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# Strip Thinning and Spacing Increases Tree Growth of Young Black Spruce

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**ABSTRACT.** *Two different thinning methods were applied to three 6- or 7-yr-old black spruce stands in northern Minnesota which were measured after 20 yr. Overall, thinning improved the growing conditions for crop trees. Strip thinning with a 0.6 m leave strip and three widths of cleared strips (1.5 m, 2.1 m, and 2.7 m), and spacing to 1.5 m, 2.1 m, and 2.7 m resulted in reduced numbers of crop trees, but with larger diameters and, in the spacing thinned plots, greater heights. Because of these contradicting trends, stand volume was unaffected by thinning. Crop tree growth was not affected by the width of the cleared strip, but the distances between the leave trees in the square spacing were positively related to the increased growth response after thinning. The study is still too young to evaluate the economic feasibility of both thinning treatments, but shorter rotations or substantially increased volume seem possible by early thinnings of black spruce. North. J. Appl. For. 13(2):68–72.*

**B**lack spruce is an important species in northern North America, occupying 800,000 ha of commercial timberland in the Lake States alone. Two-thirds of this land is found in virtually pure stands in the lowland organic soils of northeastern Minnesota (Perala 1971).

Dense, even-aged stands of black spruce are commonly initiated after fire (Johnston 1990). Current management practices do not include precommercial or commercial thinnings (Johnston 1977). While several studies have investigated the effect of thinning on black spruce growth (Steneker 1969, Weetman et al. 1980, Lavigne et al. 1987, Newton 1988, Shepard and Shottafer 1990), few studies have investigated how early density management affects future stand development. Because black spruce grows slowly, thinning treatments will only be implemented if they provide sufficient growth response and if implementation is inexpensive. Strip thinning is fairly inexpensive and has therefore been suggested as an alternative tool for species or sites for which management potential is marginal.

This study was initiated to compare the effects of strip thinning, square spacing thinning, and no-thinning to deter-

mine what range of young stand densities will result in both good tree and stand growth. This information will help land managers make effective decisions for sustainable black spruce management.

## Objectives

The objective of this study was to investigate growth of young black spruce stands growing at various densities on organic soil of varying fertility and location. Specific objectives include (1) to examine the effects of square spacing, strip thinning, and no-thinning on growth and development of individual trees and stands, and (2) to examine the effects of different thinning intensities on growth and development of trees and stands.

## Methods

This study was established in 1971 and 1972 in organic soils in Kootchiching County in north central Minnesota. Three study areas where black spruce forest was clearcut and broadcast burned 7 to 9 yr earlier were chosen. The first site is the 1964 Block V Burn; a black spruce-alder-herb forest in the Big Falls Experimental Forest. Natural seeding from surrounding timber produced black spruce seedlings averaging 21,300 trees/ha 2 yr after burning. The 50 yr site index was estimated to be 12.5 m. The site is extremely brushy and is highly variable with dense patches and openings throughout.

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NOTE: We are grateful to the late Dr. William F. Johnston for the design and installation of this study. We also appreciate the cooperation of the Minnesota DNR, Division of Forestry, for providing the study sites, arranging the logging and site preparation for regeneration, and other assistance throughout the course of the study. We acknowledge Professor Sanford Weisberg of the University of Minnesota, School of Statistics, for his help in the statistical analysis of data collected for the study. Klaus Puettmann is the corresponding author.

The other sites are the 1965 Williams Burn in Pine Island State Forest and the 1965 Block II Burn in the Big Falls Experimental Forest. Both areas are very wet and densely carpeted with sphagnum moss and labrador tea. The Williams Burn was seeded and averaged 32,000 trees/ha 2 yr after burning. Natural seeding occurred from surrounding timber on the Block II Burn, and black spruce seedlings averaged 50,000 trees/ha 2 yr after burning. Fifty-year site index for Block II was estimated in an adjacent stand to be 9.8 m and for the Williams Burn to be "intermediate" between that of Block II and Block V (Johnston 1978).

Occurrence of additional vegetation on the sites varied considerably. Generally, the two wetter sites had greater amounts of low lying vegetation, while the greatest amount of tall shrubs and woody vegetation was on the Block V site. Contrary to earlier reports that understory vegetation was generally not prevalent in Block II (Johnston 1978), understory vegetation, such as sphagnum moss, labrador tea, canada mayflower, berries, and grasses, was much more prevalent on the Williams site than on Block II. All three sites had occasional openings and patches where little additional vegetation was growing. According to the forest ecosystem classification of Sims et al. (1989), the vegetation type of Block V is V35-black spruce/speckled alder/sphagnum, and that of the other two sites is V36-black spruce/bunchberry/sphagnum/feathermoss. The soils of all three sites are type S125-wet/organic(sphagnum).

The occurrence of a variety of smaller plants and shrubs is not only important to stand diversity, but also to wildlife. All three sites exhibited signs of use by deer, bears, and a number of bird species.

## Experimental Design and Treatments

The study uses a randomized, complete-block design. Each of the three study areas has two blocks, with seven treatments per block and three treatment groups:

- 1 Spacing—Thinned to 1.5 m, 2.1 m, and 2.7 m square spacing.
- 2 Strip thinning—Leave strip 0.6 m wide, cleared strips 1.5 m, 2.1 m, and 2.7 m wide.
- 3 Unthinned controls—Two plots per block.

Leave trees in the spaced plots were selected primarily to achieve desired spacing, and larger trees were selected over smaller trees only when spacing was not affected (Wilson 1952). The initial treatment took place in 1971 or 1972. Due to invasion of hardwoods and black spruce, the thinned plots in Block II were rethinned in 1973, and those in Block V were sprayed at a rate of two and a quarter kilograms/ha with 2,4-D in water during the fall of 1972. Little damage was evident in residual black spruce (Johnston 1978). Cutting of hardwoods and tall shrubs that substantially overtopped residual black spruce was again necessary in 1976 or 1977 on Block II and the Williams Burn.

The study plots were remeasured during June 1993. Analysis was based on the method of nonoverlapping triangles

(Klier 1969, Fraser and van den Driessche 1972). Nine points were randomly selected in each treatment plot. The three crop trees closest to and encompassing the points were identified and the distances between them measured, hence allowing crop tree density to be calculated. Crop trees were defined as trees likely to survive until maturity (age 100). Tree size (dbh > 1 cm), vigor and position in the canopy, as well as spacing to neighboring crop trees were considered. Crop tree spacing was based on density information from natural stands (Fox and Kruse 1939) that indicated an average spacing of trees at age 100 of 1.7 m. Height and diameter at breast height (dbh) of the three crop trees were measured, and number of noncrop trees inside the triangle was counted. The presence of any other herbaceous plants was recorded. Stand volume was calculated based on basal area and average height of crop trees (Gevorkiantz and Olson 1955). Statistical analysis used the analysis of variance and contrast functions of MACANOVA<sup>®</sup> (Bigham and Oehlert 1993) to test for differences between treatment groups. In addition the data were tested for significant ( $P \leq 0.05$ ) linear and quadratic trends.

## Results and Discussion

The study was established on three sites to cover a range in site qualities as indicated by the different site indices. Consequently mean height, dbh, basal area, and volume were significantly different between the sites ( $P < 0.001$ ). Crop tree density (trees/ha) did not vary significantly between sites ( $P = 0.420$ ). No interactions were found relating treatment responses to site, indicating that treatments responses were consistent despite the variability among sites. Thus, the overall treatment means for variables examined are representative of the range of site conditions used in the study and are subsequently used in further analysis.

### Crop Tree and Stand Density

Significant differences were noted between the average crop tree densities in thinned and unthinned plots ( $P = 0.011$ ) (Table 1). Strip thinning left high density strips, and the lack of differentiation within the strips is evident, especially in 1.5 m strip thinnings. Average distance between crop trees, assuming square spacing, is approximately 10% shorter in the strip thinnings than in the spacings (Table 1).

Table 1 shows overall and crop tree densities at initial treatment in 1972/1973 and current (1993) crop tree as well as current overall (crop plus noncrop) black spruce densities. The data from the initial measurement show that stand density within and among study areas was fairly uniform for the spacings but varied greatly for the unthinned control and strip thinnings (Table 1).

Spacings were set up to leave only crop trees, and almost every leave tree was again selected as a crop tree in 1993. Annual mortality and/or loss of crop tree status was limited to 2.0%, 1.0%, and 0.04% in 1.5 m × 1.5 m, 2.1 m × 2.1 m, and 2.7 m × 2.7 m thinnings, respectively. Despite rethinning in 1977, the overall density (crop and noncrop trees) increased in the spaced plots between the time of initial stand density measurements (1973) and those taken in 1993. The newly established trees originated by seed (Johnston 1978) and

**Table 1. Stand density in trees/ha. All black spruce were considered crop trees in 1973. Calculation of distance between crop trees assumes square spacing.**

	Date of measurement	Treatment (m)						
		1.5	2.1	2.7	1.5 × 1.5	2.1 m × 2.1	2.7 × 2.7	Unthinned
Crop trees (tpha)	1973	27,852	9,198	15,745	3,765	1,909	1,350	53,114
	1993	3,752	2,030	1,608	2,650	1,573	1,247	3,434
Noncrop trees (tpha)	1993	18,474	5,547	8,924	2,963	4,159	3,237	22,608
Total black spruce	1993	22,226	7,576	10,531	5,612	5,732	4,483	26,042
Distance between crop trees (m)	1973	0.60	1.04	0.80	1.63	2.29	2.72	0.43
	1993	1.63	2.22	2.49	1.94	2.52	2.83	1.71

layering. Annual net mortality in the unthinned plots averaged 2.16% over the last 20 yr. Mortality estimates in the strip thinned plots are confounded by rethinning an undetermined amount of black spruce in 1977.

Increasing the strip width led to a linear reduction in crop tree density ( $P = 0.014$ ), and increased thinning intensity in the spacings led to lower crop tree numbers, though a linear trend was not significant ( $P = 0.095$ ).

Additional woody species were common on all three sites (Table 2). The four most prevalent species noted were noncrop black spruce, willow, red-osier dogwood, and speckled alder (Table 2). Other species present include, but are not limited to, paper and bog birches, quaking aspen, and balsam poplar, tamarack, white spruce, balsam fir, and serviceberries.

### Diameter

Diameter growth is known to be sensitive to differences in stand density (Smith 1986). Average tree dbh was higher in the thinned than in the unthinned plots ( $P = 0.039$ ), and higher in the spacing than in the strip thinned plots ( $P = 0.008$ ) (Table 3).

Despite a reduced density of crop trees, increasing width of cleared strips did not increase dbh growth ( $P = 0.306$ ). The width of the residual strips might be more important for dbh growth than width of the cleared strips (Skilling 1957) as growth response of crop trees has been related to the distance from the strip edge (Lotan 1967, Smith and Oerlemans 1988). Thus even with leave strips being only 0.6 m wide, crowding within the strips might have prevented crop trees from taking advantage of the full width of the cleared strips (Table 3). On the other hand, crop trees in spaced plots did not have the competition of other trees in close proximity. A linear in-

crease of dbh with increasing spacing ( $P = 0.011$ ) suggests that trees can utilize the additional growing space made available by thinning. Lavigne et al. (1987) thinned a 20-yr-old black spruce stand to spacing similar to the ones used in this study and also found increased diameter growth response with increased spacing. Newton (1988) analyzed a stand that was precommercially thinned at age 25 to a 2 m square spacing. Annual diameter growth in the thinned portions was around 0.15 cm higher in the last 5 yr as compared to diameter growth in earlier years. This is very similar to the difference in average annual diameter growth between the unthinned and the 2.7 m × 2.7 m thinned plots in this study. Shepard and Shottafer (1990) found that a 29-yr-old stand that had been thinned 11 yr earlier had an average dbh similar to an adjacent 77-yr-old stand. Further, crop trees in a black spruce stand spaced to 2.25 m at age 30 averaged 2.1 cm larger in dbh than in adjacent, unthinned stands 38 yr after thinning (Erickson 1994).

### Height

Generally height growth does not respond consistently to competition (Morris et al. 1990). In contrast to diameter, crop tree height in all thinned plots did not vary significantly from height in the control plots ( $P = 0.062$ ) (Table 3). However, as with diameter growth, the trees in spaced plots were taller than crop trees in the strip thinned plots, likely due to competition within strips ( $P = 0.015$ ). This might also explain the lack of height response with increased width of cleared strips. A positive linear trend for height was significant in spaced plots ( $P = 0.029$ ). Lavigne et al. (1987) did not find a height growth response 5 yr after thinning black spruce

**Table 2. Woody stem density and species as a percentage of the total woody stem density (no/ha) in 1993.**

Treatment (m)	Total woody stem density (tpha)	Percent of woody stems					
		Crop trees	Noncrop black spruce	Willow	Red osier dogwood	Spotted alder	Others*
1.5 strip	174,775	2	63	22	0	5	8
2.1 strip	116,194	2	30	37	11	11	9
2.7 strip	108,831	1	44	25	11	5	14
1.5 × 1.5	108,837	2	15	40	14	20	9
2.1 × 2.1	121,567	1	23	35	9	17	15
2.7 × 2.7	60,271	2	32	46	4	6	10
Unthinned	406,331	1	33	8	2	4	52

\* Other woody species include bog and paper birches, spotted alder, balsam poplar, balsam fir, quaking aspen, tamarack, white spruce, and serviceberry

**Table 3. Overall treatment averages for diameter at breast height (dbh), basal area, height, and volume of crop trees in 1993.**

Treatment (m)	Dbh (cm)	Basal area (m <sup>2</sup> /ha)	Height (m)	Volume (m <sup>3</sup> /ha)
1 5 strip	4.95	6.03	4.74	12.49
2 1 strip	6.08	6.15	5.57	14.98
2 7 strip	5.58	4.10	5.20	9.53
1 5 × 1.5	5.83	7.13	5.30	16.42
2 1 × 2.1	6.38	5.12	5.34	11.79
2 7 × 2.7	7.41	5.40	6.13	14.32
Unthinned	5.25	6.66	4.93	14.34

Several thinning studies of fast-growing species have shown that short term (5 yr) diminished height growth after thinning are subsequently offset by faster growth the next 5 yr (Lotan 1967, Puettmann 1994). In our study the faster height growth in the thinned plots is still observable after 20 yr. The long-term thinning response might be explained by the generally slower growth rate of black spruce compared to loblolly pine (Lotan 1967) and red alder (Puettmann 1994). Using the current height to estimate an average site index for the three sites indicates the site index of the 2.7 m × 2.7 m spacing plots to be around 30% (3 m) higher than the unthinned control.

### Basal Area

Crop tree basal area was less in the thinned plots ( $P = 0.045$ ) and in both spaced and strip thinned plots, and basal area decreased with increasing intensities in a linear fashion ( $P = 0.046$  and  $P = 0.027$ , respectively) (Table 3). At this stage in stand development, increased diameter growth was not enough to offset the lower crop tree density.

### Taper

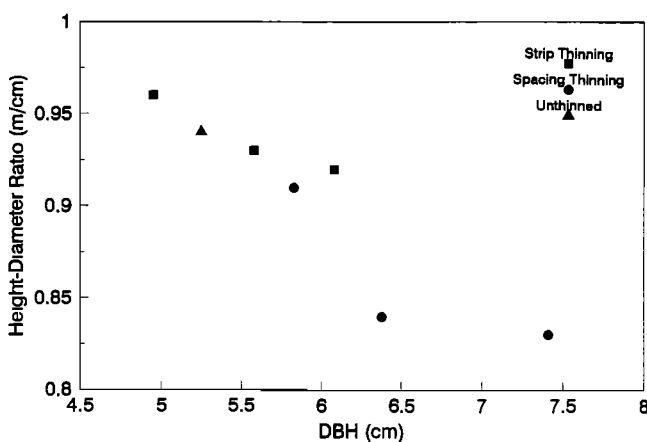
Mean height-diameter ratios are plotted over the mean diameter in Figure 1. The height-diameter ratios appear lower in the thinned plots. Considering that the height-diameter ratios are not constant but decrease with time and increased size, the graph suggests that current differences in height-diameter ratios are, at least partially, a result of an increase in dbh rather than a direct effect of the treatments on stem form.

### Volume

The equation used to calculate stand volume (Gevorkiantz and Olson 1955) assumes that stem geometry is not affected

by thinning. However, Shepard and Shottafer (1990) compared the ratios of dbh to diameters at 5 m and half the tree height for thinned and unthinned black spruce. Lower ratios in thinned stands indicated that stem geometry is influenced by stand density in a fashion that volume equations that are based on trees from unthinned stands will overestimate volume in thinned stands, with the overestimation increasing with higher thinning intensity. A method of building stem taper into currently used volume equations or a volume equation that accounts for stem taper in black spruce has not been developed. Thus, the volume equation based on unthinned stands (Gevorkiantz and Olson 1955) was used for this study. Because of the small individual tree size, the discrepancy should not be sufficient to seriously affect the trends.

In general, stand volume followed trends similar to those observed in basal area (Table 3). However, the increased variation from combining both basal area and tree height in the volume calculations made it harder to detect statistically significant relationships. Stand volume was not significantly higher in the unthinned plots than in the plots with the different thinning treatments ( $P = 0.44$ ). Also, a decreasing trend for volume with higher thinning intensity was not statistically significant ( $P = 0.225$  and  $0.386$  for the strip and spacing thinning, respectively). At this stage in stand development, effects of the lower crop tree density on stand volume in the thinning plots are offset by larger diameter and height of the trees. A similar offset was found by Lavigne et al. (1987) the first 5 yr after thinning. However, average volume per crop tree in the thinned stands is up to 275% greater than in the unthinned plots (Table 3). Assuming that the number of crop trees remains fairly stable during the rest of the rotation, the volume comparison will be increasingly influenced by average tree volume. If the current growth trends continue, tree volume in the thinned stands will exceed crop tree volume in the unthinned stands at maturity. The analysis of stand volume indicates that it is still too early in the development of the stand to evaluate the overall effectiveness of the thinning treatments. Smith and Oerlemans (1988) estimated the volume at rotation age in strip thinned jack pine to be around 70% of the volume in the unthinned controls. While a direct extrapolation of the volume growth to rotation age is not possible, the increased height growth can be used to calculate an estimate. Assuming similar basal areas in thinned and unthinned stands, a site index that is 3 m higher is equivalent to an increase in ft<sup>3</sup> yield at 100 yr of around 20% (Johnston 1977). An increase in basal area due to thinning will increase the gain substantially.



**Figure 1. Relationship between average height-diameter ratio and average tree diameter for three strip thinning treatments, three spacing thinning treatments, and an unthinned control.**

## Summary

Overall, thinning improved the growing conditions for black spruce crop trees. Both strip and spacing thinning allowed crop trees to grow faster than unthinned control. However, the stand volume is not yet affected due to offsetting trends in crop tree density and average size of the crop trees (i.e., the thinned plots are not totally occupying the site).

Width of the cleared strip did not affect growth of the residual crop trees. The distance between the leave trees in the spaced plots seems to be positively related to the increase in growth response after thinning.

Many aspects need to be considered in deciding whether to thin. Newton (1988) determined that trees in thinned stands are more vigorous and could better withstand spruce budworm attacks. In addition, Shepard and Shottafer (1990) found the specific gravity of the wood in a thinned stand to be 10% lower than in unthinned stands. This reduced the pulp yield and, in combination with more and thicker branches on the trees in the thinned stands, increased the pulping costs substantially. Thinning dense black spruce stands might also lead to invasion of other tree species and thus to increases in species diversity, which in turn might affect habitat quality for animal species.

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