1338

Analysis of Jack Pine Thinning Experiments, Manitoba and Saskatchewan

by I. E. Bella and
J. P. DeFranceschi

THIS FILE COPY MUST BE RETURNED

TO: INFORMATION SECTION,
NORTHERN FOREST RESEARCH CENTRE,
5320-122 STREET,
EDMONTON, ALBERTA.
T6H 3S5

Environment Canada / Environnement Canada

Forestry Service / Service des Forêts

Issued under the authority of the
Honourable Jack Davis, P.C., M.P.,
Minister, Environment Canada

INFORMATION CANADA
Catalogue No. Fo47-1338
OTTAWA, 1974

PRINTED IN CANADA

CONTENTS

ABSTRACT

Growth data from six jack pine thinning experiments showed generally increased diameter increment after treatment. The stands treated were between 10 and 60 years old and covered site conditions ranging from poor to good.

Improvement in yield on poor sites, if any, was minor. On average sites, precommercial thinning of initially dense stands increased cordwood yields up to 25% and nearly doubled board foot yields by age 60. On good sites, the removal of one-third of total basal area and cordwood volume by low thinning payed for itself, while the final yield 20 years later would reach, or even surpass, that of the unthinned stands. A crown thinning would generally reduce final yield in jack pine.

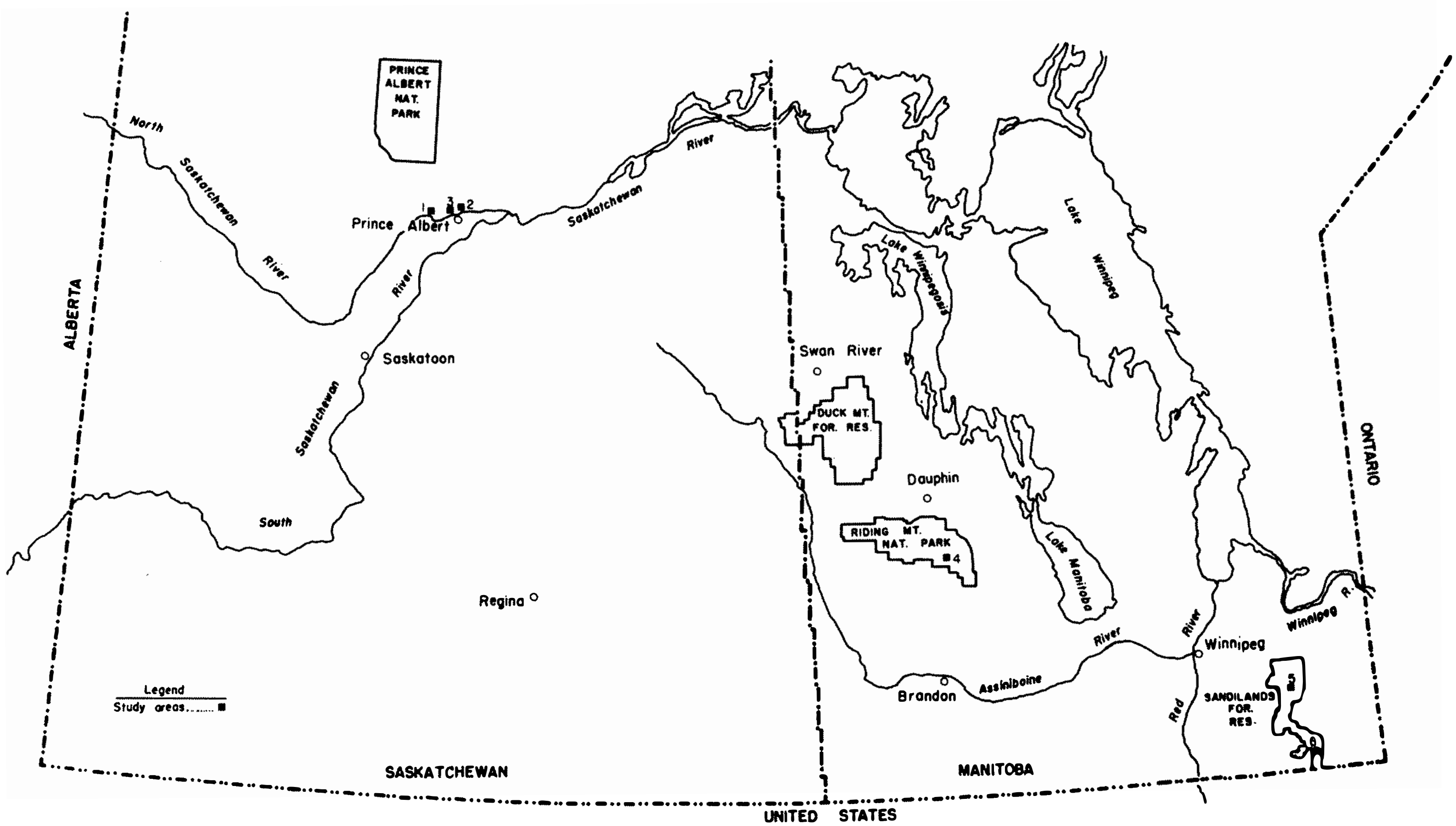
Initial density (in number of trees) had an important effect on stand development: trees in open portions of stands on average sites had greater final yield, even if unthinned, than initially denser portions that were thinned at age 19. Therefore, jack pine stands should be precommercially thinned when they are very young, preferably under 10 years of age.

RÉSUMÉ

Dans six stations de Pins gris expérimentées, le traitement par éclaircies produisit généralement des arbres à plus fort accroissement de diamètre. Les peuplements traités étaient âgés de 10 à 60 ans et les stations sous couvert variaient de pauvres à bonnes.

Dans les stations pauvres, l'amélioration du rendement, si elle existait, demeurait peu importante. Dans les stations de qualité moyenne, les éclaircies précommerciales de peuplements originalement denses augmentèrent de 25% au maximum les rendements en billes de bois et doublèrent presque les rendements en pieds-mesure-de-planche de ceux qui étaient âgés de 60 ans. Dans les stations de bonne qualité, le fait d'enlever un tiers de la surface terrière et du volume de billes au moyen d'éclaircies par le bas se dédommagea de ses propres coûts vu que le rendement final, 20 ans après, devait atteindre, ou même surpasser, celui des peuplements non éclaircis. Une éclaircie par le haut tend généralement à réduire le rendement final chez le Pin gris.

La densité (en nombre d'arbres) originale avait un effet important sur le développement du peuplement: les secteurs ayant des arbres clairsemés en stations de qualité moyenne produisirent un rendement final plus élevé, même lorsque non éclaircis, que des secteurs à peuplements originalement plus denses qui furent éclaircis à l'âge de 19 ans. Donc, les peuplements de Pins gris doivent être éclaircis précommercialement lorsqu'ils sont très jeunes, de préférence âgés de moins de 10 ans.



Location of sample areas.

ANALYSIS OF JACK PINE THINNING EXPERIMENTS, MANITOBA AND SASKATCHEWAN

INTRODUCTION

Jack pine (*Pinus banksiana* Lamb.) is an important commercial tree species in the Prairie Provinces. It is hardy, grows on a wide variety of sites, and is easily established after fire or cutting, especially on sandy soils. On light-textured dry sites jack pine grows faster than any other native tree species. These characteristics make jack pine a desirable species for maximizing wood-fiber yield.

Natural jack pine stands are often too dense to attain optimum development for timber production. Thinning may be used to reduce stand density and promote vigorous growth of the residual trees. Although the general principles of thinning are well known, specific information on the magnitude of the response of jack pine to thinning is scarce. Little is known of the extent to which response depends on age and initial stand density prior to thinning and of how different crown-class or tree-size classes respond. Results of jack pine thinning in the Lake States published as early as 1930 (Averell 1930, Schantz-Hansen 1931) were inconclusive and sometimes contradictory.

The oldest thinning studies included in this analysis were established in Saskatchewan by the Provincial Government in the 1920's. In the 1950's the Canadian Forestry Service initiated jack pine thinning studies in southeastern Manitoba. Interim results were published by Wilson (1951 and 1952), Cayford (1961 and 1964), and Steneker (1969). In this report, growth information available from six thinning studies (Table 1) has been pooled and analyzed. The trends and recommendations are intended only as general guide-lines because the coverage of data is limited, and the experimental methods differed considerably between individual studies. The report also contains cost and return estimates for various thinning treatment alternatives, the kind of information needed for more efficient allocation of investments in future silvicultural projects.

LOCATION AND DESCRIPTION OF STUDY AREAS

The study areas are in Manitoba and Saskatchewan, as shown on the accompanying map (frontispiece). The forests of southeastern Manitoba constitute the most westerly part of the Great Lakes - St. Lawrence Forest

TABLE 1. STAND AND THINNING TREATMENT SUMMARIES

Study number	Location	Soil and site	Stand age at establishment	Date of establishment	Date of remeasurement	Number of plots	Plot size	Avg d.b.h. (before thinning)	Number of trees (before thinning)	Initial density status	Thinning: Method	Thinning: Intensity
							(acres)	(inches)	(per acre)			
								1.4	4,408			Control, no thinning - 1 plot
		Fine to medium				4	1.0	1.5	3,352	Dense	Regular	Thinned: Intermediate {4 x 4 ft spacing
1	Holbein,	alluvial sand;	19	1927	1948, 1959			1.5	4,115		spacing	{5 x 5 ft spacing
	Sask.	dry to fresh			1969			1.5	4,406			Heavy 6 x 6 ft spacing
						3	0.5	1.7	2,562	Less	Regular	Control, no thinning - 1 plot
								1.9	2,436	dense	spacing	Thinned: Intermediate 5 x 5 ft - 1 plot
								1.8	2,022			Heavy 6 x 6 ft - 1 plot
	Prince	Fine to medium			1929, 1936			2.6	2,260			Control, no thinning - 1 plot
2	Albert,	sand, dry to	30	1924	1945, 1948	4	.242	NA[a]	2,050	Less	Individual	Thinned: Light {dying trees removed - 1 plot
	Sask.	medium dry			1959, 1971			NA	2,025	dense	tree selection	{dying and suppr. removed - 1 plot
								NA	2,279			Intermediate crown - dying, suppr. and a few dominants removed - 1 plot
			30	1949	1954, 1964	2	1.0	1.6	3,714	Less		Control, no thinning
		Medium to						1.6	3,427	dense		Thinned: Heavy - 7 x 7 ft spacing
	Prince	coarse sand;										
3	Albert,	dry to moder-	40	1949	1954	2	1.0	2.8	2,497	Dense	Regular	Control, no thinning
	Sask.	ately dry						2.7	2,391		spacing	Thinned: Heavy - 7 x 7 ft spacing
			60	1949	1954, 1964	2	1.0	5.4	666	Less		Control, no thinning
								5.3	810	dense		Thinned: Light - 9 x 9 ft spacing
		Sandy loam to							27,877			Control, no thinning - 1 plot
	Riding	loam, calcareous							NA	Less	Regular	Thinned: Intermediate {3 x 3 ft spacing
4	Mountain,	stony till;	10	1921	1926, 1961	5	0.25	NA[a]	NA	dense	spacing	{4 x 4 ft spacing
	Man.	fresh							NA			Heavy {5 x 5 ft spacing
									NA			{6 x 6 ft spacing
		Stratified								Less	Low selection thinning to specified Stand Density Index every 5 years	Control, no thinning - 2 plots
	Sandilands,	sand and	15	1952	1957, 1962	16	0.1	1.0-	4,700-	dense		Thinned: to 40%, 50%, 60%, 70%, 80%, 100%, and 120% of control SDI, 2 plots each
5	Man.	gravel outwash;			1967, 1971			1.9	11,100	to		
		moist								dense		
											Selection thinning; low and crown. Only trees with d.b.h. over 4 inches were removed	Control, no thinning - 4 plots
								4.7	1,050			Thinned: Heavy low 4 plots
	Sandilands,	Medium	40	1958	1963, 1968	20	0.1	4.6	1,150			Light low 4 plots
6	Man.	sand;						4.6	1,150	Less		
		fresh						5.4	900	dense		Heavy crown 4 plots
								5.0	1,050			Low crown 4 plots

[a]Not available.

Region, Rainy River Forest Section; the other forests are in the Mixedwood Forest Section of the Boreal Forest Region (Rowe 1959).

These studies cover a geographical area that is large but of fairly uniform climate. Continental climate prevails, the winters being long and cold, the summers short and fairly warm. The mean annual temperature is about 30°F. July is generally the warmest month and January the coldest, with mean daily temperatures between 60 and 65°F and -5 to -10°F respectively. The growing season (degree-days above 42°F) lasts about 150 days. The mean annual precipitation is approximately 16 inches in Saskatchewan and increases eastward to more than 20 inches in southeastern Manitoba (Anon. 1957).

Pure, even-aged, jack pine stands were selected for study. All stands originated after fire and were growing on sandy soils with excessive drainage. On these soils, site quality depends chiefly on the amount of fine materials present and on depth to water table. Stand age at the initiation of these studies ranged from 10 to 60 years. Table 1 contains summary information on the sample stands, and Fig. 1 illustrates stand conditions at different ages.

METHODS

The method of thinning has to suit the growth characteristic of the species. Jack pine is intolerant and, once overtopped, is slow to respond to release. Thinning should therefore favor the vigorous dominant and codominant trees in the stand. This is usually called "low thinning," as in Studies 2, 5, and 6. Study 6 also included selection thinning from above ("crown thinning") when trees from the dominant crown classes were removed. Thinning intensities were described by crown class designation (e.g., all suppressed and intermediate trees removed - Study 2), by stand density measures (viz., Reineke's [1933] Stand Density Index - Study 5; or basal area removed and separated into two classes: heavy or light thinning - Study 6), or by specific spacings (Studies 1, 3, and 4).

The stands were thinned only once in all but Study 5, where stands were thinned to specific Stand Density Index levels at 5-year intervals. Axes and saws were used for felling. In some studies felled trees were removed; in others, they were left on the plots. Table 1 includes a summary of treatments for individual studies.

The permanent sample plots ranged in size from 0.1 to 1.0 acre. Adjacent to each plot, a 20- to 30-foot-wide surround received the same treatment.

In all studies except no. 4, residual trees on the plots were numbered and mapped. Diameter at breast height (d.b.h.) of all trees was measured to the nearest 0.1 inch at plot establishment and at each measurement. Enough tree heights were recorded at each measurement to construct reliable height-diameter curves and estimate mean dominant height.

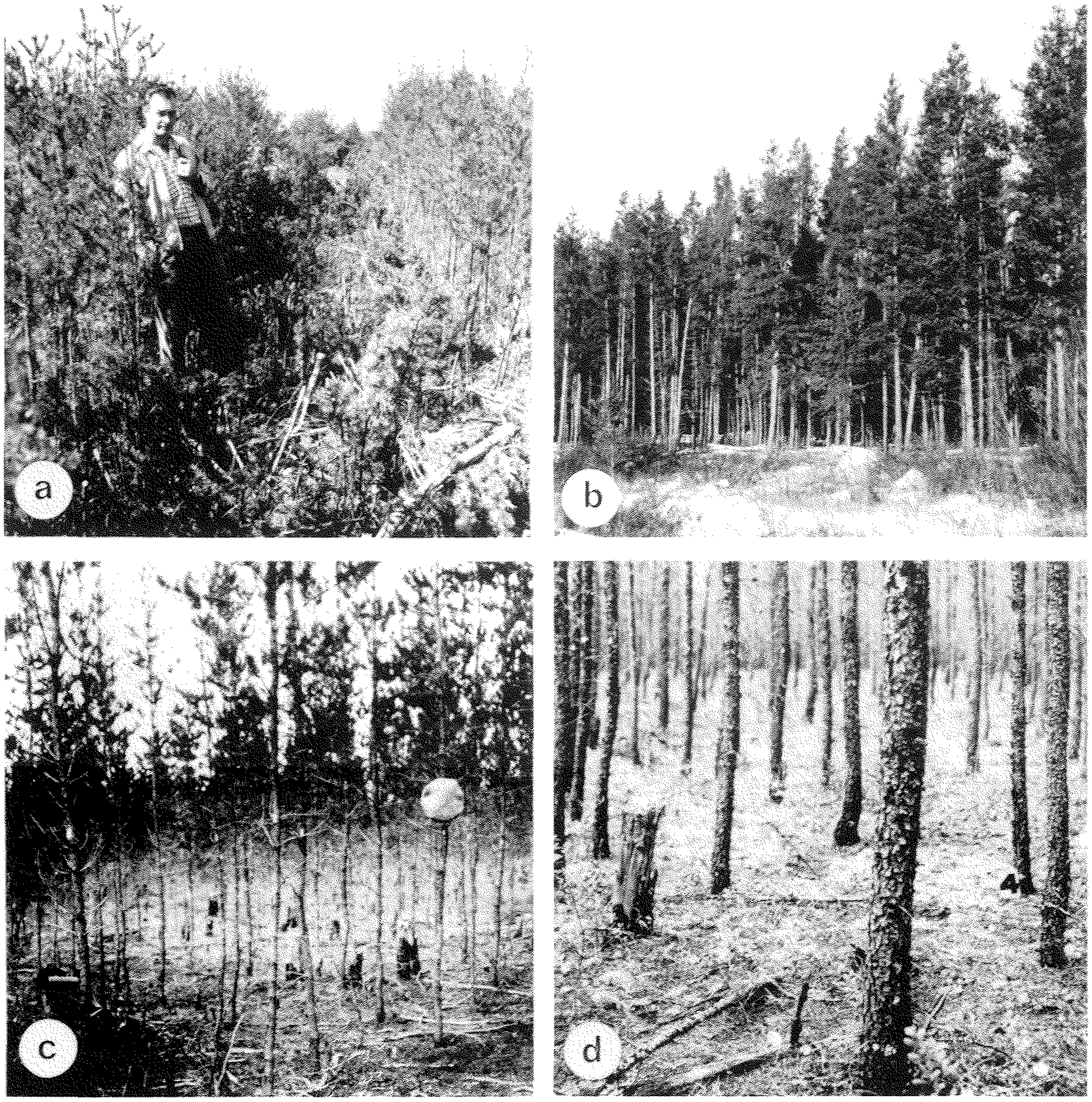


Figure 1. (a) *A 9-year-old jack pine stand growing on good (fresh to moist) sites in southeastern Manitoba.*

(b) *A 40-year-old stand before thinning in southeastern Manitoba, good sites - Study 6.*

(c) *A 19-year-old stand on average sites thinned to 4' x 4' spacing. Holbein, Saskatchewan - Study 1.*

(d) *Stand "c" at age 40, 21 years after thinning.*

Free-hand curves and regression techniques were used in the analysis. As site quality varied between, and sometimes even within, study areas, site index was used to explain associated variation in growth (Table 2). Reference curves in Fig. 2 were based on jack pine height growth in Saskatchewan (Kabzems and Kirby 1956, confirmed by Jameson 1963). The range of site quality classes in these Saskatchewan curves is wide enough to encompass thinning studies at Manitoba sites (Bella 1968).

RESULTS

Individual Tree Increment

Diameter

Diameter increment of individual trees increased after thinning in all six studies. Trees of all sizes within thinned stands responded, although relative tree size and age showed an influence. The amount of increase was determined largely by the intensity and the method of thinning (low or crown). Figs. 3, 4a, 4b, and 5 illustrate some of these findings.

Trees in the larger-than-average size classes in a stand had generally the greatest absolute increase in growth rate after thinning, whereas the smaller trees had higher relative increase (Figs. 3, 4a, and 4b). Heavy, low thinning resulted in the greatest increase in the diameter growth rate of individual trees. For example, a 40-year-old stand thinned to about 60% of its original basal area had nearly double the growth rate of the average-size trees on unthinned plots within the first 5 years after thinning (Fig. 3, Study 6). Differences in growth rate were at least as great in the second growth period in this study. Also, diameter increment of the 200 largest trees per acre increased at least 50% in heavily thinned stands (Fig. 5). The generally higher increment in the measurement period 1963-68 probably results from more favorable weather conditions (especially from greater moisture) in that period. Crown thinning stimulated diameter growth rate to a lesser extent than low thinning, and the increase was not strongly dependent on thinning intensity (Fig. 3).

Residual trees responded to release at all ages studied (Figs. 4a and 4b). There was release response to thinning in stands that were initially dense (e.g., Study 3, 30- and 40-year-old stands, Figs. 4a and 4b) and also in less dense ones (e.g., Study 6, age 40, Fig. 3). Response in tree growth occurred on all three site types, viz., poor, average, and good (respectively Study 3, stand age 30, Study 3, stand ages 40 and 60, in Figs. 4a and 4b; and Study 6 in Fig. 3).

Height

Stand density did not affect the height growth of dominants in these studies. Data from Study 3 covering three age groups are given in Table 3. These data show similar height increment among dominant trees in thinned and unthinned stands.

TABLE 2. MERCHANTABLE VOLUME YIELD IN RELATION TO THINNING INTENSITY AND TIME SINCE TREATMENT

Study number	Treatment	Number of plots	Age at establishment	Age at last remeasurement	Site index[a] Avg	Site index Min	Site index Max	Stand density at establishment; if thinned, after thinning: Basal area (ft^2) Avg	Basal area Min	Basal area Max	Spacing (ft) Avg	Spacing Min	Spacing Max	Merchantable volume at last remeasurement: Cubic feet[b] Avg	Cubic feet Min	Cubic feet Max	Cords[c] Avg	Cords Min	Cords Max	Board feet[d] Avg	Board feet Min	Board feet Max
1	Intermediate thinning	2	19	61	51 A[e]	50	52	19.2	15.9	22.5	5.6	5.2	5.9	2,343	2,297	2,388	27.6	27.0	28.1	3,533	3,229	3,837
	Heavy thinning	1	19	61	51 A	-	-	13.6	-	-	6.6	-	-	2,291	-	-	27.0	-	-	4,264	-	-
	Control	1	19	61	50 A	-	-	50.0	-	-	3.1	-	-	1,808	-	-	21.3	-	-	2,036	-	-
	Intermediate thinning	1	19	61	53 A	-	-	23.2	-	-	6.3	-	-	2,724	-	-	32.0	-	-	6,716	-	-
	Heavy thinning	1	19	61	50 A	-	-	14.7	-	-	7.7	-	-	2,705	-	-	31.8	-	-	7,203	-	-
	Control	1	19	61	51 A	-	-	44.0	-	-	4.1	-	-	2,582	-	-	30.4	-	-	5,145	-	-
2	Light thinning	2	30	77	49 A	49	49	78.6	75.1	82.0	5.0	4.8	5.2	3,214	3,119	3,309	37.8	36.7	38.9	7,616	6,984	8,248
	Intermediate crown thinning	1	30	77	46 A	-	-	54.5	-	-	5.4	-	-	2,705	-	-	31.8	-	-	6,055	-	-
	Control	1	30	77	49 A	-	-	82.0	-	-	4.4	-	-	3,364	-	-	39.6	-	-	8,741	-	-
3	Heavy thinning	1	30	45	38 P	-	-	23.7	-	-	6.4	-	-	190	-	-	2.2	-	-	13	-	-
	Control	1	30	45	36 P	-	-	52.0	-	-	3.4	-	-	84	-	-	1.0	-	-	0	-	-
	Heavy thinning	1	40	45	46 A	-	-	54.6	-	-	6.7	-	-	596	-	-	7.0	-	-	237	-	-
	Control	1	40	45	48 A	-	-	103.4	-	-	4.2	-	-	745	-	-	8.8	-	-	107	-	-
	Light thinning	1	60	75	49 A	-	-	96.6	-	-	8.7	-	-	3,028	-	-	35.6	-	-	10,737	-	-
	Control	1	60	75	49 A	-	-	107.2	-	-	8.1	-	-	2,763	-	-	32.5	-	-	9,239	-	-
4	Intermediate thinning	2[f]	10	50	48 A	48	48	Number of trees available only			4.0	3.6	4.5	1,906	1,814	1,999	22.4	21.4	23.5	2,552	2,107	2,998
	Heavy thinning	2	10	50	50 A	50	50				6.0	6.0	6.1	2,183	1,992	2,372	25.7	23.4	27.9	4,052	3,834	4,270
	Control	1	10	50	50 A	-	-				1.2	-	-	2,146	-	-	25.2	-	-	2,691	-	-
6	Heavy low thinning	4	40	50	60 G	59	62	84.2	82.1	85.7	7.6	7.4	7.9	2,135	1,971	2,229	25.1	23.2	26.2	6,849	6,252	7,157
	Light low thinning	4	40	50	62 G	59	67	101.8	98.1	105.5	7.2	6.8	7.6	2,662	2,578	2,756	31.3	30.3	32.4	7,432	6,734	8,379
	Heavy crown thinning	4	40	50	60 G	56	64	79.2	75.4	84.7	8.6	7.8	9.6	1,956	1,800	2,155	23.0	21.2	25.4	5,243	4,110	5,718
	Light crown thinning	4	40	50	62 G	59	63	98.6	94.0	100.9	7.4	7.2	7.5	2,318	2,262	2,369	27.3	26.6	27.9	5,992	5,664	6,202
	Control	4	40	50	60 G	58	63	132.7	125.0	139.0	6.4	6.1	6.8	2,851	2,658	3,018	33.5	31.3	35.5	7,174	5,241	8,261

[a] Index age 50 years.
[b] D.b.h. 4 inches and over; top diameter inside bark, 3 inches; after Honer 1967.
[c] Cordage estimated from merchantable ft^3 volume; 1 cord = 85 ft^3.
[d] D.b.h. 6 inches and over; top diameter inside bark, 5 inches; stump 0.5 ft; International ¼ Log Rule.
[e] Denotes one of three arbitrary site quality classes: A - Average site; P - Poor site; G - Good site.
[f] In addition to jack pine, the volumes on these plots included a small amount of black and white spruce advance growths.

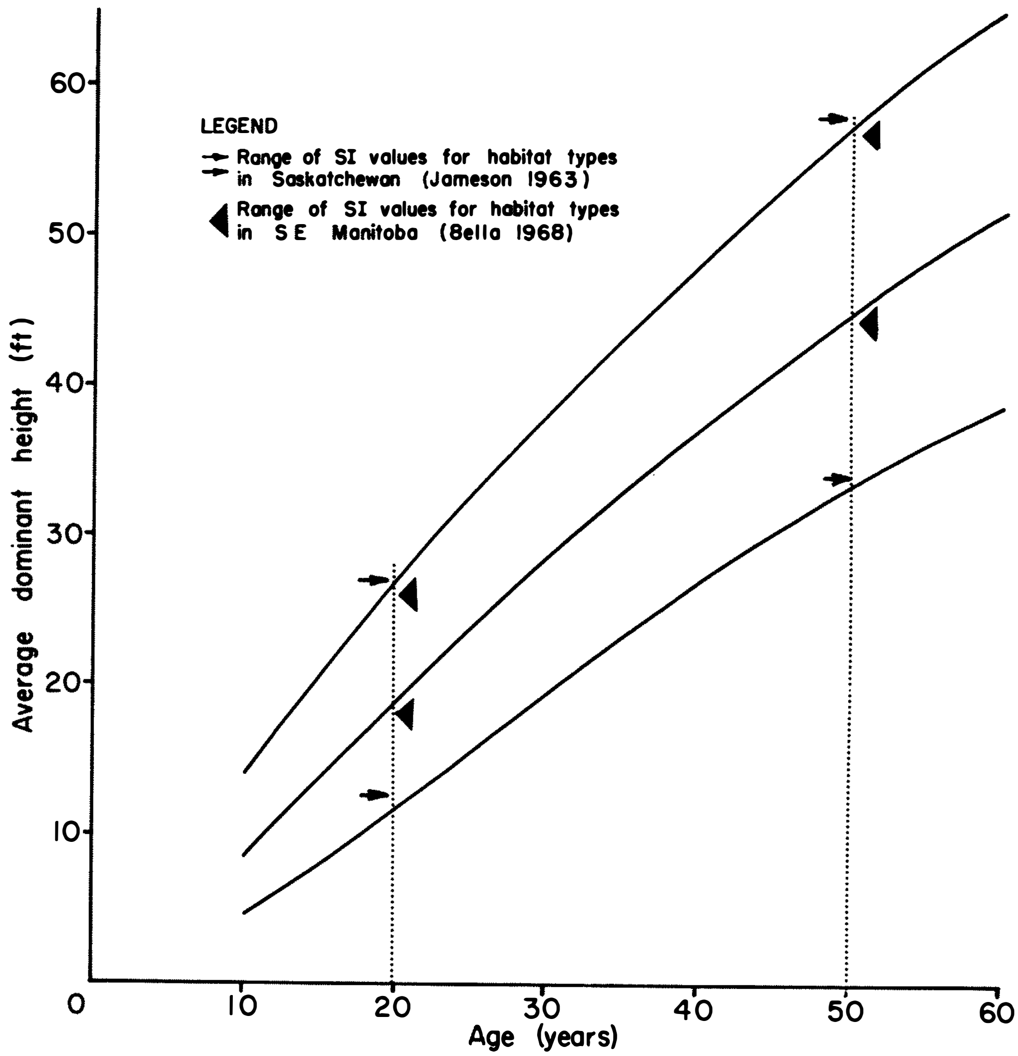


Figure 2. Jack pine site index curves for Saskatchewan (from Kabzems and Kirby 1956).

At the same time, even relatively minor variation in site quality may have noticeable effect on height growth. Difficulties in detecting such variations in dense young stands when the experiments are established lead to confounding thinning results and hinder the analysis of these experiments. For example, at the establishment of Study 5 (at age 15 years), considerable variation existed in average dominant height and stand density in the number of trees per acre. On sample plots where density was high, dominant height was low. Regression analysis revealed a negative, linear relation ($r = -0.75$; $n = 14$; significant at P.01) between number of trees per acre before thinning and mean dominant height. This suggested a density effect on dominant height growth. However, analysis of postthinning height increment found no such relation. Thinning intensity, or postthinning stand density, seemed to have no effect on height increment, whereas a significant correlation was found between original density and dominant height growth in

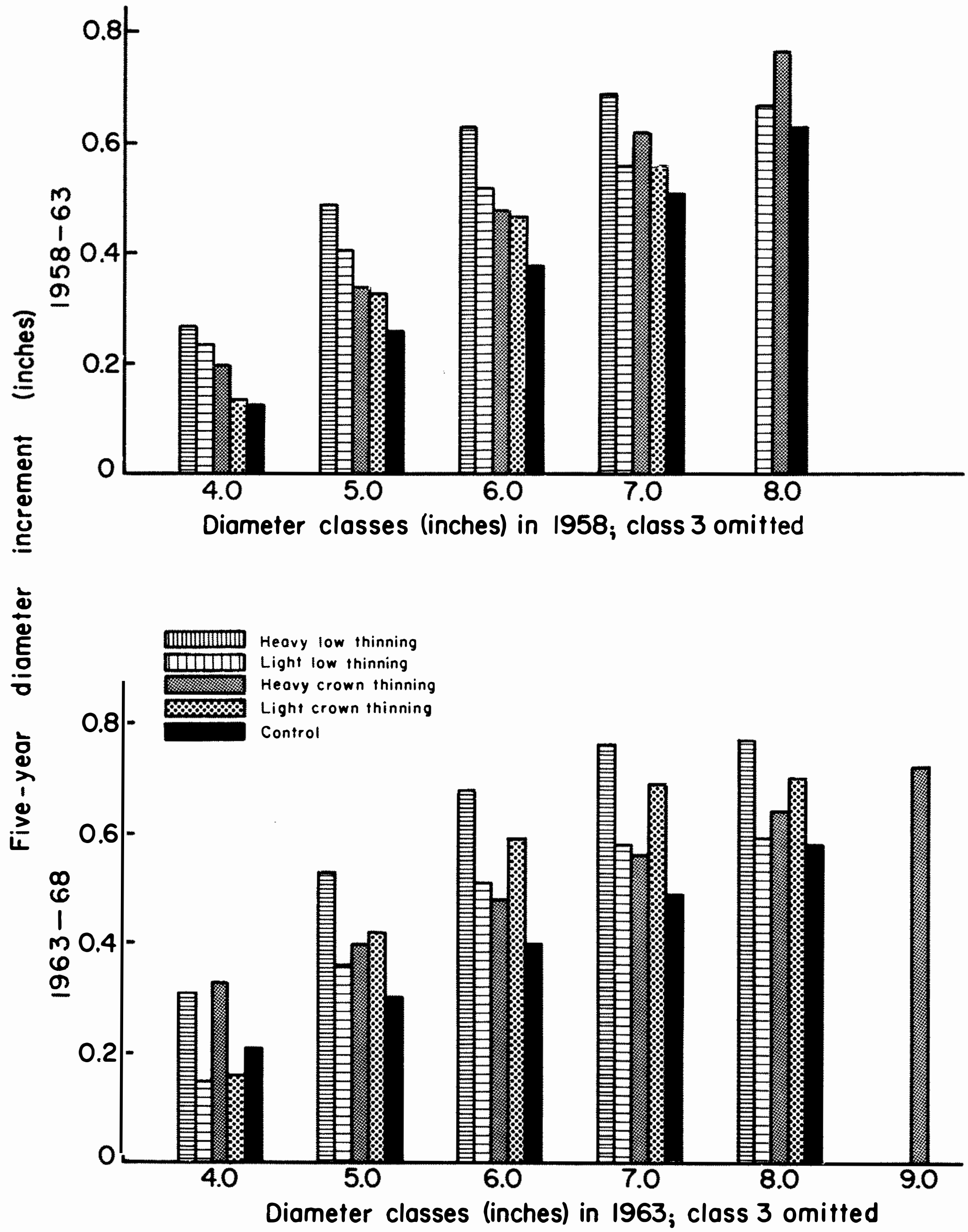


Figure 3. Smoothed values (regression estimates) of 5-year diameter increment by treatment for the major size classes present. Study 6. The stand was 40 years old in 1958. Each treatment is represented by four plots.

the three 5-year postthinning increment periods. This suggests the reverse of the foregoing relation. That is, site conditions, expressed by the height growth of dominants, influence the initial density of young jack pine stands through regeneration chance, expression of dominance, and early natural thinning.

Stand Increment per Acre

Periodic Annual Basal Area

Trends of basal area increment in relation to residual basal area density are presented for three studies in Fig. 6. The stands included represent the widest range of densities available in the present analysis. Stands in Studies 1 and 2 were growing on somewhat better-than-average sites; stands in Study 6 represent some of the best jack pine sites. Stand age at thinning ranged from 19 to 40 years; the length of increment (measurement) period varied between 6 and 21 growing seasons.

Trends in Fig. 6 indicate that maximum basal area increment occurs at basal areas 30% below control-plot stand density. For Studies 1 and 2, thinned at 19 and 30 years of age from basal areas of about 50 and 80 ft^2 per acre respectively, the greatest increase in basal area increment was around 25%. At age 19, however, basal area was reduced nearly 70% without a drop in increment below that of the control plots (Fig. 6, Study 1). Similar trends in basal area increment were observed by Steneker and Jarvis (1966) in thinned aspen stands. On the other hand, a low thinning that reduced basal area density from about 130 to 85 ft^2 per acre at age 40 in stands that were growing on good sites increased annual increment in the following 10 years from 0.5 ft^2 per acre to about 2 ft^2 per acre, while crown thinning in the same stand resulted only in a minor, if in any, increase.

The present data (Fig. 6) also show a general decline in net basal area increment with increasing age and with higher basal area densities; but the increment-density relation (i.e. the shape of the curves) seems to remain the same. Some thinning studies (e.g., Assman 1961) showed a flattening out of the basal area increment curve at higher ages and maximum increment at maximum densities. In the present study, however, even the oldest stands were only middle-aged at thinning; so some thrifty residual trees could still utilize the extra available growing space. Thinning that removed the dominants and codominants and left the smaller trees with poorer growth potential did not improve increment (Fig. 6, the part of Study 6 that received crown thinning).

Mean Annual Volume Increment

Mean Annual Increment (MAI) expressed in total cubic foot, cordwood, and board foot volumes is presented in Figs. 7a and 7b. Results from studies used in this analysis were separated into groups by initial density (dense and less dense), site quality (poor, average, good), and age at thinning; so variation in volume growth and yield that is associated with these factors, which are extrinsic to thinning treatment, could be removed. Sample plots

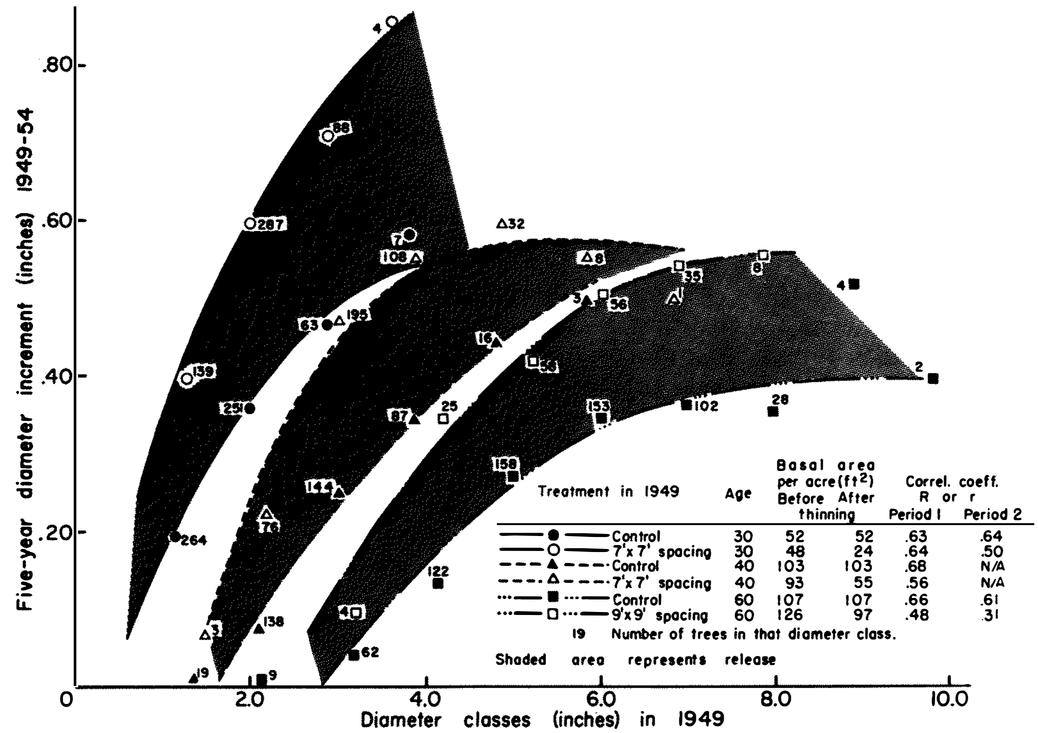


Figure 4a. *First 5-year diameter increment after thinning, over diameter by age classes and treatments. Study 3. Data are from one plot for each treatment and age.*

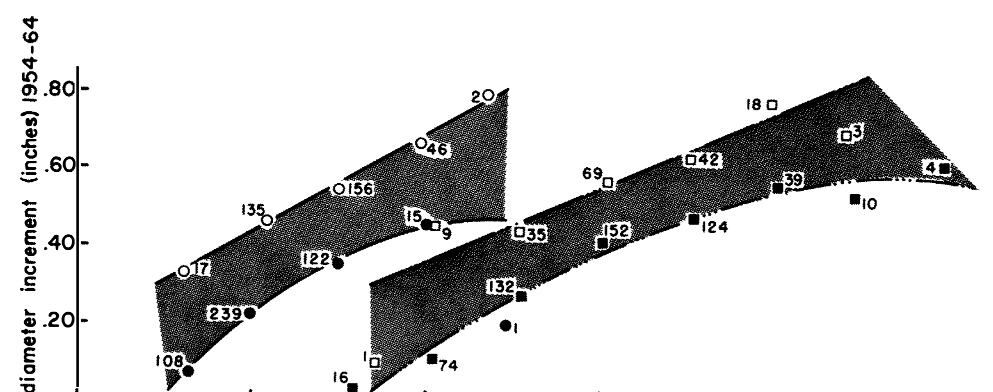


Figure 4b. *Ten-year diameter increment over diameter by age classes and treatments - second increment period after thinning (legend in Fig. 4a).*

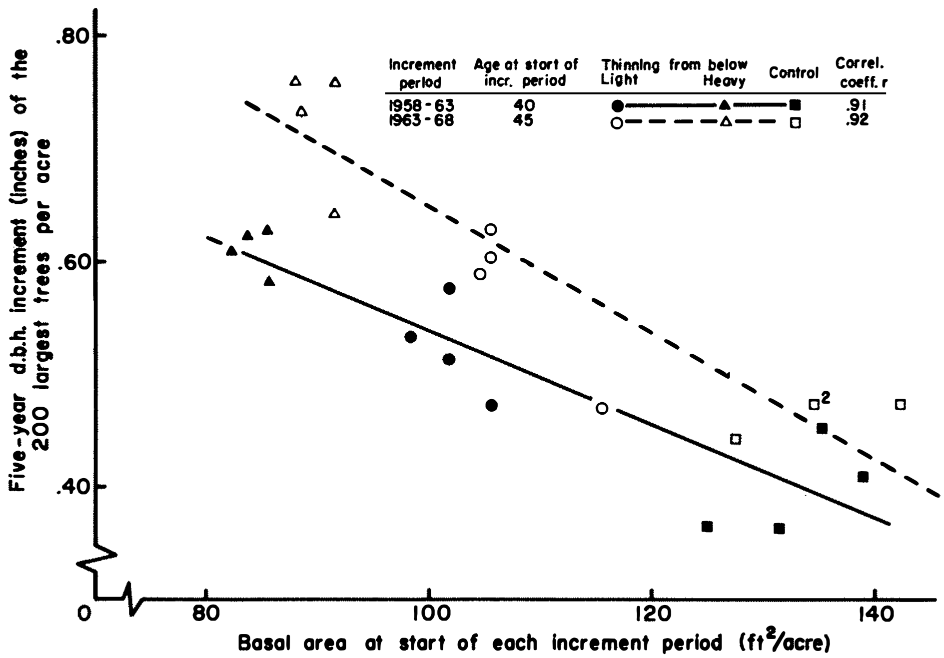


Figure 5. Five-year diameter increment of the 200 largest trees per acre over basal area at the start of each increment period. Study 6.

TABLE 3. HEIGHT INCREMENT OF DOMINANT TREES AT DIFFERENT STAND DENSITIES (CONTROL AND LOW-THINNED STANDS: STUDY 3) AND AGES

Age at establishment in 1949	Treatment	Average dominant height (ft) 1949	1954	1964	Height increment for the period (ft)
30	Thinned	25		34	9
	Control	25		32	7
40	Thinned	38	42		4
	Control	39	44		5
60	Thinned	55		65	10
	Control	53		64	11

were assigned to either of two initial density classes on the basis of development trends (in number of trees) plotted for all control plots. Thinning intensity as designated here (Figs. 7a and 7b) is also a relative measure (of intensities present in these studies) and is expressed in terms of stand density at the time of thinning. Trends from Study 6 (commercial thinning on good sites) can be viewed as quite conclusive, each treatment having been replicated four times. In other studies, where replication is inadequate, any variation confounds treatment effects.

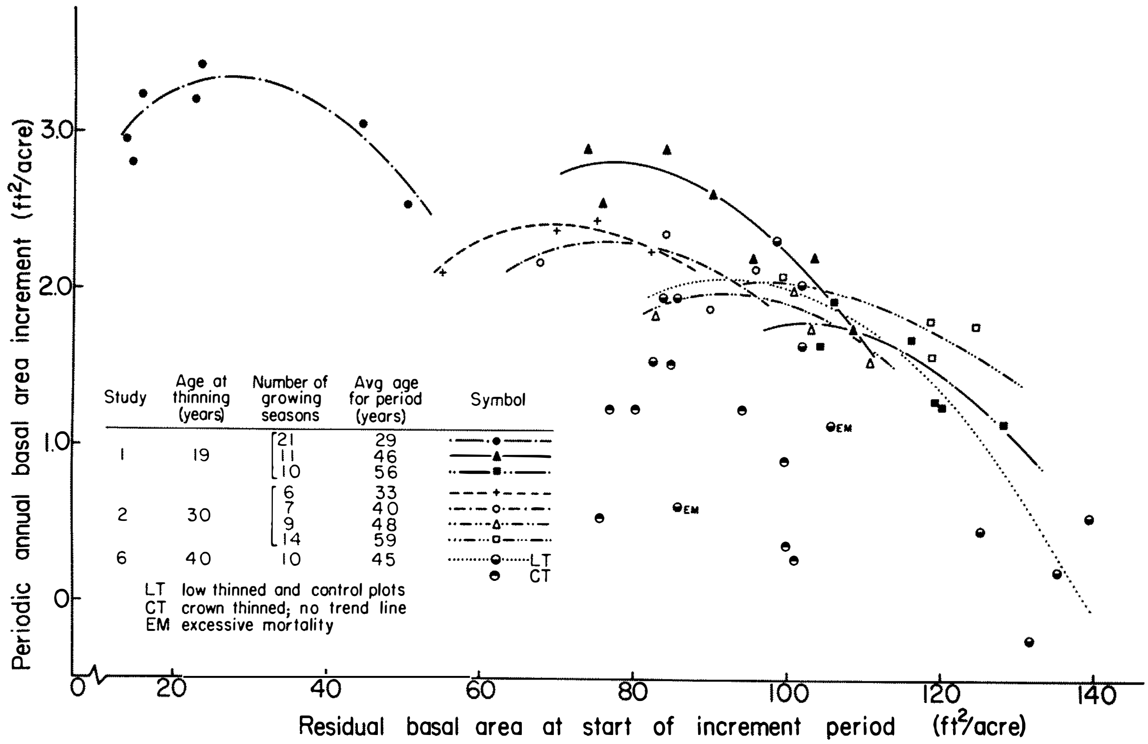


Figure 6. Periodic annual basal area increment over residual basal area.

Total cubic foot volume. MAI in total volume was generally highest in check stands and decreased as the intensity of thinning increased (Figs. 7a and 7b). Stands that were initially less dense had higher MAI whether or not they were thinned; the difference amounts to about 10% (MAI around 5 ft^3) at age 60 on average sites after precommercial thinning. Differences in MAI due to treatment diminished as time elapsed after thinning increased. The trend toward maximum, or unthinned, levels of MAI was most pronounced in stands that received low thinning at age 40, were growing on good sites, and were initially less dense (Fig. 7b), whereas no such trend was apparent after a heavy low thinning at 30 years on poor sites in stands that were initially dense (Fig. 7a). There, the residual trees did not seem to utilize fully the extra living space that became available through thinning. Results in Figs. 7a and 7b also indicate that in unthinned stands, MAI in total volume culminates at a much younger age on good sites than on average sites - approximately at 40 to 45 years in contrast to 60 to 70 years. Commercial thinning will delay the time of culmination in proportion to the intensity of thinning. Precommercial thinning appears to have the same effect, but the present results are inadequate for generalization.

Cordwood volume. Precommercial thinning between 19 and 40 years of age in jack pine stands growing on average sites resulted in an increase of up to 25% in MAI. MAI values were generally lower in stands that were initially dense than in those that were initially less dense, but the former stands gained more from thinning in terms of cordwood yield at age 60 (Fig. 7a). Intermediate crown thinning that removed some of the better trees at

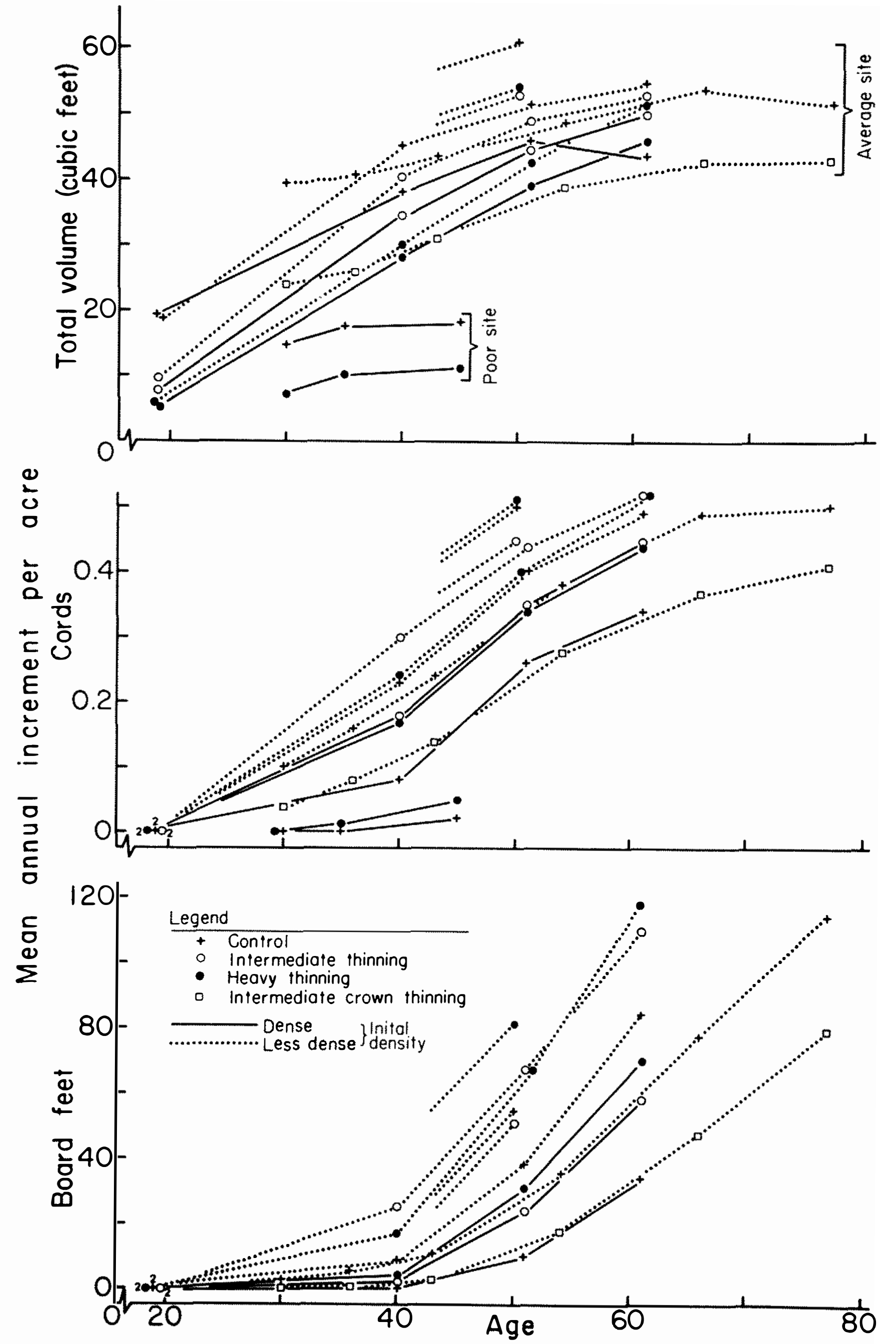


Figure 7a. Mean annual increment trends for stands thinned under 40 years of age; site quality class, initial stand density, and thinning intensity are designated.

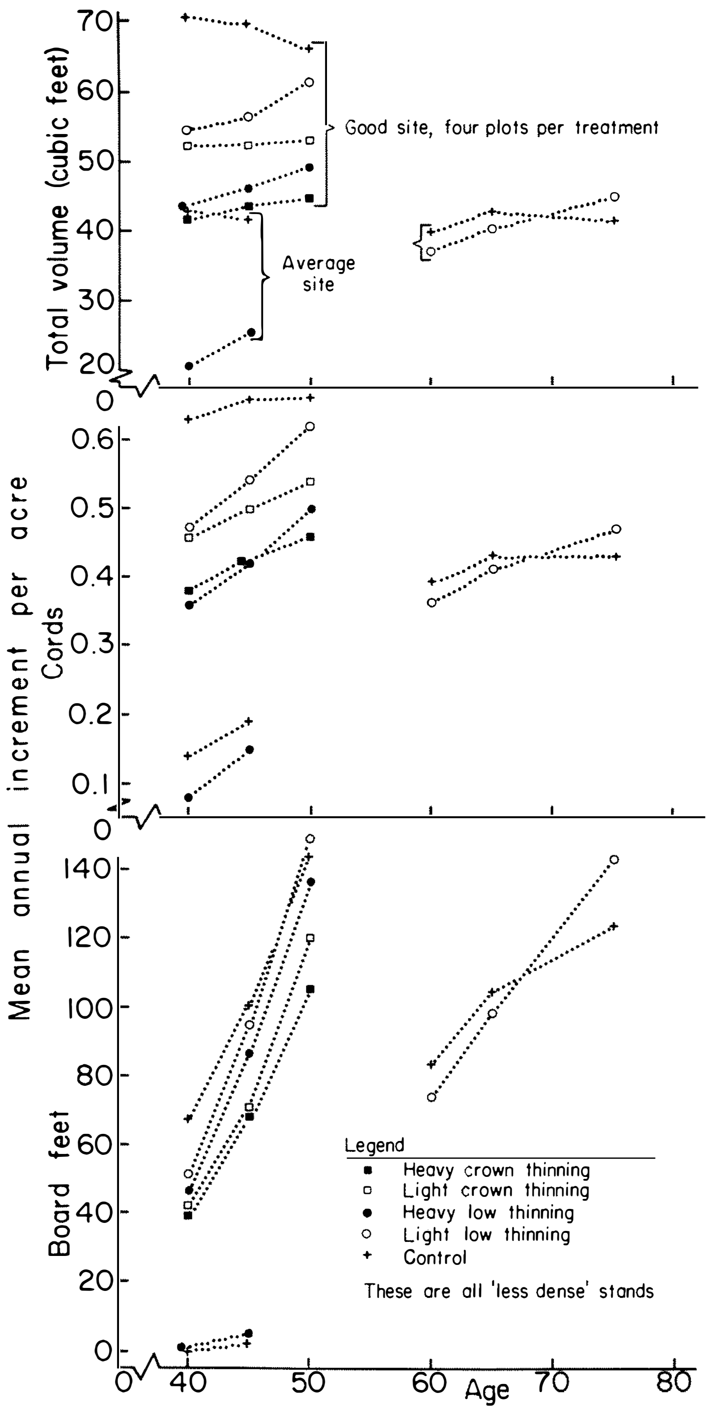


Figure 7b. Mean annual increment trends for stands thinned at 40 years and over.

age 30 was not beneficial. Dense stands on poor sites that received heavy low thinning showed some improvement in MAI, but in absolute terms this was negligible. (Such stands are probably submarginal for logging.)

Commercial thinning that removed substantial volumes from a less dense stand growing on good sites (Study 6) at age 40 resulted in a rapid increase in increment. The increase was nearly twice as much after low thinning as after crown thinning. Trends in Fig. 7b suggest that stands that received light low thinning could reach control levels of MAI within 15 years and that those that received heavy low thinning would do so within 20 years. After light crown thinning, stands might reach control levels within 25 to 30 years, but after heavy crown thinning they may never reach control levels. Low thinning in less dense stands on average sites at ages 40 (heavy thinning) and 60 years (light thinning) resulted only in a slight improvement in cordwood volume production (Fig. 7b). A heavier thinning in the older stand might have been a more effective treatment.

MAI in cordwood volume in unthinned stands seems to culminate at 45 to 50 years of age on good sites and at 70 to 75 years on average sites, i.e. 5 to 10 years later than in terms of total cubic foot volume. Precommercial thinning had no effect on the time of culmination of MAI. Commercial thinning delayed culmination, depending on the kind and intensity of thinning.

Board foot volume. Thinning generally resulted in increased MAI in board foot volume. This amounted to as much as a 100% increase in board foot yield at age 60, after precommercial thinning at age 20 in initially dense stands growing on average sites (Fig. 7a). In the less dense portions of the same stand, MAI was generally higher than in the dense portions, although the absolute increase in MAI attributed to thinning was about the same. An intermediate crown thinning at 30 years, in less dense stands on average sites, was associated with 30% reduction in board foot volumes at 70 years.

Commercial low thinning at age 40 in stands growing on good sites (Fig. 7b) so stimulated increment that 10 years later the lightly thinned plots reached and surpassed the control plots in MAI and the heavily thinned ones are likely to do so within the following 10 years. The replenishment of volume was slower in stands that received crown thinning, and they may never reach final board foot yields as high as those of unthinned stands. Similarly, a stand on an average site that was heavily low-thinned at 40 years benefited little from the treatment (Fig. 7b), but a medium-intensity low thinning 5 to 10 years later might have had better results.

The trends shown in Figs. 7a and 7b give no indication that any of these stands - up to 77 years - have reached, or are reaching, maximum levels of MAI in board feet. Further remeasurements should provide this information.

Mortality

Dense, young jack pine stands are characterized, because of suppression, by heavy mortality among the smaller trees. Larger trees may also die from other causes, but their number is relatively small. Low thinning removes the small trees, and thus the number dying from suppression is reduced in proportion to the intensity of the thinning. This relation also holds when "space" thinning (i.e. leaving trees a specified distance apart), rather than selection thinning, is applied, as shown in Table 4.

TABLE 4. DISTRIBUTION OF LIVING AND DEAD TREES BY SIZE CLASSES IN A STAND THINNED IN 1927 AT 19 YEARS OF AGE (PER ACRE VALUES: STUDY 1, INITIALLY DENSE PORTIONS)

Thinning treatment and spacing	Year and interim mortality	D.b.h. classes 1	2	3	4	5	6	7	8	9	10	Total
		Number of trees										
Heavy (6.6)	1927 living	562	414	25								1,001
	Mortality[a]	172	35									207
	1969 living		9	61	187	252	189	82	13	1		794
Medium (5.9)	1927 living	783	430	22								1,235
	Mortality[a]	241	26	1								268
	1969 living		21	137	220	324	187	64	12	1	1	967
Light (5.2)	1927 living	918	679	37								1,634
	Mortality[a]	484	108	2								594
	1969 living	1	15	179	294	303	195	44	9			1,040
Control (3.1)	1927 living	2,999	1,343	66								4,408
	Mortality[a]	2,661	515	4								3,180
	1969 living	3	86	347	365	267	123	32	5			1,228

[a]On the basis of d.b.h. in 1927.

Mortality seems much more variable in middle-aged than in young stands. Because older stands are made up of fewer but bigger trees, the number of trees dying in a year is relatively small. Thus, only one or two extra trees can markedly affect mortality statistics. Fig. 8 shows 10-year mortality plotted over basal area density after thinning in a 40-year-old jack pine stand. On the average, mortality is lower in thinned than in check stands. However, considerable variation exists in the amount of mortality in thinned stands, and it seems to be independent of residual stand density. It may be that tree injuries sustained during thinning cause this variation. At the same time, mortality is relatively stable on the control plots. Fig. 8 indicates somewhat higher mortality in stands that received crown thinning than in those with low thinning.

DISCUSSION AND CONCLUSIONS

With two exceptions (Study 3 and Study 6), the studies reported here may all be considered precommercial thinnings. With such thinnings, the increased revenue from final merchantable yield should cover the compounded cost of the thinning. No records are available on the number of man-hours required for these studies, but similar manual-selection thinning in the Lake States (Averell 1930) in 20-year-old jack pine stands (average d.b.h. 2.5 inches; 2,500 to 3,800 trees per acre, of which 1,200 to 3,500 per acre were cut) required 10 to 35 man-hours per acre. If we consider 20 man-hours per acre at an hourly rate of $2 the cost is $40. This amount invested for 30 years at nominal 4% interest should bring a $130 increase in revenue at harvest to justify thinning. On the assumption that jack pine logs are sold for pulpwood, precommercial selection thinning of jack pine stands with hand tools on average, or poorer than average, sites is clearly unfeasible, as thinning hardly improves production. At present, no long-term data are available on stands thinned on good sites, where the response to thinning is usually better.

The situation is more promising if jack pine is logged for lumber: precommercial selection thinning may as much as double board foot volume production by final harvest. Thus, the increase may be around 3,000 board feet on average sites and perhaps twice that amount on good sites (as data are lacking, the latter is a rough estimate only). However, even with a 6,000-board-foot improvement in yield, the increase in revenue at $10 Mbf of stumpage would only be $60 per acre (the maximum stumpage for jack pine in Manitoba in 1972 was $7.50 Mbf and in Saskatchewan $10 Mbf), not enough to cover the compounded cost of thinning. Furthermore, if maximum MAI is taken as the criterion for final harvest, thinning seems to delay the culmination of MAI and thus possibly lengthen rotation. If the criterion is a specified volume of merchantable yield, medium-intensity precommercial thinning may shorten rotation by about 10 years. All considered, precommercial selection thinning with hand tools in jack pine between 20 and 40 years of age is not recommended, either for pulpwood or for lumber production in Manitoba and Saskatchewan.

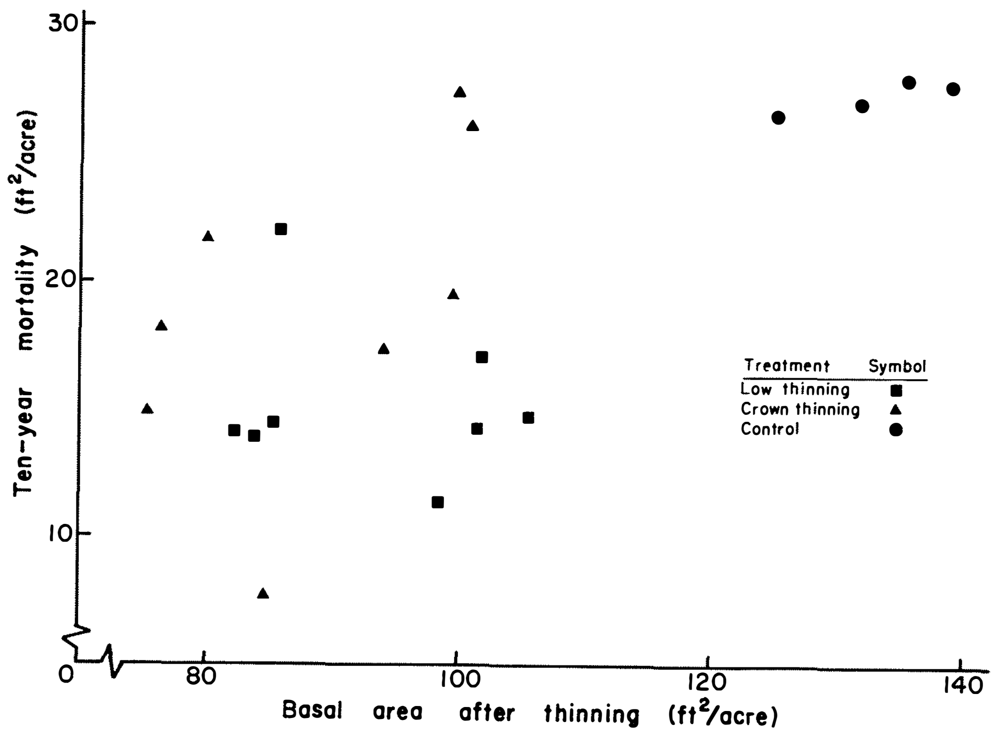


Figure 8. Basal area mortality in a 10-year period after thinning, over residual basal area. The stand was thinned at age 40. Study 6.

Although manual precommercial thinning may not be feasible under present economic conditions, commercial thinning of thrifty, middle-aged stands on good yielding sites may be financially sound. These stands would contain enough large trees to make thinning worthwhile, and the residuals would still be vigorous enough for substantial response to release. In a 40-year-old jack pine stand in Manitoba (Study 6) thinning from below so stimulated diameter increment and reduced mortality that the improvement in increment (basal area or volume) will suffice to replenish the volume removed by thinning by final harvest at 60 years of age. Thinning reduced basal area density and cordwood volume as much as 35% (from about 135 ft^2 per acre to 85 ft^2 and from 23 cords per acre to 15 cords) without adversely affecting periodic basal area increment. As post-thinning increment is realized on residual trees of relatively large size, there is considerable acceleration of MAI in terms of merchantable volume (cords or board feet), and indications are of an improvement in final merchantable yield. However, the culmination of MAI would be delayed, at least in terms of cordwood volume. As revenue from thinning covered the cost of the operation, any increase in merchantable yield at final harvest is a clear gain.

In the same study (no. 6), crown thinning that removed the same amount of cordwood as that mentioned in the preceding paragraph, by cutting the largest trees, also resulted in improvement in diameter increment. However, because the smaller trees were left and put on increment, it will take much longer, possibly 10 to 15 years longer, for these heavily thinned stands than for those that received low thinning to reach merchantable volume levels similar to those of untreated stands. Extending rotation without reasonable prospects of improvement in final yield is not practical.

In conclusion, commercial thinning that favors vigorous dominant and codominant trees (i.e. low thinning) in thrifty middle-aged stands on good sites is recommended. A fairly heavy thinning - up to 8 to 10 cords per acre - may be most desirable from the point of view of release as well as from that of immediate revenue. Commercial thinning however, would generally lengthen rotation in accordance with stand age, site, and how much and what portion of the stand are removed. Commercial crown thinning that removes the best trees is not recommended.

These studies indicate that, on average sites, stands that were initially less dense gave a higher merchantable yield, whether or not they were thinned. (No similar comparison is possible for good sites, as the one experiment available on such sites covers only initially less dense stands.) In fact, initial density in these experiments seems to override the effect of precommercial thinning (Fig. 7a), as the most effective thinning treatment in dense portions produced merchantable yield about equal to that of unthinned control in less dense stands. This indicates that good tree (especially crown) development at a very young age that occurs under less dense conditions is an important prerequisite to fast tree growth and vigor of jack pine. Thus precommercial thinning treatment beyond 15 to 20 years of age seems already too late for the best response. Preliminary results from jack pine stands on better sandy sites (above average yield) that were thinned at age 10 in southeastern Manitoba also showed the greatest response at lower stand-density levels (Bella and DeFranceschi 1971). This suggests that, even at this early age, trees in the denser portion of the stand are already showing signs of diminished vigor. Thus thinning at ages as low as 5 years may be desirable to maintain maximum diameter increment in young trees.

Manual selection thinning, however, would likely be even more costly in very young stands than in stands between 15 and 20 years of age. The labor requirement might increase because of the greater number of trees to be cut. Extending the investment period by another 10 to 15 years would substantially increase the final compounded cost.

The solution to low-cost precommercial thinning may lie in mechanization, either through nonselective, multistem strip thinning with heavy equipment (e.g., Bella and DeFranceschi 1971) or through selective thinning with light portable machines (Riley 1973). It may also be feasible, especially in young, very dense stands, to use a combination of these two methods. First, open up the young stands and create easier access by mechanical strip thinning; then follow this with selection thinning by means of portable equipment within the residual strips.

REFERENCES

Anon. 1957. Atlas of Canada. Can. Dep. Mines Tech. Surv., Geogr. Br., Ottawa.

Assman, E. 1961. The effect of different thinning intensities on growth and yield. (Transl. by F.W. von Althen, 1962.) Can. Dep. Forest., Richmond Hill, Ont. Mimeogr. 62-20. 37 pp.

Averell, J.L. 1930. How much does it cost to thin jack pine? J. Forest. 28:573-574.

Bella, I.E. 1968. Jack pine yield tables for southeastern Manitoba. Can. Dep. Fish. Forest., Forest. Br. Publication 1207. 15 pp.

Bella, I.E., and J.P. DeFranceschi. 1971. Growth of young jack pine after mechanical strip thinning in Manitoba. Can. Forest. Serv. Inform. Rep. A-X-40. 20 pp.

Cayford, J.H. 1961. Results of a 1927 jack pine thinning in Saskatchewan. Can. Dep. Forest. Tech. Note 107. 13 pp.

Cayford, J.H. 1964. Results of a 1920 jack pine thinning in western Manitoba. Can. Dep. Forest. Publication 1077. 8 pp.

Honer, T.G. 1967. Standard volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada. Can. Dep. Forest. Rural Develop., Forest. Br. Inform. Rep. FMR-X-5. 21 + 132 pp.

Jameson, J.S. 1963. Relation of jack pine height-growth to site in the Mixedwood Forest Section of Saskatchewan. Pages 299-316 *in* Forest-soil relationships in North America. Papers presented at Second N. Amer. Forest Soils Conf., Oregon State Univ., August 1963.

Kabzems, A., and C.L. Kirby. 1956. The growth and yield of jack pine in Saskatchewan. Sask. Dep. Natur. Resources, Forest. Br. Tech. Bull. 2. 66 pp.

Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. J. Agr. Res. 46:627-638.

Riley, L.F. 1973. Operational trials of techniques to improve jack pine spacing. Can. Forest. Serv. Inform. Rep. 0-X-180. 29 pp.

Rowe, J.S. 1959. Forest regions of Canada. Can. Dep. Northern Aff. Nat. Resources, Forest. Br. Bull. 123. 71 pp.

Schantz-Hansen, T. 1931. Some results in thinning 27-year-old jack pine. J. Forest. 29:544-550.

Steneker, G.A. 1969. Strip and spaced thinning in overstocked jack pine and black spruce stands. Can. Dep. Fish. Forest., Forest. Br. Inform. Rep. MS-X-16. 16 pp.

Steneker, G.A., and J.M. Jarvis. 1966. Thinning in trembling aspen stands of Manitoba and Saskatchewan. Can. Dep. Forest. Publication 1140. 28 pp.

Wilson, G.M. 1951. Thinning 30-year-old jack pine. Can. Dep. Resources Develop., Div. Forest Res. Silvicult. Leafl. 52. 3 pp.

Wilson, G.M. 1952. Thinning jack pine, Nisbet Forest Reserve, Saskatchewan. Can. Dep. Resources Develop., Forest Res. Div. Silvicult. Res. Note 99. 24 pp.

1338-5-74-2.9M