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Stand Density—A Factor Affecting Stem Quality of Young Hardwoods

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Abstract

A 14-year-old mixed oak stand was thinned in 1977 to stocking levels of 30, 50, and 60 percent and a control. From this stand, 117 trees were selected and their stem-related defects recorded. Six years later these same trees were reevaluated. The number of limb defects per square foot of surface area increased substantially more in the heavily thinned plots than in the unthinned plots. Trends in these data confirm commonly held beliefs that stand density affects stem quality after only a few years.

Introduction

Growing good quality timber is a goal of most foresters and woodlot managers. Although many factors affect timber quality, this research is aimed at determining the stocking level that optimizes quality and volume growth. Recent thinning studies show that tree quality will improve if stocking levels are maintained. Dale and Sonderman (1984) showed the effect of thinning on growth and quality of a 33-year-old white oak stand after 16 years of treatment. We found that the number of limb-related defects decreased as stand density increased. In a similar 6-year study of a 29-year-old mixed hardwood stand, I found that the number of defects per square foot of surface area and the number of epicormic branches both decreased with an increase in stocking (Sonderman 1984b). The results of a study on 80-year-old white oak trees thinned 18 years earlier (Sonderman 1984a) suggest that heavy thinning had a detrimental effect on potential stem quality by significantly increasing the number of defects per square foot of surface area. In all of the studies, limb-related defects and epicormic branches were the most serious degraders of stem quality and were affected the most by thinning.

This research is an integral part of a long-term study relating time and stocking treatments to tree quality characteristics in young hardwoods. Species, age, crown ratio, and stocking density are a few of the important factors affecting potential stem quality that are analyzed in this study.

The Stand

The 8-acre stand, located on the Vinton Furnace Experimental Forest in southern Ohio, was originally a fully stocked, even-aged mature mixed oak stand that was clearcut in 1963. The average site index of the stand was 71. The stand was thinned in 1977 and four treatments established according to Gingrich's (1967) guide on stocking percentages. The 31 plots, each 1/10-acre in size, were divided into treatments of 30, 50, and 60 percent stocking and control plots. Each treatment was surrounded by a 1/2-chain wide isolation strip, treated the same as the plot. From these plots, 117 study trees were selected. The residual stand contained mixed oaks, yellow-poplar, red maple, aspen, black walnut, blackgum, red elm, black cherry, and hickory. Five species groups were used in the analysis—oaks, yellow-poplar, red maple, aspen and a miscellaneous group. Yellow-poplar, the most common species, accounted for 45 percent of the total number of trees. The oak and red maple groups each accounted for 15 percent of the total. The aspen group made up only 4 percent. The miscellaneous group, which included black cherry, hickory, black walnut, red elm, and blackgum, accounted for 21 percent of the total number of trees.

Methods

A stratified sample of trees 3.6 inches or larger in diameter at breast height (d.b.h.) was randomly selected from plots within treatments. The quality classification system (Sonderman and Brisbin 1978) was used to measure the limb-related external defects on both the butt and second 8-foot section of the butt 16-foot log on each tree. Live and dead limbs had to be at least 0.3 inch in diameter to be measured, otherwise they were considered epicormic branches. The quality classification system was applied to the trees in 1977 and again in 1983. The quality differences between the two measurements provided a quality profile, the basis for this paper.

Tree quality characteristics (Sonderman 1979) recorded were:

- dbh
- 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

Several categories of branches were used in the classification system. Small live or dead shoots less than 0.3 inches in diameter at their bases were considered epicormic branches. In this study, these branches were grouped and coded to facilitate the analysis as follows:

0 = No epicormic branches

1 = 1 to 6 epicormic branches

2 = 7+ epicormic branches

All branches 0.3 inches or more in diameter at their bases were measured and counted on each tree section.

All measurements were summarized and analyzed by covariance analysis, using the value of the variable at initial time as the covariate.

Results and Discussion

Diameter and height growth

The effect of different stocking treatments on the diameter growth of the sample trees is apparent in Table 1. The analyses show that the largest average diameter growth was in the plots with 50 percent stocking. The diameter increased 76 percent in 6 years. The control plots, in comparison, had the slowest diameter growth—a 56 percent increase from 1977 to 1983. Of all the individual species groups, yellow-poplar and aspen increased the most in diameter in the 30 percent treatment. The oak group was the slowest growing. Aspen continued to show outstanding diameter growth in both the 50 and 60 percent stocking plots.

Average height growth for all trees combined attained a maximum in the plots with 50 percent stocking. The average growth was 7.0 feet more than that of the trees in the control. Aspen led all other species in height growth in the plots with 50 percent stocking. It grew 22 feet in height there, but only 17 feet in the control plots. No statistical tests were performed for diameter or height growth. However, in a similar study of white oak by Dale and Sonderman (1984), mean height growth was not significantly related to treatment differences. Hilt (1979) reported similar diameter-growth trends in relation to thinning treatments in an earlier study.

Crown ratio

Crown ratio is the ratio of live crown length to total tree height. For all species combined, crown ratio was greatest in the plots with 30 percent stocking (Table 1). From 1977 to 1983, average crown ratio increased from 28 percent to 39 percent in those plots and from 32 percent to 38 percent in the control plots. The data show that as the percentage stocking increased, the crown ratio decreased.

Table 1.—Summary of average tree characteristics in 1977 and 1983, by species group and stocking level

Species group	Stocking level (%)							
	30		50		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
	D.b.h. (inches)							
Oaks	4.5	6.0	4.5	7.1	4.5	6.8	4.6	6.3
Yellow-poplar	5.3	9.6	4.8	8.3	—	—	4.4	7.4
Red maple	5.0	8.1	3.6	5.9	4.1	7.0	4.7	7.2
Aspen	4.0	7.5	4.8	9.6	4.1	9.0	4.2	8.6
Miscellaneous[a]	4.2	6.5	3.6	5.5	4.2	5.6	4.4	6.2
All	4.9	8.2	4.6	8.1	4.3	6.8	4.5	7.0
	Height (feet)							
Oaks	39.5	47.0	37.0	42.0	40.6	46.8	32.6	39.6
Yellow-poplar	42.3	64.4	40.1	59.7	—	—	37.0	52.5
Red maple	39.2	52.4	32.0	48.0	38.0	51.6	39.0	47.0
Aspen	44.5	55.5	47.0	69.0	42.0	60.0	49.0	66.0
Miscellaneous	36.1	46.5	32.0	42.0	35.0	41.3	37.0	46.3
All	40.0	56.4	39.5	57.9	38.9	48.5	37.3	48.7
	Crown ratio (percent)							
Oaks	26.3	31.3	25.0	40.0	31.7	33.3	35.0	38.3
Yellow-poplar	25.0	39.3	27.6	37.4	—	—	25.0	32.5
Red maple	33.0	52.0	30.0	50.0	38.1	45.6	35.0	48.3
Aspen	32.5	37.5	35.0	35.0	40.0	45.0	30.0	45.0
Miscellaneous	30.3	35.8	45.0	35.0	33.3	45.0	38.3	35.0
All	27.6	38.7	28.8	37.9	34.8	40.2	31.6	37.8
	Defects/ft² surface area (number)[b]							
Oaks	0.403	0.207	0.663	0.252	0.870	0.148	1.112	0.549
Yellow-poplar	.273	.140	.560	.128	—	—	.481	.099
Red maple	.603	.217	.746	.476	.787	.232	.823	.223
Aspen	.923	.499	.994	.438	1.096	.374	.668	.261
Miscellaneous	.969	.345	.994	.217	1.248	.739	1.074	.397
All	.546	.226	.615	.169	.903	.275	.786	.273

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

[b] Live and dead limbs, butt 16-foot section.

Live and Dead Limb Defects per Square Foot of Surface Area

Measuring live and deal limb defects per square foot of surface area provides a relative comparison of the effects of stand density on stem quality (Table 1). There is an expansion in both diameter and surface area when a tree grows. This expansion of surface area will result in a decrease in the number of defects per square foot of surface area—if no new limb defects develop. The following tabulation shows the number of defects per square foot of surface area in the butt 16-foot section by stocking treatment from 1977 to 1983 for all species:

Year	*Stocking Treatment (Percent)*			
	30	50	60	Control
1977	0.546	0.615	0.903	0.786
1983	0.226	0.169	0.275	0.273

All of the treatments show a decrease in the average number of defects per square foot of surface area after 6 years. The 30 and 50 percent stocking levels were the least effective in reducing the number of defects per square foot of surface area. Although they were accompanied by a much larger increase in diameter growth (surface area), they had the most new defects.

Epicormic branches

Epicormic branches will normally develop when dormant buds in the tree stem are exposed to full sunlight. They will usually persist and grow into live limbs where thinning has been heavy.

In this study, none of the trees in the 50 and 60 percent stocking plots had epicormic branches when first measured in 1977 (Table 2). However, by 1983 the percentage of trees with epicormic branches had increased substantially in all treatments. The plots with 30 percent stocking had the smallest increase in percentage of trees (all species and both 8-foot sections combined) with epicormics after 6 years' growth. In this treatment, large amounts of light from the open crown resulted in continued growth of existing epicormics and live limbs rather than development of new ones. Both the number of live limbs and the crown ratio increased. The fact that the 30 percent stocking level contained a large number of yellow-poplars and some aspen species may account for the limited epicormic branch development; these species are not considered prolific epicormic sprouters.

The oak group increased uniformly in the percentage of trees with epicormic branches in all treatments. Conversely, the aspen group showed little change, except in the 50 percent treatment where the percentage of trees with epicormic branches increased in both the butt and the second 8-foot sections.

Live limbs

The number of live limbs was recorded from the butt and second 8-foot sections of each tree. The greastest effect of density on live limb development was found on the second 8-foot section (Table 3). The number of live limbs on this section increased by 5.6 percent on the plots with 30 percent stocking and decreased as the stand density increased. On the control plots, the number of live limbs decreased 87.7 percent from 1977 to 1983. The following tabulation shows the percentage change in the number of live limbs by treatment from 1977 to 1983, for the second 8-foot section for all species combined:

	Stocking Treatment (percent)			
	30	50	60	Control
Live limbs	5.6	−66.0	−43.7	−87.8

Natural pruning, epicormic branch development, and rapid live limb growth are a few of the reasons for the increase in number of live limbs in the plots with 30 percent stocking. However, tests comparing the number of live limbs for all species combined showed no significant differences among treatments.

Summarizing the data by individual species, the number of live limbs increased substantially in the second 8-foot section of trees in the oak group in both the 30 percent and 50 percent stocking plots. In contrast, the number of live limbs in both 8-foot sections of trees in the aspen group decreased in all treatments.

The largest average live limb size was found in the second 8-foot section of both the oak and the red maple groups on the control plots. These limbs decreased in size as the stocking density decreased (Table 4).

Dead Limbs

The number of dead limbs on the second 8-foot section for all species combined increased only on the control plots (Table 5). This increase was caused by the lack of sunlight under the closed canopy, which resulted in live limbs dying earlier than in the thinned plots. Given enough time, these dead limbs would be naturally pruned off. Covariance analysis tests of the number of dead limbs for all species combined in both 8-foot sections showed no significant difference among treatments.

The largest average size of dead limbs (Table 6) for all species combined occurred in the second 8-foot section of the control plots. There the dead limb size increased 58 percent from 1977 to 1983. One reason for the increase was that the larger limbs in the more densely stocked plots did not die and prune off as quickly as the smaller ones. Generally, the average size of the largest dead limbs in the second 8-foot section decreased with a decrease in stocking for all species combined.

Table 2.—Percentage of trees with epicormic branches in butt and second 8-foot sections, 1977-83, by species

Number of epicormic branches	Stocking level (%) 30		50		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				OAK				
				Butt 8-foot section				
0	100.0	25.0	100.0	—	100.0	11.2	100.0	33.4
1-6	—	25.0	—	—	—	33.3	—	—
7+	—	50.0	—	100.0	—	55.5	—	66.6
				Second 8-foot section				
0	100.0	—	100.0	—	100.0	11.2	100.0	33.4
1-6	—	50.0	—	100.0	—	33.3	—	33.3
7+	—	50.0	—	—	—	55.5	—	33.3
				YELLOW-POPLAR				
				Butt 8-foot section				
0	93.4	43.4	100.0	35.3	—	—	83.4	16.7
1-6	6.6	56.6	—	64.7	—	—	16.6	83.3
7+	—	—	—	—	—	—	—	—
				Second 8-foot section				
0	93.4	36.7	100.0	17.8	—	—	83.4	—
1-6	6.6	60.0	—	76.4	—	—	16.6	50.0
7+	—	3.3	—	5.8	—	—	—	50.0
				RED MAPLE				
				Butt 8-foot section				
0	80.0	40.0	100.0	—	100.0	12.5	100.0	—
1-6	20.0	40.0	—	100.0	—	50.0	—	33.4
7+	—	20.0	—	—	—	37.5	—	66.6
				Second 8-foot section				
0	80.00	20.0	100.0	—	100.0	25.0	100.0	—
1-6	20.00	60.0	—	100.0	—	37.5	—	66.6
7+	—	20.0	—	—	—	37.5	—	33.4

(table 2—cont.)

Number of epicormic branches	Stocking level (%)							
	30		50		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				ASPEN				
				Butt 8-foot section				
0	100.0	100.0	100.0	—	100.0	100.0	100.0	100.0
1-6	—	—	—	100.0	—	—	—	—
7+	—	—	—	—	—	—	—	—
				Second 8-foot section				
0	100.0	100.0	100.0	—	100.0	100.0	100.0	100.0
1-6	—	—	—	100.0	—	—	—	—
7+	—	—	—	—	—	—	—	—
				MISCELLANEOUS[a]				
				Butt 8-foot section				
0	100.0	44.6	100.0	100.0	100.0	66.7	100.0	66.7
1-6	—	38.8	—	—	—	33.3	—	33.3
7+	—	16.6	—	—	—	—	—	—
				Second 8-foot section				
0	100.0	44.6	100.0	—	100.0	33.4	100.0	33.4
1-6	—	38.8	—	100.0	—	33.3	—	66.6
7+	—	16.6	—	—	—	33.3	—	—
				ALL				
				Butt 8-foot section				
0	95.0	44.2	100.0	33.4	100.0	24.0	93.8	31.3
1-6	5.0	45.7	—	61.9	—	38.0	6.2	43.7
7+	—	10.1	—	4.7	—	38.0	—	25.0
				Second 8-foot section				
0	95.0	37.4	100.0	14.4	100.0	23.9	93.8	18.8
1-6	5.0	50.8	—	80.9	—	33.3	6.2	50.0
7+	—	11.8	—	4.7	—	42.8	—	31.2

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

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

Species group	30 (%) 1977	30 (%) 1983	50 (%) 1977	50 (%) 1983	60 (%) 1977	60 (%) 1983	Control 1977	Control 1983
				Butt 8-foot section				
Oaks	—	0.92	3.54	—	0.43	—	4.24	—
Yellow-poplar	—	.82	.22	.24	—	—	.33	—
Red maple	1.11	1.13	7.10	5.36	1.58	.65	—	—
Aspen	—	—	—	—	—	—	—	—
Miscellaneous[a]	.34	.92	1.78	—	—	.52	1.69	—
All	.21	.88	.94	.52	.80	.34	1.21	—
				Second 8-foot section				
Oaks	0.60	4.13	—	6.78	4.69	0.62	14.60	2.28
Yellow-poplar	2.87	4.45	6.17	1.16	—	—	6.04	—
Red maple	10.52	9.25	9.04	13.63	8.77	3.69	13.80	5.16
Aspen	4.45	—	2.24	—	15.79	—	4.51	—
Miscellaneous	7.86	6.17	13.56	—	7.11	14.28	21.02	—
All	5.22	5.51	6.44	2.18	7.23	4.07	11.74	1.43

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

Table 4.—Average diameter (in inches) of the largest live limbs in the butt and second 8-foot sections, 1977-83, by species

Species group	30 (%) 1977	30 (%) 1983	50 (%) 1977	50 (%) 1983	60 (%) 1977	60 (%) 1983	Control 1977	Control 1983
				Butt 8-foot section				
Oaks	—	0.50	1.50	—	1.50	—	1.25	—
Yellow-poplar	—	.60	.75	.50	—	—	1.25	—
Red maple	.87	.91	.75	.75	1.66	2.33	—	—
Aspen	—	—	—	—	—	—	—	—
Miscellaneous[a]	1.00	.62	.75	—	—	.50	1.12	—
All	.93	.66	.90	.58	1.60	1.87	1.18	—
				Second 8-foot section				
Oaks	1.50	0.50	—	4.00	1.41	1.83	1.41	2.25
Yellow-poplar	1.07	1.30	1.00	1.18	—	—	1.06	—
Red maple	1.30	1.62	1.00	1.75	1.12	1.95	.91	2.12
Aspen	1.00	—	1.50	—	1.25	—	1.00	—
Miscellaneous	1.21	1.79	1.00	—	1.00	1.25	1.16	—
All	1.16	1.41	1.02	1.75	1.22	1.79	1.12	2.16

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

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

Species group	Stocking level (%) 30		50		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				Butt 8-foot section				
Oaks	3.32	1.01	7.10	3.56	7.02	2.52	9.15	11.34
Yellow-poplar	1.55	1.09	3.21	.77	—	—	2.95	.29
Red maple	5.37	2.12	1.78	1.79	6.75	3.64	8.73	1.14
Aspen	7.86	6.43	10.64	7.09	12.41	7.10	1.77	1.77
Miscellaneous[a]	7.31	2.03	7.10	—	8.64	3.12	7.49	2.38
All	4.33	1.79	3.96	1.21	7.43	3.23	5.90	3.31
				Second 8-foot section				
Oaks	10.90	3.49	9.03	2.25	17.06	4.23	9.27	10.62
Yellow-poplar	6.99	3.97	11.07	6.15	—	—	6.83	5.57
Red maple	5.35	.96	—	—	6.36	3.98	5.20	6.17
Aspen	15.74	22.11	22.59	24.93	4.51	18.14	15.84	15.88
Miscellaneous	14.99	8.18	2.26	9.07	24.14	14.66	5.10	16.66
All	10.45	6.12	10.36	6.60	13.24	6.46	7.24	9.68

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

Table 6.—Average diameter (in inches) of the largest dead limbs in the butt and second 8-foot sections, 1977-82, by species

Species group	Stocking level (%) 30		50		60		Control	
	1977	1983	1977	1983	1977	1983	1977	1983
				Butt 8-foot section				
Oaks	0.75	0.62	0.75	1.50	0.97	1.57	0.83	1.25
Yellow-poplar	.71	.54	.67	.65	—	—	.96	1.50
Red maple	.55	.62	.75	1.00	.59	.85	.83	.50
Aspen	.75	.62	.50	.50	.75	.75	.50	.50
Miscellaneous[a]	.75	1.40	.50	—	.66	.58	.66	.83
All	.71	.84	.66	.78	.77	1.10	.80	.93
				Second 8-foot section				
Oaks	0.81	1.06	1.00	0.50	1.00	1.25	0.75	1.83
Yellow-poplar	.76	.69	.86	.93	—	—	.70	.91
Red maple	.75	.50	—	—	.60	.83	.58	1.00
Aspen	.75	1.00	1.00	1.75	.75	1.25	.75	1.00
Miscellaneous	.79	1.20	.50	1.00	.83	.91	.91	1.16
All	.77	.91	.86	.95	.82	1.03	.73	1.15

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

Summary and Conclusion

This research is part of a long-term quality study that will be merged with similar quality studies to determine the best stocking density to grow high-value trees fast. Trends in these data suggest that tree species, age, and stand density greatly affect the number and size of stem defects. These trends should be observed as a progression of biological events that take place as the tree grows. For example, epicormic branches develop and grow into measurable live limbs that eventually die. The dead limbs, if given enough time, will naturally prune off and become overgrowths. All of the defects from this progression will leave internal or external scars on the tree, eventually causing some degrade.

Trends in these data show that the heavier the thinnings, the greater the diameter growth and greater the chance for defects. Also, with the growth rate increase will come increases in crown ratio that eventually will result in additional live limbs.

Important results in this study are:

- Diameter (d.b.h.) growth increased with an increase in growing space.
- Average crown ratio for all trees combined increased the most in the lowest stocking level.
- At the 30 percent and 50 percent stocking levels, red maple increased the most in crown ratio.
- Live and dead limb defects per square foot of surface area increased as the stocking decreased.
- There were more epicormic branches in the second 8-foot section of the tree than in the butt 8-foot section.
- For all species combined, the number of live limbs in the second 8-foot section of the tree increased only at the 30 percent stocking level.
- Live limbs were substantially larger and more numerous on the second 8-foot section of the tree.
- The average number of dead limbs for all species combined in the second 8-foot section of the tree increased only in the control plots.
- Dead limbs were generally larger and more numerous for all species combined on the second 8-foot section of the tree.

The results of this study have limited application because only one site class and age group were studied. Therefore, caution should be exercised when applying this information to other trees and stands.

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A 14-year-old mixed oak stand was thinned in 1977 to stocking levels of 30, 50, and 60 percent and a control. From this stand, 117 trees were selected and their stem-related defects recorded. Six years later these same trees were reevaluated. The number of limb defects per square foot of surface area increased substantially more in the heavily thinned plots than in the unthinned plots. Trends in these data confirm commonly held beliefs that stand density affects stem quality after only a few years.

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