Long-Term Growth of Crop Trees After Release in Northern Hardwoods

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ABSTRACT. *Diameter growth of crop trees of paper birch, sugar maple, yellow birch, white ash, beech, and red maple was remeasured for 31 yr following a heavy release, light release, species removal, and control applied to an evenaged 25 yr old northern hardwood stand in New Hampshire. Under all regimes, final dbh of sampled crop trees was positively related to initial dbh. White ash showed no significant or consistent increase in final dbh in response to treatment, expressed in terms of residual basal area per acre. Paper birch, beech, and red maple had final average diameters up to about 2 in. larger due to heavy release as compared with the control. Sugar maple showed a gain of up to 1 in. in final dbh over the 31 yr period, while yellow birch showed a similar, though nonsignificant, gain. The study shows the long-term effects of release treatments, and the importance of releasing larger trees and responsive species. North J. Appl. For. 14(3):147–151.*

The effects of crop-tree release and early cleanings in sapling-sized northern hardwood stands in the Northeast have been clearly documented and recently summarized (Heitzman and Nyland 1991). These effects include: significant increases in diameter growth; maintenance of stems of desired species and bole quality; and possibly some quality reductions due to delayed self-pruning and epicormic branching in stands thinned too heavily or too early (Solomon and Blum 1977). However, other than a 30+ yr study in aspen-birch stands in Maine (Labonte and Leso 1990), many investigations have been short-term. To help provide additional long-term perspectives on the influence of crop-tree release, we report here on the responses of six species of northern hardwoods over a 31 yr period following three methods of release (plus a control) in a 25 yr old stand in New Hampshire. Five-year results from this study were reported by Marquis (1969).

Methods

The release treatments were applied to a 25 yr old stand in 1959 that had originated after a complete clearcutting in 1933–1935 on the Bartlett Experimental Forest, New Hampshire. Species composition (Marquis 1969) was about one-half of the basal area (trees 0.5 in. dbh and larger) in paper birch and pin cherry, another 40% in beech, sugar maple, yellow birch, and aspen (primarily bigtooth aspen), and the remaining 10% in white ash, red maple, striped maple, conifers, and occasional stems of other species. Mean dbh of these stems was 1.8 in., and average basal area was 99 ft^2. The site was excellent: a fine-textured till over basal till; site index for paper birch was about 70 ft, base age 50.

Twenty 1/4 ac plots were laid out with 1 chain isolation strips between plots. An average of about 95 crop trees were selected and marked per plot (about 380 crop trees per acre). Preference was given to the birches, ash, and sugar maple in the upper crown classes with good bole quality; but beech and red maple, and stems of intermediate crown class, were accepted as well to maintain spacing and provide an adequate sample across species. The crop trees averaged 3.7 in. dbh in 1959. Then, the three treatments and control were assigned to plots, five replications of each:

1. Heavy Release: All trees competing directly with the crowns of each crop tree were removed.
2. Light Release: A maximum of one competing tree (the most competitive) around each crop tree was removed. In a few cases, where the crop tree was a strong dominant or the removal of a competing tree released two crop trees, no competitors were removed.
3. Species Removal: All aspen, pin cherry, and striped maple were removed as well as most red maple sprout clumps, regardless of their position with respect to the crop trees. In addition, these plots received a second treatment in 1975, a crop-tree release/fertilization application which removed about one-third the basal area and added lime and a complete fertilizer to about half the crop trees.
4. Control: No removal.

NOTE: Acknowledgements to David A. Marquis, Research Forester (retired), who initiated this study.

Table 1. Residual basal area per acre (ft^2) by treatment. Basal area for the species removal treatment refers to the initial (1959) treatment.

Treatment	Dbh 0.5 in.+	Dbh 1.5 in. + Mean	Range
Heavy	56	51	39–92
Light	72	60	53–69
Species	66	59	52–66
Control	100	94	76–108

The treatments were applied in late August, 1959, using sodium arsenite in frills, except in the few cases where crop trees were part of a sprout clump; here the release was done by cutting. Because of the large number of crop trees, the treatments resembled an areawide treatment. Residual basal areas were lowered appreciably by the treatments (Table 1), but the range within the treatments was quite large, especially within the heavy treatment and control.

To monitor the effects of release, up to four crop trees per species per plot were selected and numbered for repeated dbh measurements to 0.1 in. precision (Table 2). The remeasurement periods varied somewhat among treatments, but a common remeasurement was available for 1969 (age 35) and 1990 (age 56) following the initial measurement in 1959 (age 25). During the 31 yr period, about 22% of the original sample trees died and were not used in this study (Table 2). Much of the mortality was in paper birch, primarily in small trees and mostly during the last growth period (1975–1990); apparently, the small birch had been overtopped by more tolerant species. Although the mortality seems high, records on the entire stand showed that roughly two-fifths to three-fifths of the trees (> 1.5 in. dbh) died over the 31 yr period regardless of treatment.

The analysis consisted of plotting average sample-tree dbh by species and treatment over the 31 yr period, based solely on trees that lived throughout the period, followed by regression analysis of the effects of initial sample-tree dbh and basal area on 1990 dbh (the species removal was eliminated from the latter analysis because of the double treatment using two different approaches). We used 1990 dbh as the dependent variable, rather than growth (change in dbh), because this provides a very practical overview of the tree sizes that can be attained over time from the various treatments. We used basal area in trees >1.5 in. dbh, rather than >0.5 in. as in the 5 yr analysis, since the small understory trees were not competing for sunlight with the crop trees.

Table 3. Regression coefficients for 1990 dbh (in.) = Constant (C) + Initial dbh (D, in.) + Initial dbh × Residual Basal Area (DBA, basal area in ft^2/ac, trees 1.5 in. dbh +). Levels of significance: * = $P < 0.05$, ** = $P < 0.01$.

Species	C	D	DBA	Adjust. R^2
Paper birch	1.966	1.715 **	−0.005 *	0.68
Sugar maple	−1.715	3.035 **	−0.006 *	0.80
Yellow birch	0.151	1.802 **	−0.003	0.62
White ash	1.292	1.733 **	0.005	0.69
Beech	0.708	2.005 **	−0.009 *	0.43
Red maple	−1.063	2.799 **	−0.007 *	0.73

Several regression models were tried, all providing somewhat different interpretations. As with the 5 yr analysis, initial dbh of the sample trees was a strong predictor of 1990 dbh. Plot basal area (trees 1.5 in. dbh and larger) was used rather than release treatments (as dummy variables) since it usually was a stronger predictor and helped account for the wide range in residual basal area produced within each treatment. Both basal area and the interaction between basal area and initial tree diameter were significant predictors for most species, but not when used in the same regression equation. We chose to use the interaction term, rather than basal area alone, since it seemed biologically reasonable that the effects of basal area would vary with tree size. The use of the interaction term tended to emphasize the practical differences among treatments, especially in the larger tree sizes, although there was not much difference in precision between the regression model with interaction as compared to the use of basal area without interaction. Crown class, which had been determined (six classes) for each sample tree prior to treatment, also was tested by regression; however, it was significant for only two species (red maple and yellow birch) and added a small amount to the regression precision when used in combination with initial tree size.

Results

We discuss results by species: looking first at trends over time in average sample-tree dbh (Figure 1) and then the predictions of 1990 dbh from regression analysis (Figure 2, regression coefficients in Table 3).

Paper Birch

Paper birch showed a slower rate of increase in average sample-tree dbh between 1969–1990 as compared to 1959–

Table 2. Numbers of sample trees living in 1990 by treatment, and number that died since 1959.

Treatment	Status	Paper birch	Sugar maple	Yellow birch	White ash	Beech	Red maple	All
Heavy	Alive	10	20	15	15	7	13	80
	Dead	10	0	5	0	2	1	18
Light	Alive	15	19	12	12	17	7	82
	Dead	5	1	5	0	1	2	14
Species	Alive	4	17	10	8	15	11	65
	Dead	16	2	10	5	2	2	37
Control	Alive	9	14	18	9	18	7	75
	Dead	10	2	3	1	0	2	18
All	Alive	38	70	55	44	57	38	302
	Dead	41	5	23	6	5	7	87

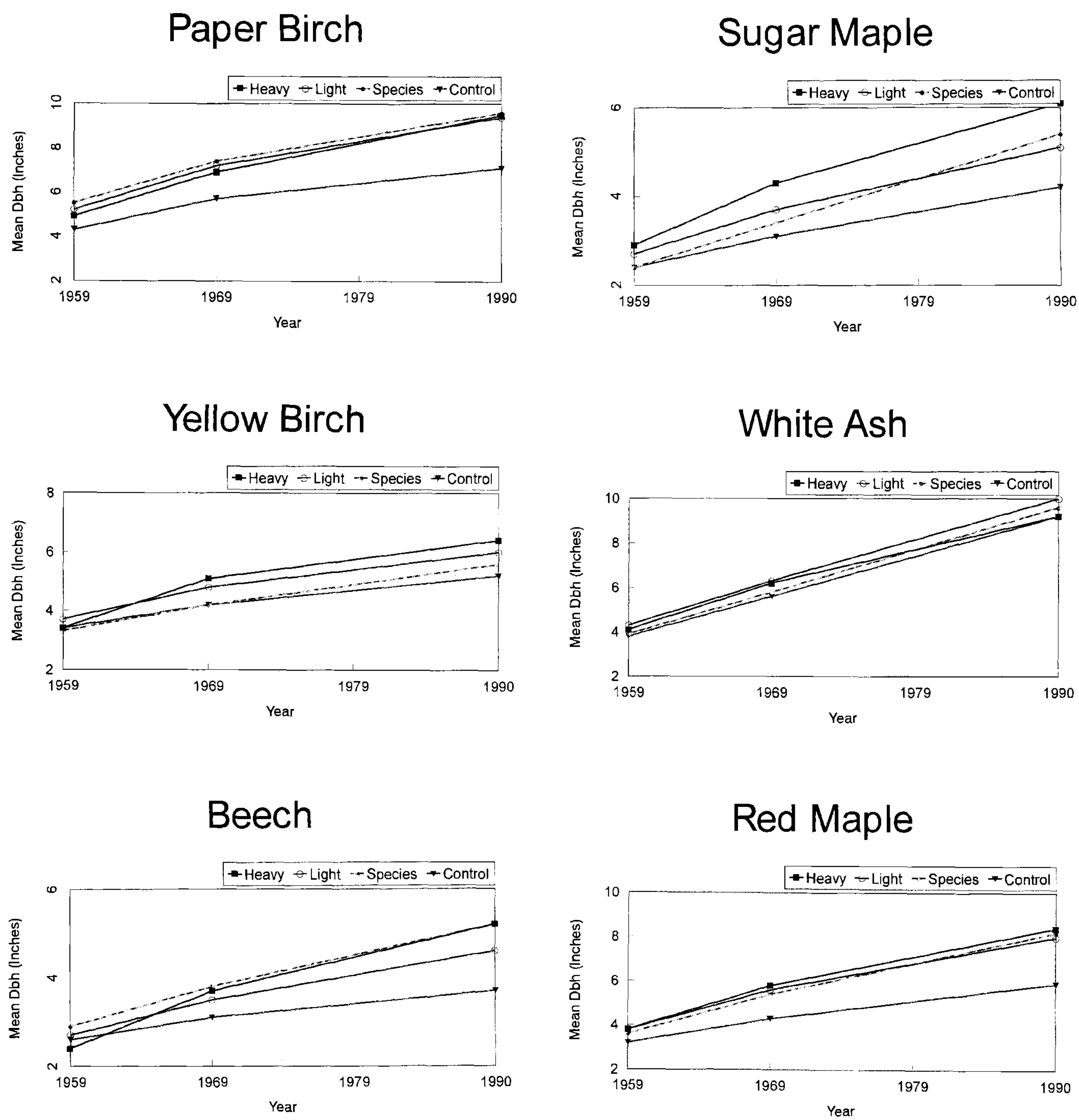

Figure 1. Average dbh by year for sample trees living throughout the period from 1959 through 1990, by species.

1969 (Figure 1). By 1990, the average dbh on control plots was about 2 in. less than on the heavy release plots; diameters on the other treatments were slightly above or below the heavy. However, note that the initial dbh varied among treatments: the control sample trees initially were smaller than the samples in the three treatments. This problem was dealt with by the regression analysis.

The regression model showed (Figure 2) that the 1990 dbh is positively related to initial sample-tree dbh, and negatively related to initial basal area. The effects of basal area vary with initial sample-tree size; large trees responded better than small ones. At initial tree sizes of 4 to 5 in., 1990 tree sizes on plots at 40 ft^2 of initial basal area are 1 to 1.5 in. larger than those on plots at 100 ft^2 of initial basal area. For initial diameters of 6 to 7 in., 1990 dbh's approach 2 in. larger under 40 ft^2 basal area as compared to 100 ft^2 of basal area.

Sugar Maple

Average sample-tree dbh over time showed a slower rate of increase between 1969–1990 as compared to 1959–1969 (Figure 1). The heavy-release treatment resulted in about a 2 in. greater dbh in 1990 than the control while the other treatments had an intermediate effect. As with paper birch, initial sample-tree diameters varied among treatments.

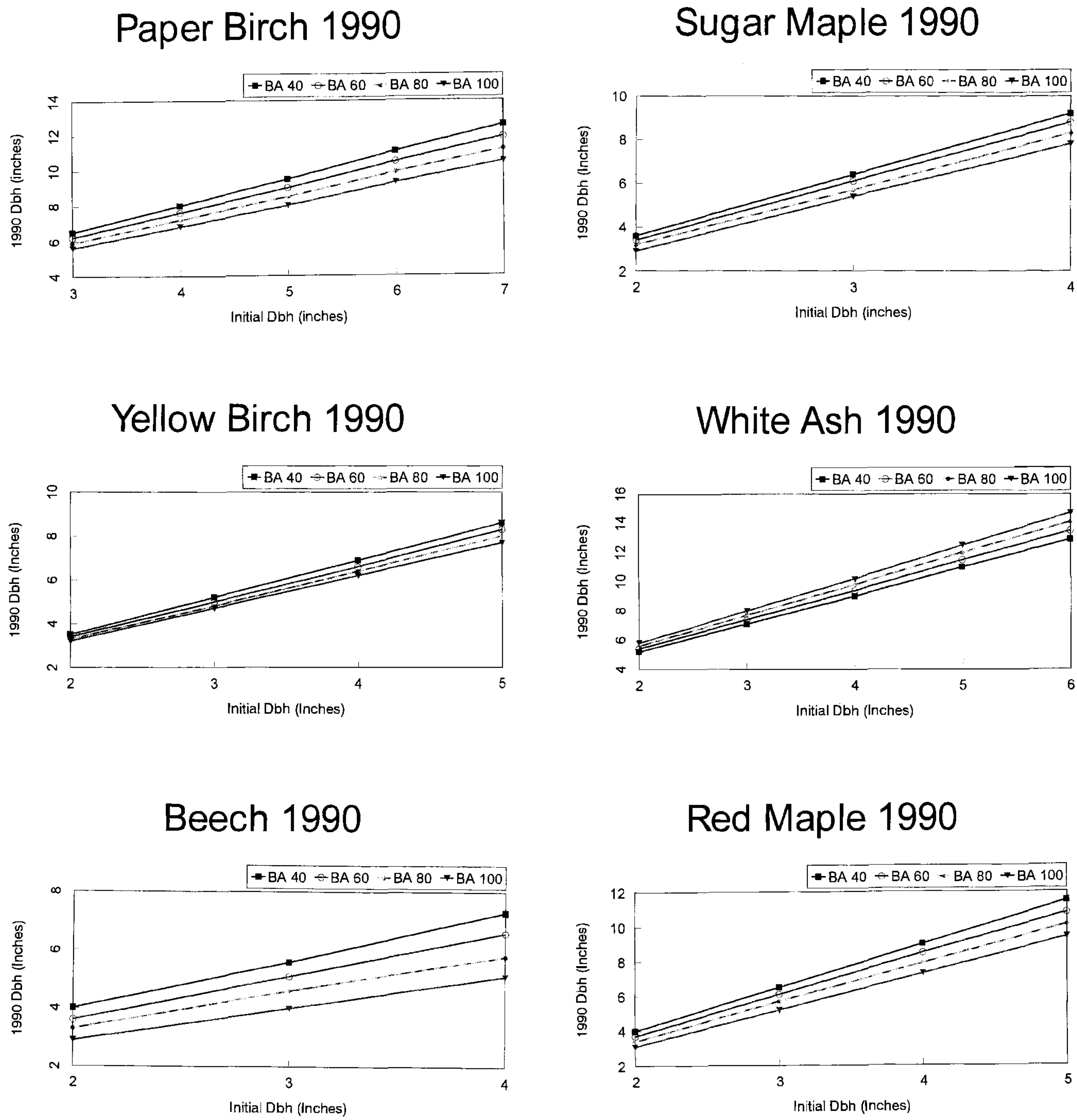

Figure 2. Regression estimates of 1990 dbh related to initial dbh (1959) and the interaction between 1959 dbh and initial residual basal area for the heavy and light release treatments and the control, by species.

The regression model, which accounted for different initial tree sizes, showed that the difference in 1990 dbh between low and high initial basal areas is about 1 in. or less (Figure 2).

Yellow Birch

The average rate of increase in sample-tree dbh was less between 1969–1990 than 1959–1969, especially for the heavy-release treatment (Figure 1). The difference in 1990 dbh between heavy release and the control was about 1 in. Initial sample-tree dbh averaged about the same for these two treatments.

In the regression model (Figure 2), the interaction of basal area and initial dbh was not significant ($P = 0.20$). Additional analyses showed that basal area by itself had no significant effect. However, the consistency of the responses in both Figures 1 and 2 suggests that the treatments did accelerate dbh growth but that the effects were obscured by high variability. Initial dbh did have an appreciable effect.

White Ash

Average sample-tree dbh increased fairly regularly over the 31 yr period, and differences among treatments in 1990 dbh were inconsistent . the heavy release and control ended up with a similar average dbh, slightly below that of the other treatments (Figure 1).

The regression model (Figure 2) showed no significant effect of the interaction term (initial dbh × basal area) and the predicted values of 1990 dbh reversed the usual order: predicted 1990 dbh was higher in proportion to initial basal area.

Beech

Increase in average sample-tree dbh was less rapid between 1969–1990 than 1959–1969, especially for the heavy-release treatment (Figure 1). The difference in 1990 dbh was more than 1 in. greater under the heavy release as compared to the control, even though the latter had a higher average initial dbh.

The regression model illustrated (Figure 2) that low initial basal areas can result in increased 1990 diameters of up to about 2 in., depending on initial sample-tree dbh.

Red Maple

Rate of increase in average sample-tree dbh declined somewhat after 1969 (Figure 1). All of the release treatments produced similar 1990 diameters, about 2 in. larger than the control. However, the control had a smaller initial average tree size.

The regression model shows (Figure 2) gains of up to 2 in. in 1990 dbh, at the largest initial tree sizes, under the lowest basal area levels.

Discussion and Applications

This study dealt with a single application of a heavy and a light release treatment and a species removal treatment coupled with a crop-tree release 16 yr later. The results from the heavy and light release treatments might have been different with more than one application, although the species removal/release combination did not produce a superior response. However, because of the costs involved in precommercial treatments, and the long (100–120 yr) rotations common in northern hardwoods, the use of a single precommercial treatment is a logical option.

Several practical implications came from this study. Two species (white ash and yellow birch) did not show any significant response to treatment in terms of increased final dbh. However, final dbh was strongly related to initial dbh. The 5 yr results from this study showed only minimal responses in white ash, but substantial responses with yellow birch (Marquis 1969). Other studies in both New England and the Lake States have shown appreciable short-term growth responses in sapling-sized yellow birch following release (Erdmann et al 1975, Erdmann et al 1981, Hannah 1978). Based on our results, and these citations, we suggest that single precommercial treatments are not warranted for white ash and yellow birch, but that more than one precommercial treatment might maintain a growth advantage in yellow birch. Possibly, release of these species could be justified on the basis of improvement in species mix and average bole quality of the stand. However, a detailed analysis of stand development showed that these release treatments had very little impact on stand characteristics.[1]

The other four species showed significant responses to treatment or lowered basal area. The maximum response came from releasing larger-than-average trees, which would be in the dominant and upper codominant crown classes. With paper birch and red maple, the heaviest release increased the final dbh of the larger trees by about 2 in. as compared to the control. In other words, trees that were about 5 in. (red maple) or 6–7 in. (paper birch) dbh in 1959 were close to 12 in. dbh in 1990 following a heavy release and about 10 in. dbh in 1990 with no release. With beech, the maximum increase was a little more than 2 in. With sugar maple, the increase over controls was a little over 1 in. Whether these long-term responses to release are large enough to warrant a precommercial investment depends on market expectations and treatment costs. Although this study did not follow long-term changes in tree quality, the 5 yr analysis showed no real differences among treatments in general bole quality, forks, and epicormic branching (Marquis 1969).

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