8-foot section of the butt 16-foot log decreased in the 30 percent stocking plots and increased in all other stocking plots.
- The unthinned plots had the lowest percentage of trees with epicormic branches in the butt 16-foot section.
- Yellow-poplar increased the most in diameter growth, height growth, and crown ratio of all the species.
- For all trees combined, all stocking levels had some epicormic branches after thinning. The majority of the trees had 1 to 6 epicormic branches.

Acknowledgments

The author wishes to thank the following forest technicians for assistance in collecting the data: John Beaton, William Pierce, and Deloris Weiss.

Literature Cited

Dale, Martin E.; Sonderman, David L. **Effect of thinning on growth and potential quality of young white oak crop trees.** Res. Pap. NE-539. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1984. 12 p.

Gingrich, S. F. **Measuring and evaluating stocking and stand density in upland hardwood forests in the central states.** Forest Science. 13:38-52; 1967.

Godman, Richard M.; Books, David J. **Influence of stand density on stem quality in pole-size northern hardwoods.** Res. Pap. NC-54. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1971. 7 p.

Sonderman, David L. **Guide to the measurement of tree characteristics important to the quality classification system for young hardwood trees.** Gen. Tech. Rep. NE-54. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1979. 12 p.

Sonderman, David L. **Quality response of 29-year-old, even-aged central hardwoods after thinning.** Res. Pap. NE-546. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1984. 9 p.

Sonderman, David L. **Stand density—A factor affecting stem quality of young hardwoods.** Res. Pap. NE-561. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 8 p.

Sonderman, David L. **Changes in stem quality of young thinned hardwoods.** Res. Pap. NE-576, Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 9 p.

Describes changes in limb-related defects on 18-year-old, even-aged hardwoods 6 years after thinning. Stocking levels of 30, 45, and 60 percent were studied. There were fewer defects per square foot of surface area in the higher stocking plots than in the lower stocking plots. The average number of live limbs decreased 83 percent in the unthinned plots and increased slightly in the heavily thinned plots. The results showed that frequency and size of limb-related defects are affected by stand density over a short period of time.

ODC 228.1:242:851:852.11

Keywords: Stand density, thinning, stem quality

☆U.S. GOVERNMENT PRINTING OFFICE: 1986-602-026:20042

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.