INTENSITY OF PRECOMMERCIAL CROP-TREE RELEASE INCREASES DIAMETER AND CROWN GROWTH IN UPLAND HARDWOODS

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Abstract: In 1988 seven study areas were established in Connecticut to examine the effects of precommercial crop tree release on bole and crown growth. Each study area has 27 8x8 m plots centered on a northern red oak, black oak, or scarlet oak identified as a potential crop-tree (PCT). The 27 plots at each study area were divided into 3 treatments: no cutting, removal of all stems with crowns within 1 m of the crown of a PCT, and removal of all stems with crowns within 1 m of the crowns of a PCT and 2 other potential crop-trees. After cutting, 7191 stems remained. A consequence of crop-tree release is the partial release of trees surrounding crop-trees. The percentage of release of these surrounding trees was assessed in 25% increments. Diameter growth increased with amount of release and crown class. Relative to unreleased trees, 4-yr diameter growth of northern red oak increased by 86%, black/scarlet oak by 65%, red maple by 56%, and black birch by 52%. Release slowed height growth of dominant and codominant oaks for only the first 2 yr. In sapling stands with few oaks in upper canopy positions, precommercial release could be used to augment oak density. Survival and diameter growth of oaks in the intermediate and suppressed crown classes increased with release intensity. Release also increased height growth of northern red oak in the suppressed crown classes.

INTRODUCTION

Approximately 59% of Connecticut's land area is classified as commercial forest and more than half of the forest is oak-hickory (Dickson and McAfee 1988). Many of these forest stands were established around 1900 and are becoming economically mature. Sawtimber stand area has increased from 17% of commercial forest area in 1952 to 35% in 1972. There has been a concurrent 81% increase in the volume of sawtimber harvested (Dickson and Bowers 1976).

One consequence of the increased harvesting is an increase in the number and area of sapling stands. Unfortunately, many sapling stands are dominated by less valuable species such as red maple and black birch. The shift towards more mesophytic species following final harvest of mature oak forests has been noted throughout the central hardwood region (Lorimer 1989). The change in species composition will affect not only the quality and makeup of forest products available to future generations, but will also affect the quality and variety of wildlife habitats (Scanlon 1992).

Precommercial crop-tree release provides an opportunity to simultaneously manipulate stand composition and concentrate growth on individual stems of high value species. Growth concentrated on high value species by crop-tree release increases the value of the mature stand. Increasing the growth of individual stems shortens the rotation by reducing the time needed to grow stems to a desired size. However, crop-tree release is risky in that the management effort is concentrated on relatively few stems (Trimble 1974) and degradation of bole quality is possible (Holsoe 1947, Lamson and Smith 1978, Sonderman 1985, 1986).

Precommercial thinning generally increases individual stem diameters relative to stems in unthinned stands (Downs 1946, Holsoe 1947, Allen and Marquis 1970, Della-Bianca 1975). Although release usually increases diameter growth of northern red oak (Trimble 1974, Lamson and Smith 1978, Lamson 1983, Pham 1985, Sonderman 1985), some

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studies have reported no diameter growth gain (Trimble 1974, Smith 1977, Lamson 1988). Precommercial release has also increased diameter growth of scarlet oak (Mitchell and others 1985), red maple (Marquis 1969, Trimble 1974, Smith 1977, Lamson 1983, Pham 1985, Lamson 1988) and black birch (Smith and Lamson 1983).

The effect of release on height growth is less clearly understood. Downs (1946) and Sonderman (1986) reported increased total height growth was associated with precommercial thinning. Other studies found height growth was unaffected (Hilt and Dale 1982), or reduced (Holsoe 1947, Allen and Marquis 1970) by thinning. Release generally has been reported to have little effect on height growth of oaks (Trimble 1974, Smith 1977, Sonderman 1985, Mitchell and others 1985), red maple (Trimble 1974, Smith 1977, Lamson 1983, Sonderman 1985), and black birch (Smith and Lamson 1983).

Oak may have a 2-stage height growth response to release. Lamson (1983) reported 5-yr height growth of northern red oak was reduced by release, but that heights of released and unreleased trees were similar after 10 yr (Lamson 1988). Similarly, Trimble (1974) found the 5-yr height growth of released and unreleased northern red oak were similar because released trees grew slower for 2-yr and then faster the next 3-yr.

The objective of this study was to determine how intensity of crown release affected survival, diameter and height growth of hardwood saplings. These results will provide information for forest managers considering precommercial crop-tree release to alter stand composition and concentrate growth on selected trees on the eastern boundary of the central hardwood forest.

METHODS

Study Design

Seven study areas (stand ages 7-22 yr) were established in 1988 in western and central Connecticut (Table 1). Canopy closure was complete on all plots at the beginning of the study. Each study area has 27 8x8 meter plots (1/63 ac). Each plot was centered on a northern red, black, or scarlet oak identified as a potential crop-tree (PCT). Within each plot, location of each stem (> 2 cm dbh) was mapped and stem diameter (at 1.4 m aboveground), crown class (Smith 1962), and top height of live crown were recorded. Diameter height was permanently marked with paint. Diameter measurements were to nearest millimeter. Height measurements to the nearest decimeter were made with 10.5 and 13.5 m telescoping poles. A total of 9429 stems were mapped and measured. Diameter and crown class have been

Table 1. Description of study areas used in precommercial thinning study in Connecticut and median initial size of dominant and codominant northern red/black/scarlet oaks.

Study area	Stand age	Site quality	Number of stems on plots: Before cutting	After cutting	Median initial size: Dbh (cm)	Height (m)
Tunxis	7	High	2023	1660	4.4	6.3
Hunter's Mountain	11	Medium	1318	972	4.8	6.9
Overlook	12	Low	1414	1120	4.1	5.9
Blueberry	12	Low	1196	920	3.9	5.4
Woodchopper	15	Medium	1185	856	6.0	7.5
Mott Hill	19	High	1128	795	6.8	8.6
Rockytop	22	Low	1165	868	6.7	7.1

measured yearly on all live trees during the dormant season. Because of time constraints, heights were not remeasured on all plots the same year. Heights on the Tunxis plot remeasured in 1989 and 1991. Heights on all other plots were remeasured in 1990 and 1992.

At each study area, the 27 plots were divided among 3 treatments: no cutting within the plot (control); removal of all stems with crowns within 1 m of the crown of a PCT; and removal of all stems with crowns within 1 m of the crown of three PCTs. All cutting was done after the 1988 growing season. After cutting, 7191 stems remained. It became apparent after cutting that many trees surrounding PCTs on the thinned plots had been partially released (Fig. 1). This provided an opportunity to examine growth response to partial release. Therefore, the percent release of trees surrounding PCTs was assessed in 25% increments. This rating system is similar to the free-to-grow rating system detailed in Lamson and others (1990). Trees on control plots were assigned a release factor of 0%.

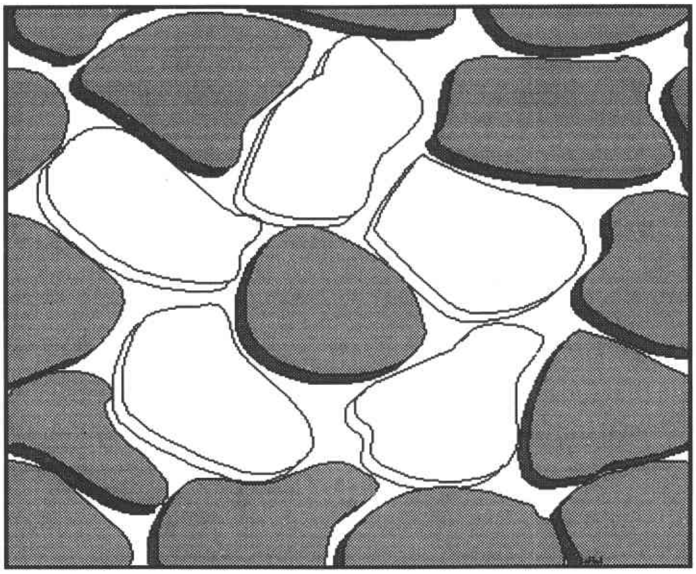

Figure 1. Hypothetical crown map of upper canopy trees with released crop-tree (dark shaded in center), cut trees (unshaded), and surrounding trees.

Data Analysis

Four species groups were selected for analysis: northern red oak (*Quercus rubra*), black/scarlet oak (*Q. velutina*, *Q. coccinea*), red maple (*Acer rubrum*), and black birch (*Betula lenta*). Number of trees in each combination of crown class and species group are shown in Table 2. Tukey HSD test (SYSTAT 1992) was used to test differences in diameter and height growth among crown classes, release categories, and release categories by crown class. Least square means are presented in tables of combined crown classes and release categories to adjust for larger sample sizes in lower crown classes and lesser release categories. Chi-square statistics were used to determine whether mortality/survival was independent of crown class and release factor. Differences were considered significant at $P \leq 0.05$.

Table 2. Number of saplings in Connecticut by crown class, percent release, and species.

Initial Crown class	Percent release	Northern red oak	Scarlet\ Black oak	Red maple	Black birch
Dominant	0-100%	127	129	185	144
Codominant	0-100%	200	203	516	156
Intermediate	0-100%	238	242	704	164
Suppressed	0-100%	188	150	659	131
Combined classes	0- 24%	440	432	1328	398
Combined classes	25- 49%	128	138	406	109
Combined classes	50- 74%	63	69	232	48
Combined classes	75-100%	122	85	98	40
Dominant	0- 24%	54	69	111	90
Dominant	25- 49%	10	16	24	19
Dominant	50- 74%	9	13	29	19
Dominant	75-100%	54	31	21	16
Codominant	0- 24%	103	115	318	101
Codominant	25- 49%	28	28	93	25
Codominant	50- 74%	21	27	62	11
Codominant	75-100%	48	33	43	19
Intermediate	0- 24%	149	161	462	118
Intermediate	25- 49%	53	55	149	32
Intermediate	50- 74%	19	13	72	12
Intermediate	75-100%	17	13	21	2
Suppressed	0- 24%	134	87	437	89
Suppressed	25- 49%	37	39	140	33
Suppressed	50- 74%	14	16	69	6
Suppressed	75-100%	3	8	13	3

RESULTS

Diameter growth

Median diameter of dominant and codominant northern red, black, and scarlet oaks at the beginning of the study ranged from 3.9 cm (1.5 in) on the Blueberry plot to 6.8 cm (2.7 in) on the Mott Hill plot (Table 1). Diameter growth was not independent of either the degree of release or crown class (Table 3). Releasing trees more than 75% (complete release) nearly doubled diameter growth compared with unreleased trees. Diameter growth of dominant trees was more than 5 times greater than for suppressed trees. All crown classes responded to release. Within each crown class, 4-yr diameter growth of completely released trees was approximately 1 cm (0.4 in) more than for unreleased trees.

Table 3. 4-yr diameter growth (cm) of saplings in Connecticut by crown class, percent release, and species.

Initial Crown class	Percent release	Northern red oak		Scarlet\ Black oak		Red maple		Black birch	
Dominant	0-100%	3.08	a[a]	3.38	a	1.81	a	2.88	a
Codominant	0-100%	2.16	b	2.14	b	1.34	b	1.88	b
Intermediate	0-100%	1.33	c	1.25	c	.74	c	1.13	c
Suppressed	0-100%	.83	d	.63	d	.41	d	.65	c
Combined classes	0- 24%	1.37	a	1.42	a	.81	a	1.27	a
Combined classes	25- 49%	1.67	b	1.58	a	.96	b	1.61	b
Combined classes	50- 74%	1.80	b	2.05	b	1.25	c	1.74	b
Combined classes	75-100%	2.56	c	2.34	b	1.26	c	1.92	b
Dominant	0- 24%	2.50	a	2.75	a	1.59	a	2.45	a
Dominant	25- 49%	3.12	ab	3.33	ab	1.57	a	2.96	a
Dominant	50- 74%	-[b]		3.75	b	2.14	b	3.11	a
Dominant	75-100%	3.79	b	3.69	b	1.94	ab	3.00	a
Codominant	0- 24%	1.77	a	1.64	a	.96	a	1.63	a
Codominant	25- 49%	1.84	a	1.82	ab	1.26	b	1.81	ab
Codominant	50- 74%	2.12	a	2.22	bc	1.62	c	1.77	ab
Codominant	75-100%	2.90	b	2.87	c	1.50	bc	2.29	b
Intermediate	0- 24%	.85	a	.92	a	.49	a	.71	a
Intermediate	25- 49%	1.16	b	.71	a	.64	b	1.08	b
Intermediate	50- 74%	1.25	b	1.32	ab	.88	b	1.19	b
Intermediate	75-100%	2.07	c	2.06	b	.94	b	-	
Suppressed	0- 24%	.36	a	.38	a	.19	a	.27	a
Suppressed	25- 49%	.56	b	.48	a	.39	b	.61	b
Suppressed	50- 74%	.91	c	.92	b	.38	b	-	
Suppressed	75-100%	-		-		.68	b	-	

[a] Values within a column followed by the same letter were not significantly different at $P \leq 0.05$. Tested using Tukey HSD test.
[b] Less than 10 trees.

Diameter growth of all species groups was increased by release. Release had a greater effect on the diameter growth of oaks than on red maple and black birch (Table 3). Relative to unreleased trees, 4-yr diameter growth of completely released northern red oaks was increased 1.2 cm, black/scarlet oak by 0.9 cm, black birch by 0.7 cm, and red maple by 0.5 cm. Diameter growth within a crown class for each species group also increased with thinning intensity (Table 3).

Diameter growth of released dominant and codominant trees has been greater than unreleased trees through the first 4 years (Fig. 2). Decreased growth during the 1990 and 1991 growing seasons was probably related to extended mid-summer droughts. Annual diameter growth of northern red oak, black oak, and scarlet were similar and greater than for black birch and red maple.

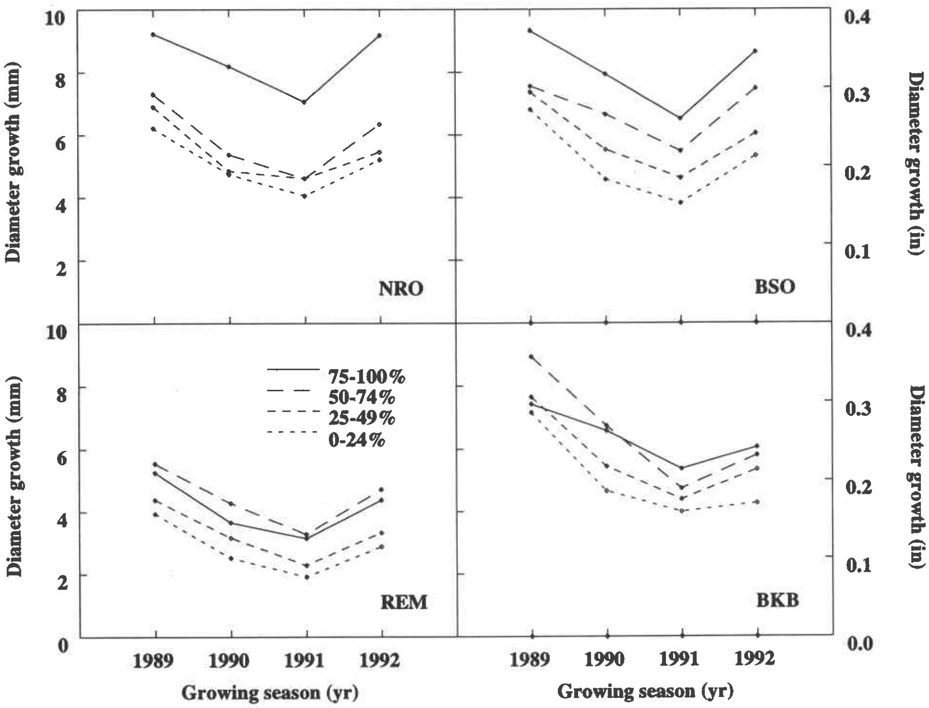

Figure 2. Mean annual diameter growth (mm) of upper canopy trees (dominant and codominant) by year, percent release (0-24%, 25-49%, 50-74%, 75-100%), and species group (NRO-northern red oak, BSO-black/scarlet oak, REM-red maple, BKB-black birch).

Height growth

Median initial heights ranged from 5.4 m (18 ft) on the Blueberry plot to 8.6 m (28 ft) on the Mott Hill plot (Table 1). Median height on most plots was less than the 7.6 m (25 ft) recommended by (Perkey and Wilkins 1994). Height growth was independent of the degree of release, but not crown class (Table 4). Four year height growth of dominant trees, 1.8 m (5.9 ft), was more than 3 times that of suppressed trees, 0.5 m (1.6 ft). There was an interaction between the degree of release and crown class for height growth. Release slowed height growth of taller trees and increased height growth of smaller trees. Height growth of unreleased dominant and codominant trees was greater than for completely released trees. In contrast, height growth of unreleased suppressed trees was significantly less than for trees released 50-75% when, because of small sample size, completely released trees were removed from the analysis.

Release resulted in significant height growth depression codominant black/scarlet oak and red maple (Table 4). Height growth depression of dominant northern red oak by release was not significant ($P \leq 0.058$). Although height growth of suppressed northern red oak and red maple saplings which were completely released was greater than for unreleased trees, the increase was only significant for northern red oak.

Height growth depression on codominant and dominant oaks by release was short-term (Figure 3). ANOVA of height growth between 1988-1990 revealed significant differences among release intensities ($F = 5.56$, d.f. = 3, $P \leq 0.001$). Mean 2-yr height growths between 1988-1992 ranged from 1.0 m for unreleased trees to 0.8 m for completely released trees. There was no significant difference of height growth between 1990-1992 among release intensities ($F = 0.30$, d.f. = 3, $P \leq 0.829$).

Table 4. 4-yr height growth (m) of saplings in Connecticut by crown class, percent release, and species.

Initial Crown class	Percent release	Northern red oak		Scarlet\ Black oak		Red maple		Black birch	
Dominant	0-100%	2.00	a[a]	2.30	a	1.41	a	1.80	a
Codominant	0-100%	1.80	a	1.85	b	1.31	a	1.74	a
Intermediate	0-100%	1.31	b	1.38	c	.88	b	1.44	a
Suppressed	0-100%	.71	c	.52	d	.50	c	.64	b
Combined classes	0- 24%	1.38	a	1.54	a	1.12	a	1.28	a
Combined classes	25- 49%	1.44	a	1.44	a	1.05	a	1.35	ab
Combined classes	50- 74%	1.49	a	1.60	a	.99	a	1.70	b
Combined classes	75-100%	1.51	a	1.47	a	.95	a	1.29	ab
Dominant	0- 24%	2.01	a	2.30	a	1.60	a	1.78	a
Dominant	25- 49%	2.26	a	2.38	a	1.51	a	1.98	a
Dominant	50- 74%	-[b]		2.31	a	1.31	a	2.01	a
Dominant	75-100%	1.70	a	2.21	a	1.22	a	1.42	a
Codominant	0- 24%	1.97	a	2.03	a	1.45	a	1.83	a
Codominant	25- 49%	1.72	a	1.81	ab	1.39	ab	1.62	a
Codominant	50- 74%	1.71	a	1.92	ab	1.30	ab	1.89	a
Codominant	75-100%	1.79	a	1.66	b	1.11	c	1.62	a
Intermediate	0- 24%	1.23	a	1.36	a	1.02	a	1.07	a
Intermediate	25- 49%	1.38	a	1.23	a	.84	a	1.43	a
Intermediate	50- 74%	1.22	a	1.60	a	.84	a	1.65	a
Intermediate	75-100%	1.40	a	1.31	a	.83	a	-	
Suppressed	0- 24%	.29	a	.49	a	.41	a	.44	a
Suppressed	25- 49%	.41	ab	.32	a	.46	a	.38	a
Suppressed	50- 74%	1.00	b	.59	a	.50	a	-	
Suppressed	75-100%	-		-		.63	a	-	

[a] Values within a column followed by the same letter were not significantly different at $P \leq 0.05$. Tested using Tukey HSD test.

[b] Less than 10 trees.

Mortality

Release reduced 4-yr mortality rates for smaller, but not larger trees (Table 5). Mortality rates were significantly different among release levels for suppressed ($\chi^2 = 47.60$, d.f. = 3, $P \leq 0.001$) and intermediate trees ($\chi^2 = 8.15$, d.f. = 3, $P \leq 0.043$). Mortality rates for unreleased suppressed and intermediate trees was more than 3 times higher than for completely released trees. Releasing suppressed trees decreased mortality for all species groups (Fig. 4). Mortality rates of codominant and dominant trees were independent of release intensity (Table 5).

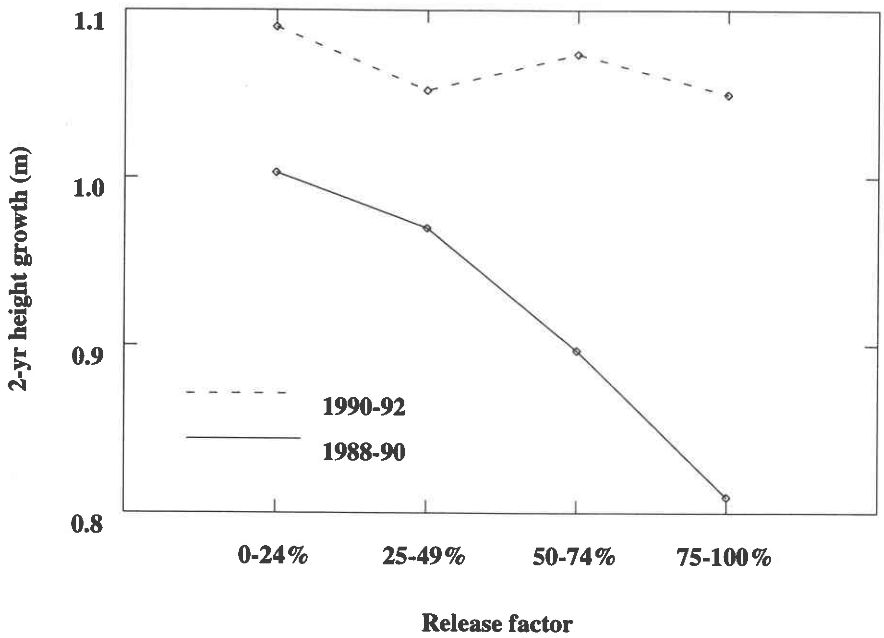

Figure 3. 2-yr height growth (m) of upper canopy oaks between 1988-1990 and 1990-1992 by percent release.

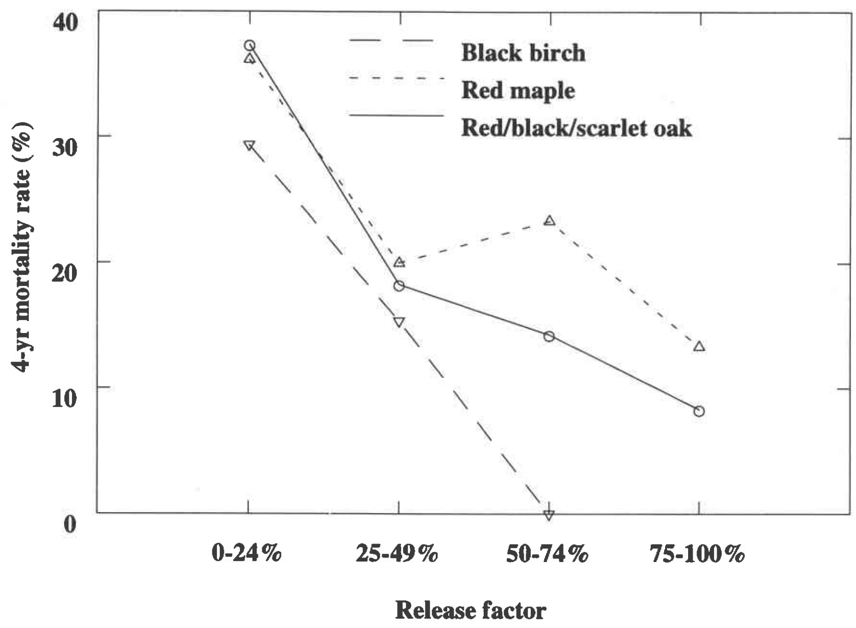

Figure 4. 4-yr mortality rates of suppressed trees by percent release and species group.

Table 5. 4-yr mortality rates (%) of saplings in Connecticut by crown class and release intensity.

Percent release	Crown class in 1988 Suppressed	Intermediate	Codominant	Dominant
0- 24%	35.8	6.2	1.9	1.8
25- 49%	18.9	2.4	1.7	1.4
50- 74%	20.0	4.9	0.8	0.0
75- 100%	10.0	1.9	2.1	2.4

DISCUSSION

Precommercial thinning increased diameter growth of both dominant and codominant trees. Both the diameter growth and the increase in growth with degree of release are similar to results in West Virginia (Lamson and others 1990). Not surprisingly, diameter growth response to complete release was greater for codominant trees, 80% increase, than for dominant trees, 47% increase. The diameter growth response of oaks was better than for red maple and black birch (Table 3). Released trees have continued to grow faster than unreleased trees for 4-yr after thinning. An earlier study suggests diameters of released trees should continue to grow faster than unreleased trees for 6 yr (Lamson 1988).

Unfortunately, release also decreased height growth of dominant and codominant oaks (Fig. 3). However, the depression of oak height growth was short-term and height growth 2-4 yr after release was independent of release. Trimble (1974) reported height growth of northern red oak was slower for 2 yr after release and then faster for next 3 yr. Because diameter growth of released upper canopy oak saplings continues to be greater than for unreleased trees, the short-term decreased height growth appears to be a transient and inconsequential phenomenon.

Precommercial crop-tree release dramatically and significantly increased diameter growth of saplings in intermediate and suppressed crown classes (Table 3) without negatively impacting height growth (Table 4). Releasing suppressed oaks was especially effective. Relative to unreleased trees, diameter growth of completely released intermediate trees increased by 145% and suppressed trees by 226% (Table 3). This study found that young suppressed oaks can response positively to release, unlike older suppressed oaks (Sander 1977). Reducing stocking to 10% doubled diameter growth of suppressed and intermediate oaks and yellow-poplar (Allen and Marquis 1970). Diameter growth of intermediate northern red oaks was increased by a cutting all trees within 5-ft of each crop-tree (Trimble 1974). However, partial release often does not increase diameter growth of intermediate oak saplings (Smith 1977, Lamson and Smith 1978). While this study did not find that release increased height of intermediate northern red oak as reported by Lamson and Smith (1978), release did not decrease height growth of intermediate oaks. Height growth of suppressed northern red oak was increased by release (Table 4).

There is little doubt that an immediate benefit of precommercial thinning is reduced mortality rates in the suppressed and intermediate crown classes (Fig. 3). Reduced mortality following precommercial thinning has been noted for northern red oak (Trimble 1974, Della-Bianca 1983, Pham 1985), scarlet oak (Mitchell and others 1985), and red maple (Trimble 1974, Pham 1985).

These results indicate that not only can precommercial release be used to increase growth of larger trees (Trimble 1974, Smith 1977, Lamson 1983,1988), but also intermediate and suppressed trees (Allen and Marquis 1970). The ability of suppressed oak saplings to respond to release provides forest managers with a technique to increase oak densities in sapling stands with few oak in upper canopy positions. It is likely that suppressed and intermediate trees will need to be released at least once more to assure their continued presence in the upper canopy. While precommercial crop-tree release is difficult to justify on an economic basis (Dwyer and others 1993), the practice may be profitable for valuable species on high quality sites (Miller 1986). Increasing oak density also increases wildlife and esthetic values.

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