Crown releasing of red maple poles to shorten high-quality sawlog rotations

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The effects of six crown-release treatments on growth and bole quality development of 54-year-old dominant, codominant, and intermediate red maples (*Acer rubrum* L.) were evaluated on a good red maple site (site index = 19.3 m at 50 years) in upper Michigan. Results showed that crown release stimulated the growth of dominants, codominants, and strong intermediates without appreciably degrading log quality. The heavier 1.5- to 4.6-m crown-release treatments resulted in 7-year average DBH growth increases over the unreleased controls of 70% for dominants, 96% for codominants, and 108% for intermediates. Crown release had no effect on 8-year height growth, 3-year epicormic branching, or bole quality. Three years after treatment, unreleased trees had almost as many epicormic branches as released trees. The number of epicormic branches on individual trees was a function of dominance, log position, or height above ground, but was not related to residual stand density. Epicormic branching was also strongly correlated with the number of pretreatment epicormic branches on boles of intermediate trees, but not on dominant or codominant trees.

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Les effets de six traitements de dégagement de la cime sur la croissance et le développement qualitatif du fût d'érables rouges (*Acer rubrum* L.) âgés de 54 ans et occupant des positions dominante, co-dominante et intermédiaire furent évalués sur une station propice à cette essence (indice de fertilité de 19,3 m à 50 ans) dans le nord du Michigan. Les résultats indiquent que le dégagement des cimes a stimulé la croissance des dominants, des co-dominants et des plus forts sujets intermédiaires sans déprécier indûment la qualité des fûts. Les traitements les plus intensifs (dégagement de 1,5–4,6 m) ont produit, par rapport aux sujets non dégagés, des accroissements en diamètres supérieurs de 70% chez les dominants, 96% chez les co-dominants et 108% chez les intermédiaires sur une période de 7 ans. Les dégagements de la cime n'ont eu aucun effet sur la croissance en hauteur durant 8 ans, la formation de branches adventives durant 3 ans et la qualité des fûts. Après trois ans, les sujets non dégagés présentaient presque autant de branches adventives que ceux qui l'avaient été. Le nombre de ces branches dépendait de la position des sujets individuels dans le couvert végétal et de la position de la bille le long du fût, mais n'était pas relié à la densité du peuplement. La formation des branches adventives était fortement corrélée au nombre de ces branches présentes avant le traitement sur les fûts des sujets intermédiaires, mais non chez les sujets dominants ou co-dominants.

[Traduit par le journal]

Introduction

Recent dramatic increases in red maple (*Acer rubrum* L.) stocking and volumes have been reported in Michigan, the northeastern states, and eastern Canada. In northern Michigan, red maple now accounts for the first or second largest volume of growth on hardwood growing stock, yet the red maple resource is being underutilized (Jakes 1982; Smith 1982; Spencer 1982). Red maples are also abundant and underutilized in northern Wisconsin (Spencer and Thorne 1972). The majority of these Lake State stands are pole sized and less than 80 years old. Red maple growing stock volume and acreage are rapidly expanding in northern hardwood or mixed hardwood stands because of the species' intermediate shade tolerance, regular seed supply, minimum seedbed requirements, delayed germination ability, prolific sprouting, and relatively fast growth, particularly after heavy cutting or high grading.

Red maple is a moderately tolerant, short- to medium-lived species that grows on a wide variety of sites ranging from extremely droughty upland sands to lowland swamps. It grows in association with many commercial species, but reaches its best development on moist, fertile, loamy soils in the sugar maple – beech – yellow birch (No. 25), sugar maple (No. 27), black ash – American elm – red maple (No. 39), and red maple (No. 108) Society of American Foresters (SAF) cover types (Eyre 1980).

Large diameter red maple sawlogs are valuable in the manufacture of soft maple furniture. Red maple wood is softer than that of sugar maple, but can be substituted for it for most purposes. To date, very little is known about managing red maple in pure or mixed stands in the United States or Canada. Red maple has a poor reputation as a sawlog species because of its poor form when grown in sprout clumps and because of the defects and decay often associated with it.

Crop tree release is a low-cost alternative for improving growth rates and concentrating growth on the highest quality trees in a stand. More intensive culture of red maple crop trees would shorten sawlog rotations and help alleviate the short supply of high-quality sugar maple sawlogs.

In 1976, we established a study to determine the effects of six crown-release treatments on the growth and bole quality development of dominant, codominant, and intermediate pole-size red maple crop trees growing in an even-aged stand. Early results are reported here.

[1]Revised manuscript received March 26, 1985.

Study area

This cooperative study with the Michigan Department of Natural Resources was established in a 54-year-old, even-aged northern hardwood stand on the Escanaba River State Forest near Sands, MI, U.S.A. The stand is growing on a level site about 8 km south of Lake Superior at an elevation of 335 m. It became established following commercial clear-cutting and wildfire that undoubtedly eliminated most advance sugar maple regeneration and left huge charred pine stumps. The soil is a Rousseau fine sand (sandy, mixed, frigid Entic Haplorthods), a very weakly developed spodosol, which formed on outwash plains. This spodosol intergrades to a Kalkaska variant (sandy, mixed, frigid Typic Haplorthods). Fine sand predominates in this soil, which is deep and well drained. Although most rooting occurs within the upper 28 cm of soil, occasional roots extend beneath the weakly cemented B32 horizon from 48 to 64 cm, with chunks of ortstein, to a depth of about 122 cm. The site index for red maple was estimated from stem analysis data to be 19.3 m at age 50 years. This is considered a highly productive site for red maple in Michigan and northern Wisconsin.

Before release, the uniformly stocked stand contained 1305 trees (10.2 cm DBH and larger) with a basal area of 27.5 m^2/ha. The stand was composed primarily of seedling-origin trees with only a few sprout clumps present. Species composition obtained from 108 circular 0.02-ha plots showed that red maple, sugar maple (*Acer saccharum* Marsh.), and paper birch (*Betula papyrifera* Marsh.) accounted for 64, 24, and 7% of the basal area, respectively (total of 95%). Other species present included yellow birch (*Betula alleghaniensis* Britton), balsam fir (*Abies balsamea* (L.) Mill.), black cherry (*Prunus serotina* Ehrh.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), aspen (*Populus grandidentata* Michx. and *Populus tremuloides* Michx.), white spruce (*Picea glauca* (Moench) Voss), pin cherry (*Prunus pensylvanica* L.f.), American mountain ash (*Sorbus americana* Marsh.), and northern red oak (*Quercus rubra* L.).

Methods

Six groups of dominant and five groups of both codominant and intermediate crown class red maple crop trees were selected from the study area for treatment comparisons. Only single-stemmed trees of seedling or possibly seedling–sprout origin were selected as study trees. Each group consisted of six individual trees that were well matched as to stem diameters (at DBH and at the top of the first and second log), total height, stem quality characteristics, and crown size and density. Initial DBHs ranged from 21.9 to 31.7 cm for dominant, 16.8 to 20.0 cm for codominant, and 13.0 to 15.2 cm for intermediate groups. The six intensities of release that were randomly applied to individual trees within each group were (*i*) unreleased control, (*ii*) single most important crown competitor cut, (*iii*) two most important crown competitors cut, (*iv*) crown of selected tree given complete release beyond its crown perimeter averaging 1.5 m for expansion, (*v*) released 3.0 m for expansion, and (*vi*) released 4.6 m for expansion. Crown-release treatments were applied to the 96 study trees before leaf out in May 1976. Each release treatment was represented by 16 trees (6 dominants, 5 codominants, and 5 intermediates). The single or two most important crown competitor release treatments have been commonly used in releasing crop trees in the Lake States.

Diameter growth at breast height was measured annually to the nearest 0.1 cm. Diameter at 5.3- and 10.3-m heights above ground (or at the top of the first and second logs), height to live crown, clear bole length, and epicormic branch development were measured using Swedish climbing ladders and recorded before release and after the third growing season. Total height was measured initially and again after 8 years.

Results

Diameter growth

Over the 7-year period, diameter growth of red maple poles at breast height varied by initial tree crown class and degree of release (Table 1). Diameter growth rates for dominant, codominant, and intermediates averaged 0.52, 0.45, and 0.42 cm/year, respectively. For dominants, this represents a 16% greater DBH growth than for codominants and a 24% greater DBH growth than for intermediates; DBH growth for codominants exceeded that for intermediates by 7%. Differences in mean DBH growth rates among each of the three crown classes the year before release were significiant (P = 0.01). For 7 years after release, dominants maintained their greater diameter growth rate over intermediates (P = 0.01) and codominants (P = 0.10), but differences between codominants and intermediates were no longer significant (P = 0.05). Crown-release treatments resulted in average growth stimulations above the controls of 26–83% for dominant stems, 27–108% for codominant stems, and 67–131% for intermediate stems (Table 1).

TABLE 1. Average beginning and ending diameters and diameter growth of dominant, codominant, and intermediate red maple crop trees at breast height over a 7-year period after release

Crown class	Treatment*	Diameter, cm		Diameter growth, cm	
		Beginning	Ending	7 year	Average annual
Dominant	Control	25.9*a*	28.4	2.48*a*	0.35*a*
	1 tree	25.8*a*	28.9	3.13*b*	0.45*b*
	2 trees	25.8*a*	29.4	3.55*c*	0.51*c*
	1.5 m	26.0*a*	30.0	3.95*d*	0.56*d*
	3.0 m	25.7*a*	29.9	4.15*d*	0.59*d*
	4.6 m	25.6*a*	30.2	4.55*d*	0.65*d*
Average		25.8			0.52
Codominant	Control	18.2*a*	20.2	2.00*a*	0.29*a*
	1 tree	18.3*a*	20.8	2.54*b*	0.36*b*
	2 trees	17.9*a*	20.5	2.60*c*	0.37*c*
	1.5 m	18.3*a*	21.9	3.64*d*	0.52*d*
	3.0 m	18.2*a*	22.4	4.16*d*	0.59*d*
	4.6 m	18.4*a*	22.3	3.94*d*	0.56*d*
Average		18.2			0.45
Intermediate	Control	14.2*a*	15.9	1.66*a*	0.24*a*
	1 tree	14.2*a*	17.1	2.88*b*	0.41*b*
	2 trees	14.3*a*	17.1	2.78*b*	0.40*b*
	1.5 m	14.4*a*	17.5	3.10*b*	0.44*b*
	3.0 m	14.1*a*	17.5	3.44*b*	0.49*b*
	4.6 m	14.1*a*	17.9	3.84*b*	0.55*b*
Average		14.2			0.42

NOTE: Means followed by the same letter in a column are not significantly different at P = 0.05.
*See full treatment descriptions in Methods.

Within each crown class, released red maples grew faster (P = 0.05) in diameter than unreleased control maples (Figs. 1–3).

After three growing seasons, dominants crown released for 1.5 m or more had outgrown (P = 0.05) dominants freed from either one or two important crown competitors (Fig. 1). Although these growth relations continued through seven growing seasons, the significance of the differences in diameter growth between the two-competitor treatment and the more heavily released treatments (1.5, 3.0, and 4.6 m) diminished. For dominants, the 1.5, 3.0, and 4.6-m crown-release treatments were equally effective in stimulating growth.

For codominants, significant growth responses to different degrees of crown release occurred by the end of the second growing season (Fig. 2). At this time, codominant stems

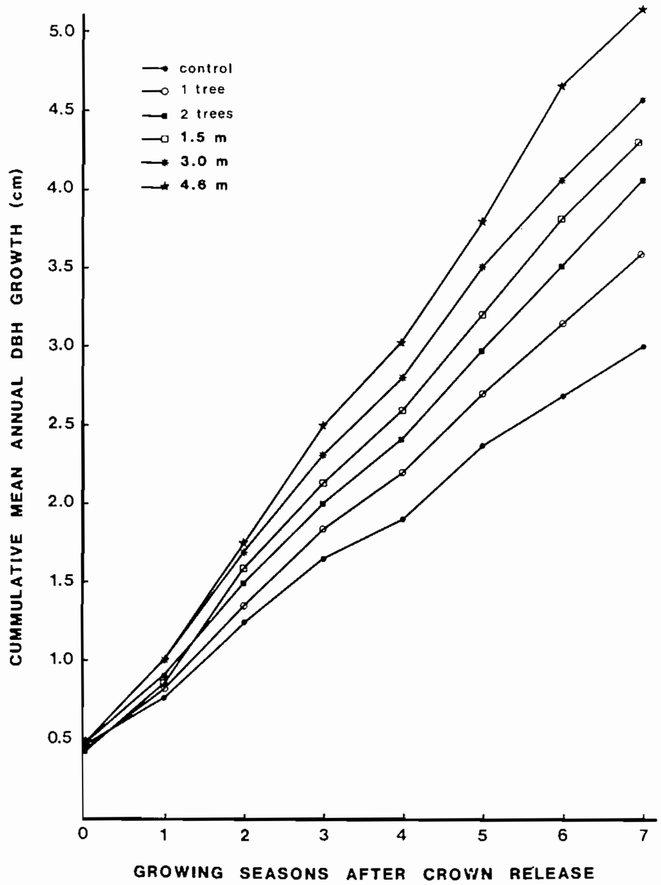

FIG. 1. Effect of six crown-release treatments (see Methods) on cumulative mean annual DBH growth of dominant red maple poles for seven growing seasons after release.

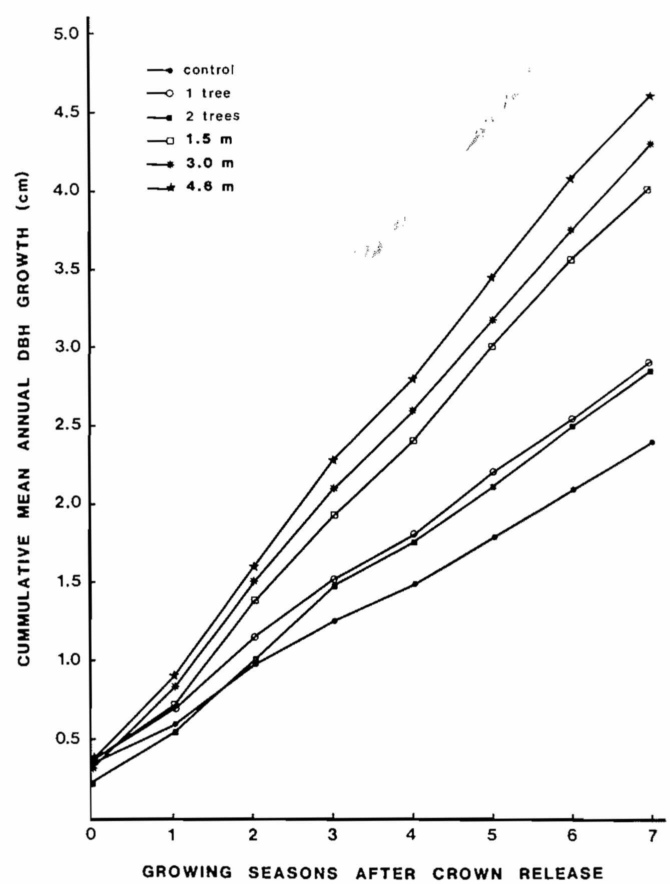

FIG. 2. Effect of six crown-release treatments (see Methods) on cumulative mean annual DBH growth of codominant red maple poles for seven growing seasons after release.

released for 1.5–4.6 m were already outgrowing ($P = 0.05$) codominants released from either one or two crown competitors. For the first three growing seasons, growth rates of codominants released from 3.0 to 4.6 m were also better ($P = 0.05$) than those stems released for 1.5 m. After the third season, however, there were no significant differences in growth rate among these three treatments, but they were still superior ($P = 0.05$) to less drastic treatments. Although codominants benefited ($P = 0.05$) from the single- and two-tree crown-release treatments, growth responses appeared to be very similar between these two treatments throughout the 7-year study period.

All released intermediate stems, like released upper canopy stems, grew faster ($P = 0.05$) than the controls throughout the study period (Fig. 3). However, it was only from the third growing season through the sixth season that intermediate stems crown released for 1.5 m or more outgrew ($P = 0.05$) intermediate stems freed from two crown competitors. After 5 years, intermediates freed from only one competitor were growing about as well as those freed from two crown competitors.

During the 7-year period, the one- and two-tree crown-release treatments increased average growth over control stems by 35% for dominants, 28% for codominants, and 70% for intermediates, while the heavier 1.5- to 4.6-m crown-release treatments resulted in average growth increases of 70% for dominants, 96% for codominants, and 108% for intermediates (Table 1).

No significant differences in average diameter growth rate were found among the three vertical sampling points at the end of the third growing season following release. Annual growth at the three sampling points averaged 0.51 cm for dominants, 0.43 cm for codominants, and 0.40 cm for intermediates (Table 2). Average diameter growth responses to crown release measured at 5.3 and 10.3 m above ground on red maple boles were almost identical to those measured at breast height and average responses were similar to those reported for the entire 7-year period. Dominants outgrew ($P = 0.01$) intermediates at breast height and outgrew both codominants and intermediates at 5.3 and 10.3 m.

Height growth

Before release, dominant, codominant, and intermediate red maple poles averaged 20.8, 19.6, and 17.7 m tall, respectively. During the first 8 years after release, height growth averaged 1.7 m for intermediate trees and 1.4 m for dominant and codominant trees. Analyses of these 8-year data indicated that the average annual height growth of intermediate trees was 20% faster ($P = 0.10$) than that of either dominant or codominant trees. There were no other significant differences in height growth among the various degrees of release within each of the three crown classes tested.

Bole quality

At the beginning of the study, clear bole length (height above ground to the first dead branch, stub, or live limb) averaged 6.5, 7.4, and 5.9 m for dominant, codominant, and inter-

TABLE 2. Average annual diameter growth of dominant, codominant, and intermediate red maple crop trees at three vertical sampling points over a 3-year period after release

Crown class	Treatment*	Vertical sampling points DBH	5.3 m	10.3 m	Average
Dominant	Control	0.37*a*	0.31*a*	0.39*a*	0.36
	1 tree	0.46*b*	0.42*b*	0.42*b*	0.43
	2 trees	0.49*c*	0.46*c*	0.49*c*	0.48
	1.5 m	0.57*d*	0.50*d*	0.58*c*	0.55
	3.0 m	0.61*d*	0.54*d*	0.58*c*	0.58
	4.6 m	0.66*d*	0.66*d*	0.59*c*	0.64
Average		0.54	0.48	0.51	0.51
Codominant	Control	0.29*a*	0.28*a*	0.27*a*	0.28
	1 tree	0.38*b*	0.33*b*	0.30*b*	0.34
	2 trees	0.41*c*	0.34*c*	0.41*c*	0.39
	1.5 m	0.52*d*	0.45*d*	0.45*c*	0.47
	3.0 m	0.62*d*	0.53*d*	0.47*c*	0.54
	4.6 m	0.59*d*	0.53*d*	0.51*c*	0.54
Average		0.47	0.41	0.40	0.43
Intermediate	Control	0.24*a*	0.23*a*	0.26*a*	0.24
	1 tree	0.42*b*	0.37*b*	0.39*b*	0.39
	2 trees	0.37*b*	0.37*b*	0.37*b*	0.37
	1.5 m	0.42*b*	0.37*b*	0.35*b*	0.38
	3.0 m	0.47*b*	0.43*b*	0.47*c*	0.46
	4.6 m	0.53*b*	0.50*b*	0.55*c*	0.53
Average		0.41	0.38	0.40	0.40

NOTE: Means followed by the same letter in a column are not significantly different at $P = 0.05$.
*See full treatment descriptions in Methods.

mediate red maple poles, respectively. About 32% of the stem was in clear bole for dominants and intermediates, while about 38% was in clear bole for codominants. Ninety-three percent of the clear bole length stoppers were either dead branches or stubs; 7% were live branches more than 61 cm long. Little change in clear bole length by crown class or crown-release treatment occurred within three growing seasons after release.

Average initial height to the first live branch more than 61 cm long averaged 10.2 m for codominant trees: 0.8 m higher ($P = 0.05$) than for either dominant or intermediate trees. In just 3 years, the average limb-free height for both codominants and intermediates was significantly ($P = 0.05$) reduced by 0.7 m when compared to the dominants where no reduction occurred. Yet no significant differences in limb-free height occurred among any of the six crown-release treatments within each crown class. Even on the unreleased trees, no natural pruning occurred.

Before release, the 54-year-old red maples averaged less than one epicormic branch[2] on the butt log and about two epicormic branches on the second log (Table 3). Student's *t*-test indicated that the number of pretreatment epicormic branches on the butt logs did not differ significantly by crown class. However, dominant trees had fewer ($P = 0.05$) pretreatment epicormic branches on their second log than either codominant or intermediate trees. Similar tests after three growing seasons showed the importance of crown dominance in controlling the initiation of new epicormic sprouts. More than 94% of the dominants and 70% of the codominants had no new epicormic

[2]Any live branch less than 61 cm long or any short shoot with a dormant bud or bud cluster with leaves on the bole was considered an epicormic branch.

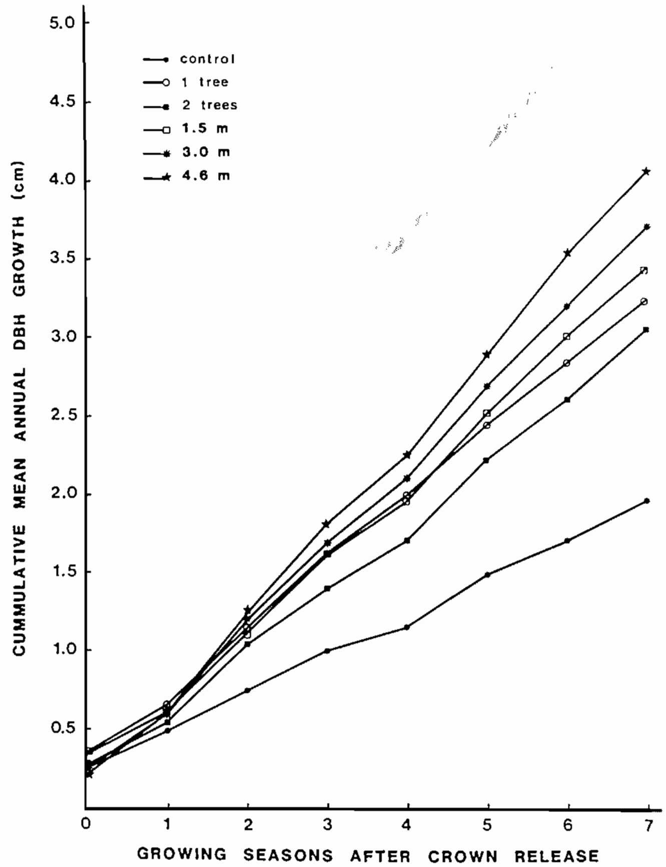

FIG. 3. Effect of six crown-release treatments (see Methods) on cumulative mean annual DBH growth of intermediate red maple poles for seven growing seasons after release.

sprouts on their butt logs, but only 40% of the intermediates were free of new sprouts. This increased epicormic sprouting was greater ($P = 0.05$) on both the first and second logs of intermediate trees (7.0 per tree) than on either dominant (1.0 per tree) or codominant trees (2.7 per tree); similarly, codominants had more ($P = 0.05$) new epicormic sprouts on their first two logs than dominant trees. During the 3 years after release, dominants lost 0.1 sprout on their butt logs, while codominants gained 0.4 sprout and intermediates gained 1.8 sprouts. Each of these changes in the number of living sprouts among the three crown classes was significant ($P = 0.05$), but differences in 3-year mortality among crown classes were not significant in either the first or second log. The number of living epicormics in the second log increased from 0.4 sprout for dominants to 1.3 sprouts for codominants to 4.2 sprouts for intermediates. These 3-year changes in the number of sprouts were greater ($P = 0.05$) for intermediates than for dominants and codominants. After 3 years, 92% of the dominants had less than four new epicormic branches on their first two logs, while 73% of the codominants and only 40% of the intermediates produced less than four epicormic branches on their first two logs.

Analysis of variance indicated that crown release did not stimulate epicormic sprouting ($\sqrt{\text{number} + 1}$ transformation was analyzed) within three growing seasons after treatment, regardless of the crown class tested. At this time, crown-released red maples within each crown class had about the same number of new epicormics on their first two logs as unreleased maples.

TABLE 3. Effect of crown class on the average number of epicormic branches in the first two logs of red maple crop trees initially and 3 years following release

	Butt 5.0-m log					Second 5.0-m log				
		After 3 years					After 3 years			
Crown class	Initial	New	Dead	Alive	Change	Initial	New	Dead	Alive	Change
Dominant	0.3*a*	0.1*a*	0.2*a*	0.1*a*	0.1*a*	0.8*a*	0.9*a*	0.4*a*	1.2*a*	0.4*a*
Codominant	0.6*a*	0.6*b*	0.2*a*	1.0*b*	0.4*b*	2.2*b*	2.1*a*	0.8*b*	3.5*b*	1.3*a*
Intermediate	1.4*a*	2.2*c*	0.4*a*	3.2*b*	1.8*c*	3.4*b*	4.8*b*	0.5*a*	7.7*c*	4.2*b*
Total	2.3	2.8	0.8	4.3		6.3	7.8	1.8	12.4	
Mean	0.8	0.9	0.3	1.4		2.1	2.6	0.6	4.1	

NOTE: Means followed by the same letter in a column are not significantly different at $P = 0.05$.

Epicormic sprouting was greater ($P = 0.05$) on second logs than on butt logs of codominant and intermediate trees, but not on dominant trees, where little epicormic sprouting occurred. Linear regression analysis further revealed a strong, positive correlation between the average number of new epicormic sprouts and height on the bole for dominant ($r^2 = 0.68$), codominant ($r^2 = 0.75$), and intermediate trees ($r^2 = 0.89$) and the three crown classes combined ($r^2 = 0.91$).

Linear regression of epicormic sprouting following release for the three crown classes also revealed a strong, positive correlation with the number of pretreatment epicormic branches existing on boles of intermediate trees ($r^2 = 0.81$), but not on dominant ($r^2 = 0.17$) or codominant trees ($r^2 = 0.41$). After 3 years, epicormic sprouting was greatest on intermediate boles with the most pretreatment epicormic branches and lowest on intermediate boles with the fewest pretreatment epicormic branches.

Further analysis indicated that new epicormic sprouting was not correlated with residual stand density around individual dominant, codominant, or intermediate trees. Residual stand density ranged from 7.3 to 46.6 m^2/ha within an 8.0-m radius of 96 individual study trees. Forty-one of the 592 epicormic sprouts that appeared before and during the 3 years after release grew to branch size[3] on one dominant, eight codominant, and nine intermediate red maple trees. All but 3 of the 41 new branches occurred on the second 5.0-m log. Eighty-eight percent of these new branches originated from short epicormic shoots or dormant buds present before release; the remaining (12%) branches emerged from externally nonvisible dormant buds apparently embedded in the bark. Fewer ($P = 0.05$) epicormic sprouts grew to branch size on the lower 10.3 m of dominant boles (only 1 of 73 sprouts) than on either codominant boles (17 of 164 sprouts) or intermediate boles (23 of 355 sprouts). Although not one sprout developed into a branch on the unreleased controls, separate analysis of variance for each crown class showed that there was no significant difference in the number ($\sqrt{\text{number} + 1}$ transformation analyzed) of branches that grew to branch size among the six crown-release treatments tested. Actual numbers of epicormic sprouts that grew to branch size on the lower boles of both released and unreleased dominant, codominant, and intermediate trees averaged 0.03, 0.57, and 0.77 sprouts, respectively.

Before release, the 36 pretreatment epicormics that developed into branches on codominant and intermediate trees averaged 12.7 cm long. They elongated 11.2 cm in the 1st year, 36.8 cm in the 2nd year, and 43.1 cm in the 3rd year following release: a total of 91.1 cm of lateral growth during the 3 years. Lateral epicormic branch growth during each succeeding year following release was greater ($P = 0.05$) than in each preceding year. At least 36 pretreatment epicormic sprouts and 5 newly emerging sprouts appear to be vigorous enough to become permanent branches until crown closure occurs again. The fastest growing pretreatment epicormic extended 171 cm in just 3 years.

[3] Any epicormic sprout that grew into the 61 cm or longer size class was considered a branch.

TABLE 4. Shoot growth on all surviving epicormic branches during the 3 years following release

Crown class	Unreleased, cm	Released, cm	All trees, cm	Basis*
Dominant	1.68*a*	3.49*a*	3.19*a*	49
Codominant	3.08*b*	11.11*b*	9.77*b*	135
Intermediate	4.70*b*	3.91*b*	12.38*b*	317

NOTE: Means followed by the same letter in a column or row are not significantly different at $P = 0.05$.
*Number of sprouts.

Analysis of 3-year lateral growth data on all surviving epicormics on dominants, codominants, and intermediates indicated that epicormic sprouts on unreleased red maples grew about as well as those on released maples (Table 4). In addition, the lateral growth of epicormic sprouts was 3–4 times faster ($P = 0.05$) on codominants and intermediates than on dominants.

During the third growing season, sprout growth was still 2–3 times faster ($P = 0.05$) for codominants (5.7 cm) and intermediates (7.6 cm) than for dominants (2.5 cm).

Discussion and conclusions

Results of this study show that red maple trees from 13.0 to 31.7 cm DBH on good sites (site index = 19.3 m and higher at 50 years) respond well to crown release. Released trees can maintain their growth advantage over the controls for at least 7 years following release. Trees released for 1.5 m or more beyond their crown perimeters grew 90% faster than the controls and 33% faster than when only one or two important crown competitors were removed. For dominant, codominant, and intermediate trees, complete crown release represents a growth improvement of 25, 55, and 22%, respectively. To date, the 1.5-, 3.0-, and 4.6-m crown-release treatments were equally effective in stimulating diameter growth. Three-year diameter growth responses were similar at breast height, 5.3 m, and 10.3 m.

Dominant and codominant trees are preferred over intermediates for crop trees because they respond best, have better formed boles, and have larger crowns, which limit any appreciable degradation in bole quality as a result of epicormic sprouting following release. Intermediates with their weaker crowns are more prone to increased epicormic sprouting following release. However, if inadequate numbers of well-spaced upper canopy trees are available for release, strong intermediates with less than four pretreatment epicormic branches on their first two logs will also make satisfactory crop trees because they will not sprout profusely after release.

The number and distribution of new epicormic sprouts that appeared on red maple boles 3 years after release were related more to crop tree crown vigor or crown class and position on the bole than to the intensity of the crown release treatment or residual stand density. Most of the epicormic branches that grew into vigorous branches originated from short pretreatment epicormic shoots located immediately beneath the live crown. These new branches account for the average 0.7 m reduction in limb-free length experienced by the codominant and intermediate trees. Our results on epicormic sprouting confirm previous findings with red maple in old-growth (Jemison and Schumacher 1948) and 60-year-old, second-growth (Smith 1966; Trimble and Seegrist 1973) Appalachian hardwood stands regarding its increased sprouting in relation to log position and its relative sprouting ability. Dominant and codominant red maples have few branches and produce few epicormic sprouts following heavy cutting compared with many other hardwood species. For dominant and codominant trees in second-growth stands in the Lake States, we would rate red maple as being among the least susceptible to epicormic sprouting. The following species are ranked in increasing order of susceptibility toward epicormic sprouting: white ash, basswood, red maple, yellow birch, sugar maple, American beech, northern red oak.

Dominant and codominant red maple trees, like yellow poplar trees, can be thinned heavily (Della-Bianca 1972; Smith 1977) or left along borders of openings (Smith 1965; Trimble and Seegrist 1973) because no appreciable losses in lumber grade should occur as a result of epicormic sprouting.

More time is required in this study to assess the duration of the treatment responses and their effects on the growth and persistence of epicormic branches. However, past research with other northern hardwood species more prone to epicormic sprouting suggests that most epicormic sprouts will disappear after crown closure (Erdmann and Peterson 1972).

Results of this study and other studies in a younger 7-year-old sprout stand in West Virginia (Trimble 1974) and a 25-year-old pole-size stand in New Hampshire (Marquis 1969) indicate that red maple growth rates can almost be doubled by release. With regularly scheduled crop tree release thinnings and growth rates that have been experienced for 2.5-cm saplings to 31.7-cm, small sawlog size trees, it would take about 85 years to produce a stand of red maple trees averaging 45.7 cm DBH. Without release, 42 additional years would be required to produce a stand of similar-sized trees.

A conservative strategy for the best growth and quality development for red maple on good sites would be to crown release about 185 (dominant and codominant) unforked crop trees per hectare from all crown competition within 1.5−3.0 m of their crown perimeters and then cut from below to recommended residual stocking levels for even-aged stands (Tubbs 1977; Erdmann et al. 1982). Small forks on crop trees can be corrected by retaining adjacent tree crown closure next to the smaller fork member until after fork correction occurs. The cutting interval will depend on the time required for crown closure and lower branch mortality.

Initially, managers have many options in managing even-aged stands of dominant and codominant red maples because crop trees respond well to release up to the 4.6-m crown-release treatment without any appreciable loss in butt log or second log quality from epicormic sprouting. The best growth and quality development appears to occur at about 13.8 m^2/ha of residual basal area density in 40- to 50-year old stands averaging 12.7−15.2 cm DBH. Under this option, almost all growth would be concentrated on the best quality stems and about 20 years would be required for basal area to increase to desirable levels for an operable cut. After this initial treatment, well-managed even-aged stands should be thinned at regular 10- to 12-year intervals to salvage mortality more effectively and to allow residual basal area densities to increase to recommended levels for best growth and quality development as average stand diameter increases.

Our results apply primarily to red maples growing on good sites (site index = 18.3 m and higher at 50 years). Red maple often occurs in mixtures with aspen and paper birch on droughty coarse sands and with balsam fir, black spruce (*Picea mariana* (Miller) B.S.P.) and northern white cedar (*Thuja occidentalis* L.) on sites too wet for its best development. On these sites, the advantages of release are less certain.

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