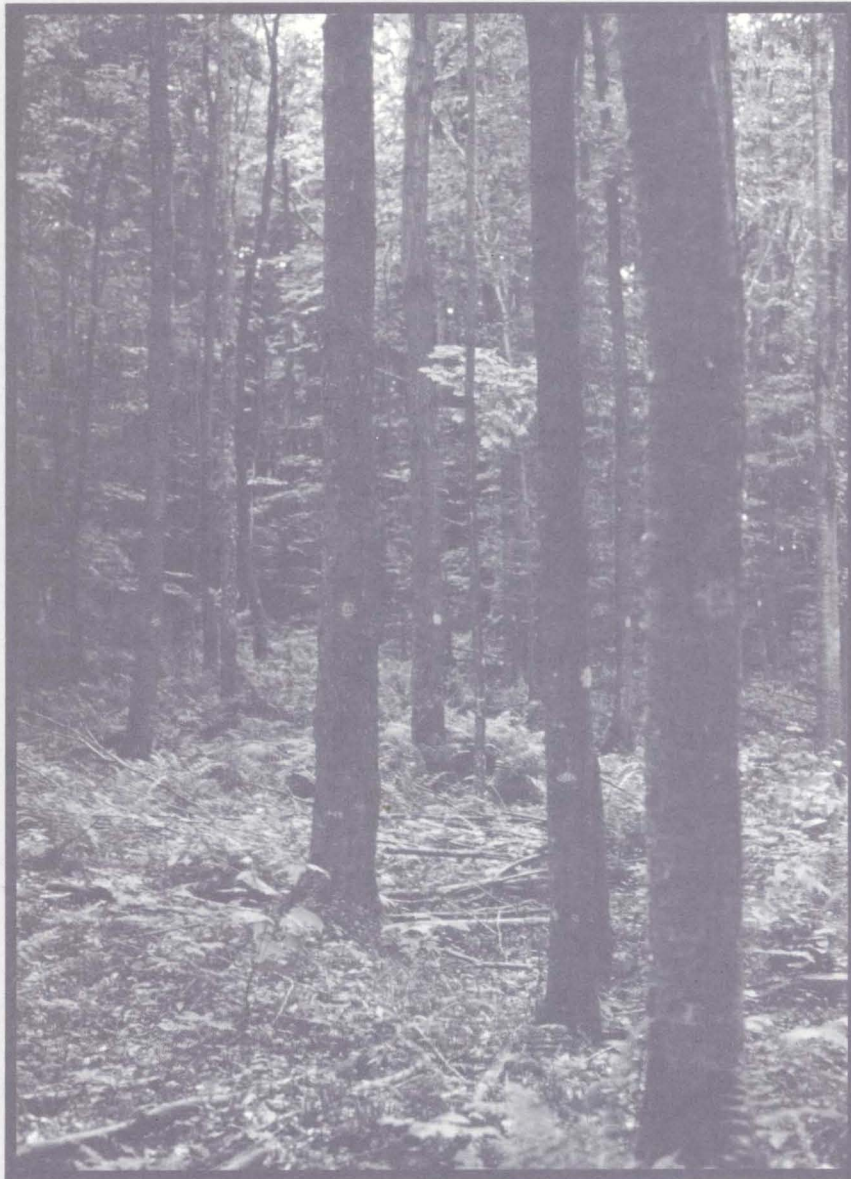# Reaction of principal hardwood species to light felling in a maple-yellow birch forest in the Eastern Townships

Richard Zarnovican and Claude Laberge
Quebec Region • Information Report LAU-X-109E

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Richard Zarnovican

Richard Zarnovican has been working at the Laurentian Forestry Centre since 1977. He earned a Ph.D. in silviculture and management from Université Laval and is currently carrying out research on silviculture and growth and yield of managed forests. He also worked for the Service des études écologiques régionales from 1974 to 1976.

Claude Laberge

Claude Laberge earned a bachelor's degree in statistics and a master's degree in mathematics (statistics option) from Université Laval. He is presently finishing his doctorate in water science at INRS-Eau (branch of the Université du Québec). He has occupied several research positions at INRS-Eau, CIRAL (Université Laval) and the Canadian Forest Service. He is specializing in the application of statistics in environmental studies and in trend detection in time series.

Reaction of principal hardwood species
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Cette publication est également offerte en français sous le titre «Réaction des principales essences feuillues à l'éclaircie de mise en lumière dans une érablière à bouleau jaune en Estrie» (Numéro de catalogue Fo46-18/109F).

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ABSTRACT

The effect of combined and selective thinnings, and of thinning from above, with a thinning intensity of 50%, 35% and 44% based on cut volume, was studied on the radial increment of the main maple-yellow birch forest species in the 56-year-old Saint-Zacharie forest, Richmond County, Quebec.

Thinnings were carried out in three experimental plots and the effect was studied for sugar maple, beech, yellow birch, white ash and basswood.

The reaction of sugar maple was on the whole positive; intensive thinning from above in Plot 1 and selective thinning in Plot 3 succeeded in significantly stimulating radial growth, while intensive combined thinning in Plot 2 failed to produce the anticipated effect.

Beech reacted positively to both thinning from above and combined thinning, even though the latter reaction was not statistically significant. These results confirmed the species' tolerance to shade and great adaptability to type of treatment.

The reaction of yellow birch to individualization of crop trees was mixed, while analysis of variance made it possible to detect a significant increase following thinning from above and a significant decrease following selective thinning. This reaction was mainly due to the difficulty this species experiences in progressing in a fixed social hierarchy.

The study reveals that there was no reaction to selective thinning in basswood and white ash. This suggests that individualization of these species must take place sufficiently early to achieve the desired effect.

RÉSUMÉ

L'effet des éclaircies combinée, sélective et par le haut, avec une intensité d'intervention de 50, 35 et 44 % selon le volume coupé, a été étudié sur l'accroissement radial des principales essences d'une érablière à bouleau jaune à la forêt de Saint-Zacharie, âgée de 56 ans, dans le comté de Richmond, au Québec.

Ces éclaircies ont été effectuées dans trois parcelles expérimentales, et leur effet a été étudié pour l'érable à sucre, le hêtre à grandes feuilles, le bouleau jaune, le frêne d'Amérique et le tilleul d'Amérique.

La réaction de l'érable à sucre s'est avérée positive dans l'ensemble; l'intervention intense par le haut dans la parcelle 1 et l'intervention sélective dans la parcelle 3 ont réussi à stimuler la croissance radiale de façon significative, alors que l'intervention intense combinée dans la parcelle 2 n'a pas produit l'effet escompté.

Le hêtre à grandes feuilles a réagi positivement, tant à l'éclaircie par le haut qu'à l'éclaircie combinée, même si cette dernière réaction n'est pas significative au plan statistique. Ces résultats confirment la nature tolérante à l'ombre et la grande plasticité au type d'intervention de cette espèce.

La réaction du bouleau jaune aux traitements d'individualisation a été mitigée; l'analyse de variance a permis de détecter une augmentation significative à la suite de l'éclaircie par le haut et une diminution significative à la suite de l'éclaircie sélective. Cette réaction est principalement due à la difficulté que connait cette essence à progresser dans une hiérarchie sociale fixée.

Enfin, l'étude révèle qu'il n'y a eu aucune réaction à l'éclaircie sélective chez le tilleul d'Amérique et le frêne d'Amérique. Cela laisse entendre que l'individualisation de ces essences doit avoir lieu suffisamment tôt pour obtenir l'effet désiré.

INTRODUCTION

To obtain acceptable timber quality, in particular with hardwoods, foresters must carry out an early quality selection (De Saint-Vaultry 1969) by using the radial growth regulation mechanism, which is situated in the green top of the tree at the crown level. The forester's operations should result in harmonious development of the entire girth of the tree, with a view to obtaining regular, sustained growth.

Appropriate silvicultural treatment will thus ensure or improve processing quality since the level of timber properties depends, in addition to its intrinsic qualities, on the thickness and regularity of rings (Leclercq 1980). Production of quality hardwoods, although linked to site fertility, basically depends on adapting treatment methods to the species, considering the social position of the individual in the stand and the density of growing stock compared with the processing properties of the timber (Leclercq 1975; Stroempl 1983). Tending of hardwood stands is justified by the added value of the assortments produced, since the quality index may double or even triple between Grade F-3 and Select Grade (Mendel and Peirsol 1977).

Silvicultural and management practices on hardwoods in the Eastern Townships are recent activities, often associated with research carried out in the Dudswell experimental forest (Roberge 1975; 1987; 1988). In general, current 50- to 60-year-old stands are the result of clear cuttings or diameter-limit cuttings carried out in the 1930s. Forest management at that time basically involved harvesting timber, and stands formed by natural means were often of mediocre bole quality (Roberge 1987). Since the social differentiation and qualitative structure of these stands were already set, the silviculturist had only a few ways to improve timber quality, except by accelerating residual production by intensive treatments before final cutting.

Management of hardwood forests by intensive thinning was developed in the middle of the 19th century in Germany by Seebach for deteriorated beech groves (Assmann 1961). One-time thinning, or with repetition later on, removed up to 60% of the total growing volume to stimulate growth in the residual stand and, for all practical purposes, to shorten the rotation. The results of this management system were not all positive. A critical analysis of certain experiments showed that improvement in qualitative yield was offset by "unjustified" quantitative losses (Mahler 1937 *in* Assmann 1961; Assmann 1943 *in* Assmann 1961). Light thinning, which is appropriate for management of low-quality hardwoods (Zimmerle 1944 *in* Assmann 1961; Assmann 1950 *in* Assmann 1961), must be based on careful selection of the

best residual trees to avoid schematic action; it must also be tailored to stand condition so as not to exceed the critical stocking level.

Objective of study

The research was carried out in the Saint-Zacharie experimental forest to verify maple grove management by intensive light felling. The objective of the study was to assess the effect of this type of thinning on radial increment for the main species found in maple-beech and yellow birch forests and maple-white ash and basswood forests: sugar maple (*Acer saccharum* Marsh.) (SM), beech (*Fagus grandifolia* Ehrh.) (BE), yellow birch (*Betula alleghaniensis* Britton) (YB), white ash (*Fraxinus americana* L.) (WAS) and basswood (*Tilia americana* L.) (BA).

MATERIALS AND METHODS

Description of stands

This study was carried out on three 0.25-ha experimental plots in the Saint-Zacharie forest, Richmond County, Quebec. This 70-ha woodland, which is the property of Domtar Inc., is located at 45°35' north latitude, 71°45' west longitude and at an elevation of 340 m (Figure 1).

The forest classification of Rowe (1972) places the Saint-Zacharie forest in region "L", Great Lakes and St. Lawrence River, in Section "L-5", Eastern Townships, while according to Thibault (1986), it lies in ecological region "2d", in the maple-yellow birch forest subarea.

According to the Atmospheric Environment Service of Environment Canada at the Sherbrooke Airport, regional climatic conditions are characterized by a growing season of 130 days, annual precipitation of 949.9 ± 126.2 mm, with rainfall of 709.6 ± 107.1 mm, while annual snow accumulation is 253.2 ± 69.1 cm. The mean annual temperature is $5.9 \pm 0.5°C$, while the mean annual minimum is $1.1 \pm 0.5°C$ and the mean annual maximum is $10.7 \pm 0.6°C$.

The geological substrate is part of a high-schistose, intensely folded, volcano-sedimentary assemblage in the Ascot formation, from the Lower Cambro-Ordovician Age (Dubois 1973), and the surface deposit is a uniform Pleistocene till.

Figure 1. Location of the experimental forest.

The stand in Plot 1 was a high forest composed, by volume, of sugar maple (60%), yellow birch (21%), beech (9%) and red maple (*Acer rubrum* L.) (RM) (7%). The cover type was characterized by the constancy of *Dryopteris spinulosa* and *Lycopodium lucidulum* and by the sporadic presence of *Acer pennsylvanicum*. The plot occupies the foot of a moderate, regular 8% slope, facing northeast. The soil was a well-drained, acid orthic humo-ferric podzol, with low base saturation. Texture was skeletal and loamy, and lithic contact was generally less than 1 m.

Plot 2 was a high forest made up of sugar maple (73%), beech (17%) and yellow birch (9%). In the understory were *Dryopteris spinulosa* and *Lycopodium lucidulum*. The plot was situated at the top of a regular 4% slope, slanting northward. The soil of the plot was an orthic humo-ferric podzol, moderately well drained, with a skeletal loam texture and lithic contact generally less than 1 m. According to the reaction, the soil was acid, with a low base saturation.

Plot 3 was at the foot of a moderate, regular 2% slope, facing northeast. The soil was a thin orthic gleysol, with a loamy texture and deficient drainage. This was an acidic soil, but richer on the base saturation rate for the B horizon than the soils of the first two plots. The stand was a high forest of sugar maple (47%), white ash (39%), basswood (9%) and yellow birch (5%). Composition of the herbaceous stratum was characterized by the constancy of *Tiarella cordifolia*, *Dryopteris phegopteris* and *Dryopteris disjuncta*.

Mensuration and treatment protocol

In 1986, three experimental plots measuring 50 m by 50 m (0.25 ha) were traced out in the forest; their location was chosen at random on a 70 m by 70 m grid.

In each plot, the diameter of all living trees with a $dbh_{o.b.}$ greater than 7 cm was measured to the nearest millimeter; tree height was also noted to the nearest ½ m. All these trees were numbered. Timber quality for each tree was assessed visually in the field using the three criteria used to characterize sawlog lumber (Petro and Calwert 1976), namely the classes good, medium or poor. We modeled our classification on that of Stroempl (1983); the "good" class was thus assigned when there were no visible defects on the first 5 m of stem. The "medium" class was assigned when there were only slight defects and the length of the butt log was at least 3.5 m. The "poor" class was assigned to stems with severe defects or to those that failed to satisfy sawlog criteria. Trees were scaled from $dbh_{o.b.}$ and total height

was calculated using the tariffs of Tremblay (1966), except for black cherry (*Prunus serotina* Ehrh.) (CH), where the tariffs of Honer et al. (1983) were used.

Cultural treatment was aimed primarily at individualization of the best subjects without creating excessive openings in the stand or having the forest floor overgrown by undesirable vegetation. Trees for thinning were marked in the fall of 1986 and felled in 1987 by Domtar Inc.

The reaction of the stand to the silvicultural treatment was assessed on the basis of radial increment of remaining trees following temporal comparison. To do so, radial increment 4 years before thinning was compared with radial increment 4 years after thinning. Radial increment was measured in the spring of 1992 on core samples taken with a Pressler borer, using an electronic caliper, to the nearest 1/100 mm.

Temporal comparison was chosen since it was difficult to make up control plots in the unmanaged forest with the same dimensions and the same stand conditions. This method was also chosen to avoid the effect of structure altered by cutting (Marquis and Ernst 1991), since the composition of plots was not monospecific and plot structure (diametral and vertical) was not perfectly normal.

The comparison period was determined from the results of Roberge (1987) and Stroempl (1983) for 52- and 61-year-old maple groves. According to these authors, radial increment reaches a maximum 4 to 5 years after cutting for sugar maple and 3 years after cutting for yellow birch and basswood.

The results of stem analysis showed that the average age was 52 years in 1987, thus confirming the 1935 cutting origin of plots. Stem analysis also showed that at the time of thinning, dominant trees had already passed the full growth phase, and the effect of thinning might temporarily result in a changing trend in radial increment.

Statistical analysis

The effect of thinning on radial increment was studied using analysis of variance, considering the following factors: 1) thinning with two modalities (before and after); 2) species with a different number of modalities for each plot; and 3) tree with the number of modalities varying significantly with species and plot.

We did not consider tree strength in the form of equivalent growth classes (Horne et al. 1986), because of the absence of significant correlations between tree size and reaction to thinning (i_r after/i_r before).

Note that trees were nested in species and represented blocks on which two measurements were taken (before and after thinning). We were thus using a randomized complete block design. The dependent numeric variable corresponded to radial increment (mm. yr^{-1}).

When the hypothesis of non-interaction between thinning and species factors was rejected, separate analyses were performed for each species. The various statistical tests were carried out using software from the SAS Institute Inc. (1985) with a 5% critical level.

RESULTS AND DISCUSSION

Status of stands in 1986

The 1986 inventory provided a clear picture of the structure of the stands under study. The diameter distribution of stems in Plot 1 (Figure 2) was not normal, but neither was it an inverse J-shaped distribution characteristic of uneven-aged stands. The left-skewed structure was linked to the presence of two tolerant species: sugar maple and especially beech. Yellow birch presents a normal distribution pattern, like red maple, while the intolerant black cherry was confined to the larger diameters.

The vertical structure (Figure 3) is characterized by a right-skewed distribution with a clear concentration of stems in the overstory, which is dominated by sugar maple and yellow birch. This is a regular high forest with a fairly simple stratification.

Plot 2 showed a diameter distribution (Figure 4) similar to that of Plot 1; however, the position of beech and yellow birch in the stand was different. In Plot 1, beech was confined to small and medium logs, while in Plot 2, it followed the distribution of sugar maple in all diameter classes. Yellow birch in Plot 2 was confined to pulpwood and saw logs only.

The vertical distribution (Figure 5) of Plot 2 was more balanced (almost normal), and the overstory was mainly formed of sugar maple. The limited presence of yellow birch in the overstory and its concentration in the middle stratum might be due to a delay in social differentiation.
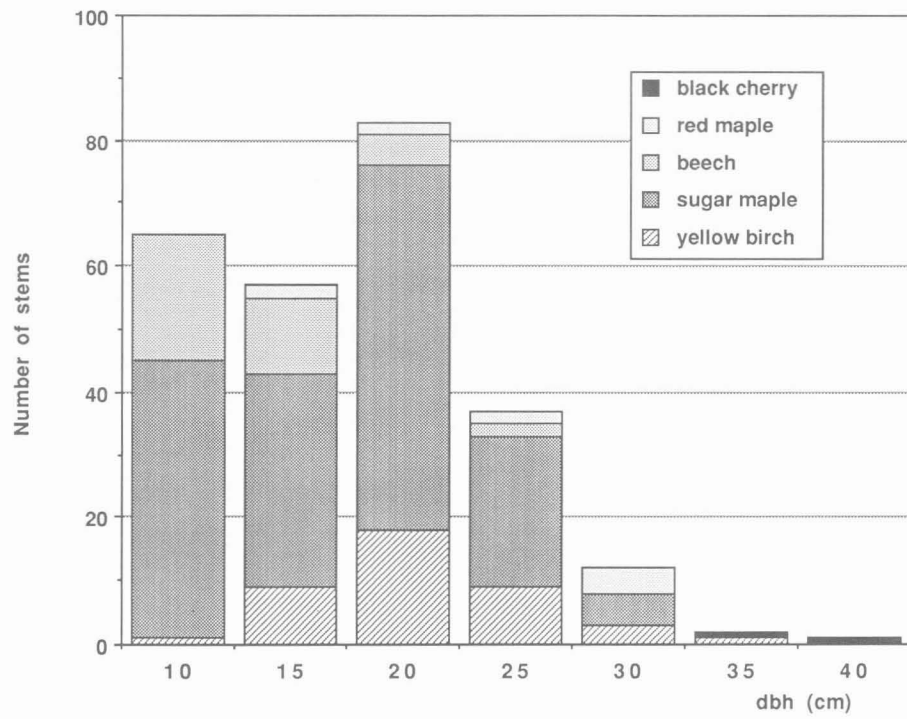
Figure 2. Diameter distribution of Plot 1 in 1986.
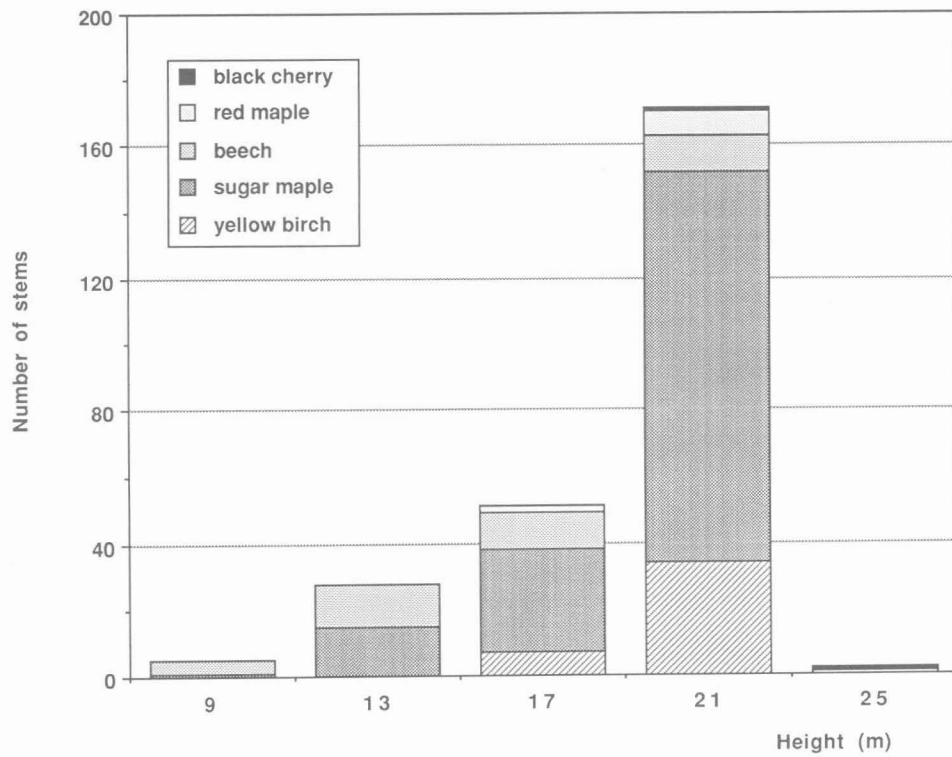
Figure 3. Vertical distribution of Plot 1 in 1986.

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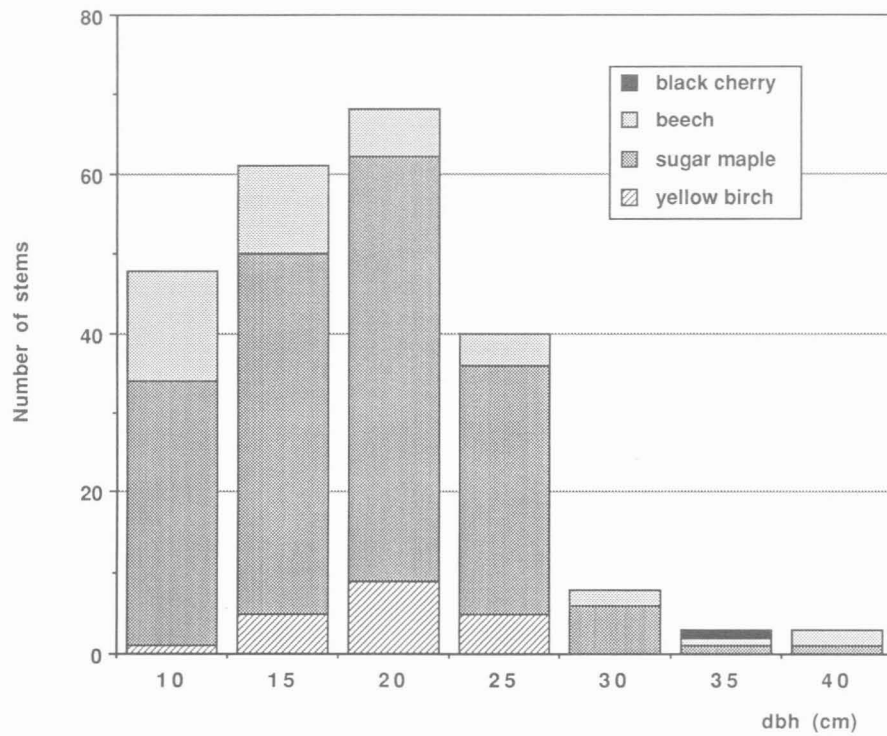
Figure 4.   Diameter distribution of Plot 2 in 1986.

Figure 5.   Vertical distribution of Plot 2 in 1986.

Plot 3 had a more complex structure than the first two plots. The diameter structure (Figure 6) was clearly left-skewed and similar to structures in uneven-aged stands (inverse J-shape). Overlapping of species could be observed as follows: yellow birch, sugar maple, white ash and basswood. It should be noted that yellow birch was confined to small diameters only.

The vertical structure (Figure 7) showed two distinct stages: the understory (yellow birch and sugar maple) and the overstory,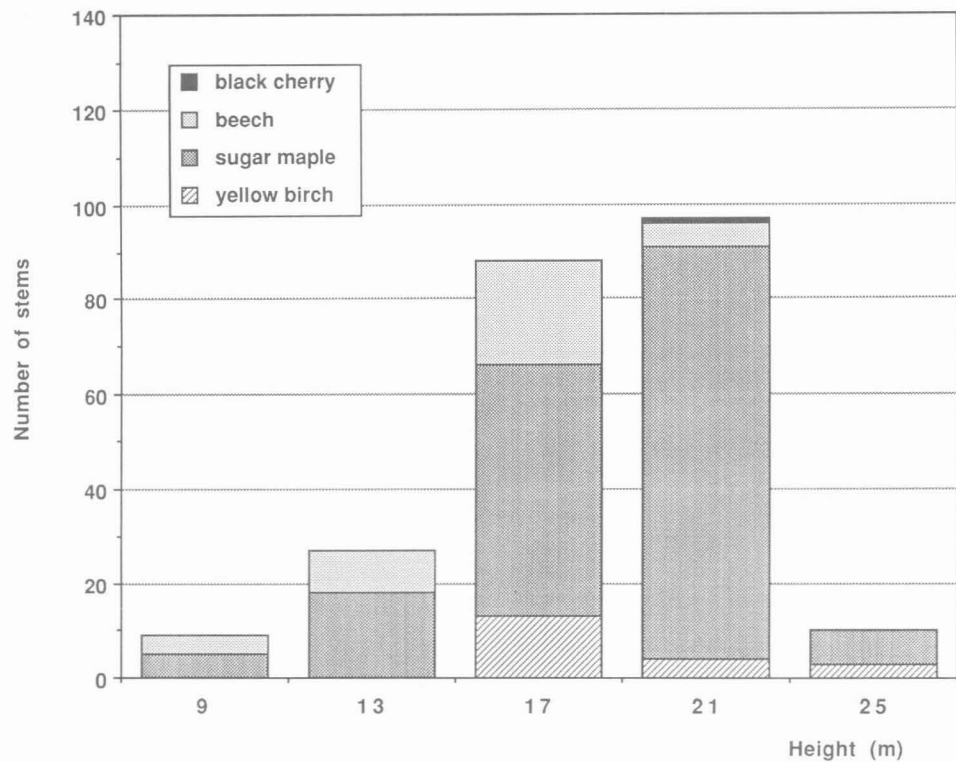 formed by white ash, sugar maple and basswood. This observation suggests that the stand in Plot 3 underwent major social differentiation where white ash and basswood imposed a specific hierarchy by their sustained apical growth and where only sugar maple took advantage of available openings.

Despite the moist site, yellow birch was unsuccessful in competing for sunlight; it is therefore destined to disappear in the dynamics of vertical structure.

The 1986 inventory of plots indicated (Table 1) that in comparison with the guide in Roach (1977) and with the tables in Plonski (1981), plots were well stocked and productive, with mean annual volume increment at 51 years of 4.74 $m^3.yr^{-1}. ha^{-1}$ for Plot 1, 4.22 for Plot 2 and 5.29 $m^3.yr^{-1}. ha^{-1}$ for Plot 3.

Table 1. Plot characteristics before and after thinning

Plot	n	$dbh_{o.b.}$ (cm)	h (m)	g (m^2)	$v_{o.b.}$ (m^3)	R.D. (%)
Plot 1						
Initial	258	18.5	18.9	6.971	60.44	110
Cut	95	20.2	19.6	3.035	26.52	
Residual	163	17.5	18.6	3.936	33.92	
Plot 2						
Initial	232	19.1	18.3	6.631	53.90	104
Cut	103	20.3	17.8	3.324	27.00	
Residual	129	18.1	17.7	3.307	26.90	
Plot 3						
Initial	271	18.7	18.5	7.442	67.43	95
Cut	72	20.9	19.2	2.463	23.28	
Residual	199	17.9	18.2	4.983	44.15	

Note: n = number of stems; $dbh_{o.b.}$ = diameter at breast height outside bark; h = height; g = basal area; $v_{o.b.}$ = volume outside bark; R.D.: relative density or stocking based on Roach (1977).
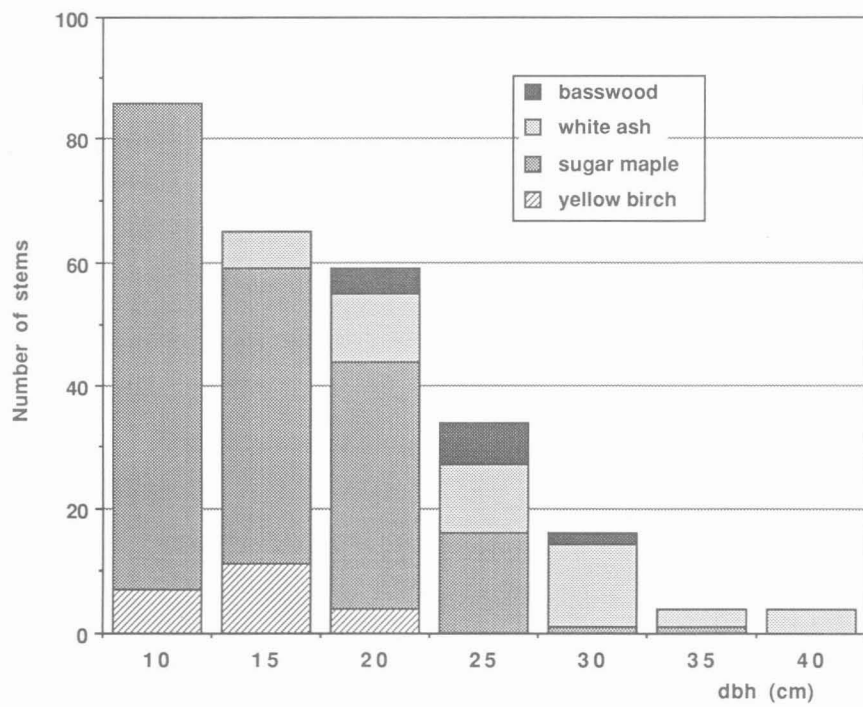
Figure 6.   Diameter distribution of Plot 3 in 1986.
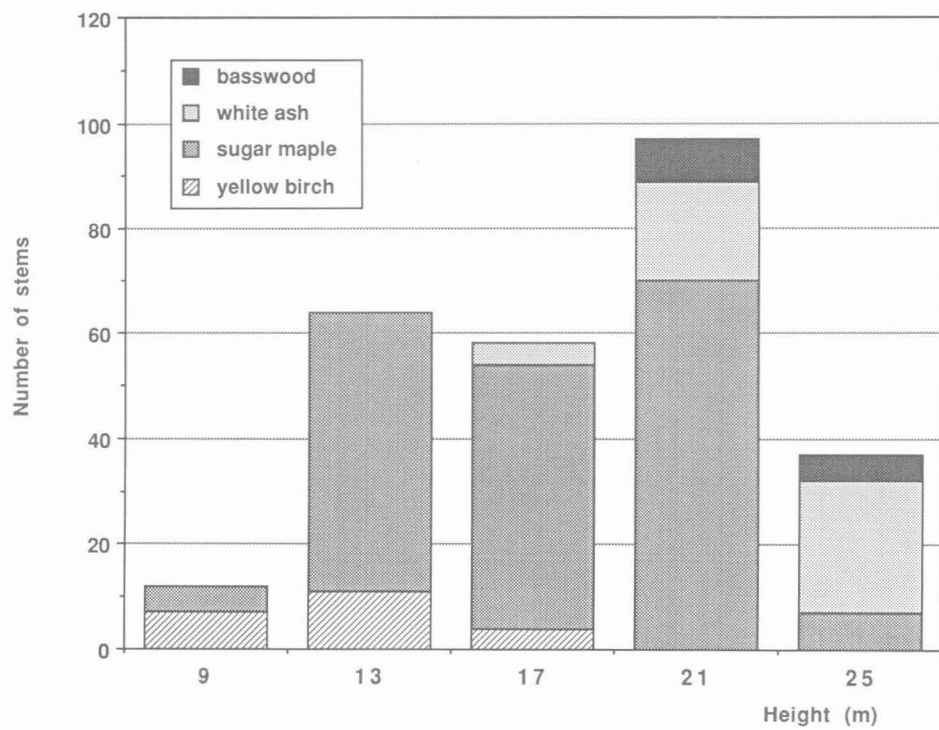
Figure 7.   Vertical distribution of Plot 3 in 1986.

A study of the quality of growing stock (Table 2), however, revealed a very high proportion of poor-quality timber, suitable mainly for pulp, while the volume of high-quality sawlog was low.

Table 2. Volume distribution by quality class

| Plot	Quality class (%)		
	good	medium	poor
1	7.8	44.8	47.4
2	8.7	54.4	36.9
3	10.7	58.6	30.7

A qualitative inventory of plots emphasized the need to adopt an appropriate hardwood management program to enhance the value of assortments and make forest production profitable, since natural development is no guarantee of quality production.

Nature and intensity of the thinnings

Considering the quality of stumpage, intensive thinning was carried out in the three plots by individual selection of the best trees, with care being taken not to create excessive openings. In Plot 1, the intensity of thinning was 44% by volume cut (Table 1). Thinning from above was concentrated around the 20-cm class (Figure 8), since it mainly affected trees in the overstory (Figure 9).

In Plot 2, the intensity of thinning (Table 1) corresponded to 50% of volume and thinning mainly eliminated trees in the 15- and 20-cm classes (Figure 10). This was a combined thinning (Figure 11), since it involved trees in the overstory, but especially affected those in the middle stratum.

In Plot 3, the intensity of selective thinning (Table 1) corresponded to 35% of volume and cutting was carried out on all size classes (Figure 12), affecting trees in all strata (Figure 13).
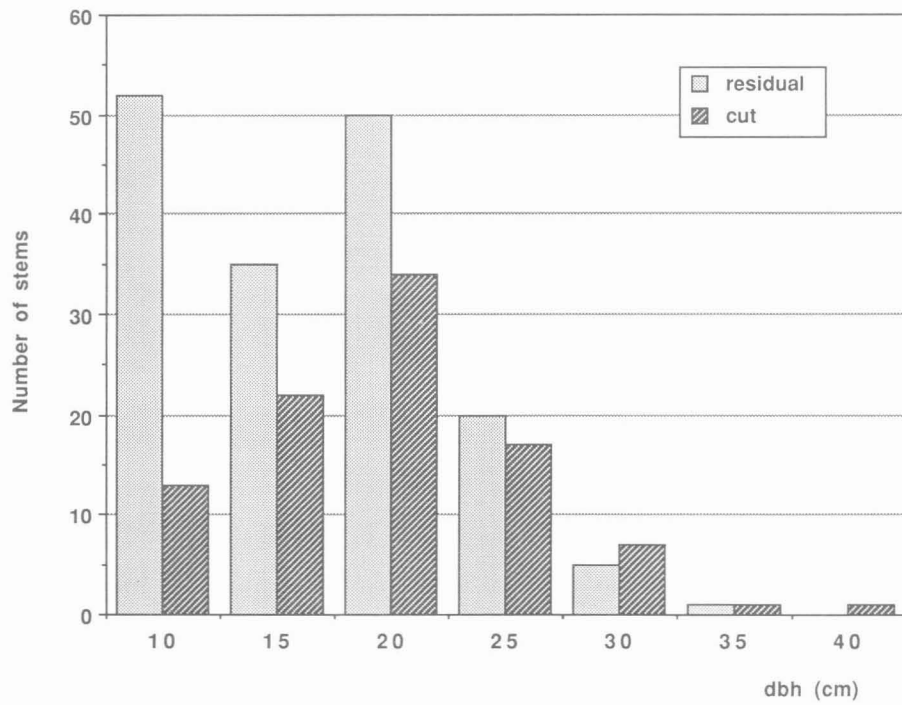
Figure 8.   Diameter distribution of Plot 1 after cutting.
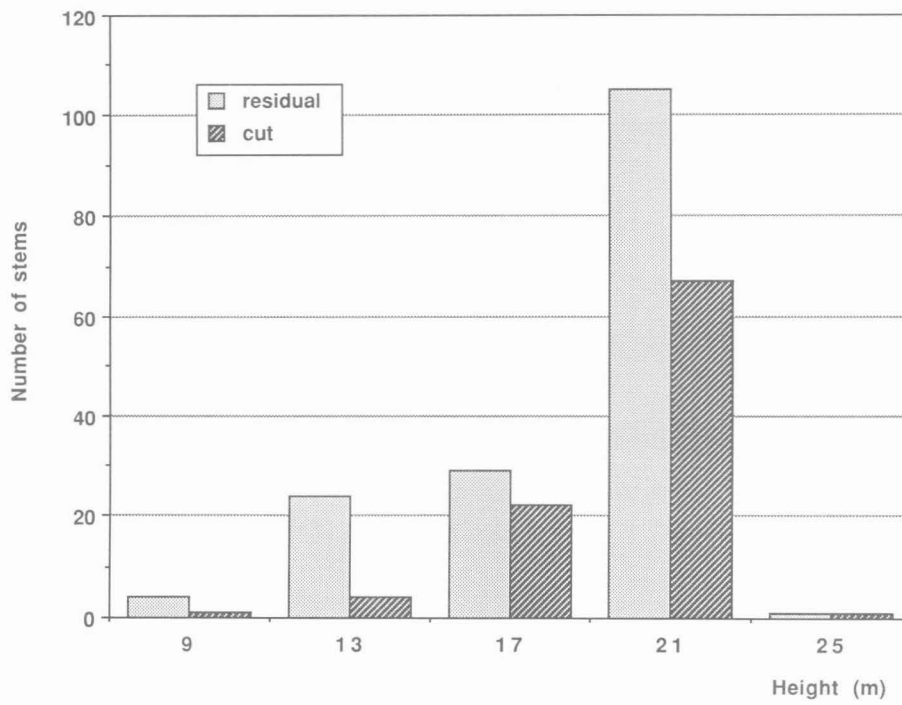
Figure 9.   Vertical distribution of Plot 1 after cutting.
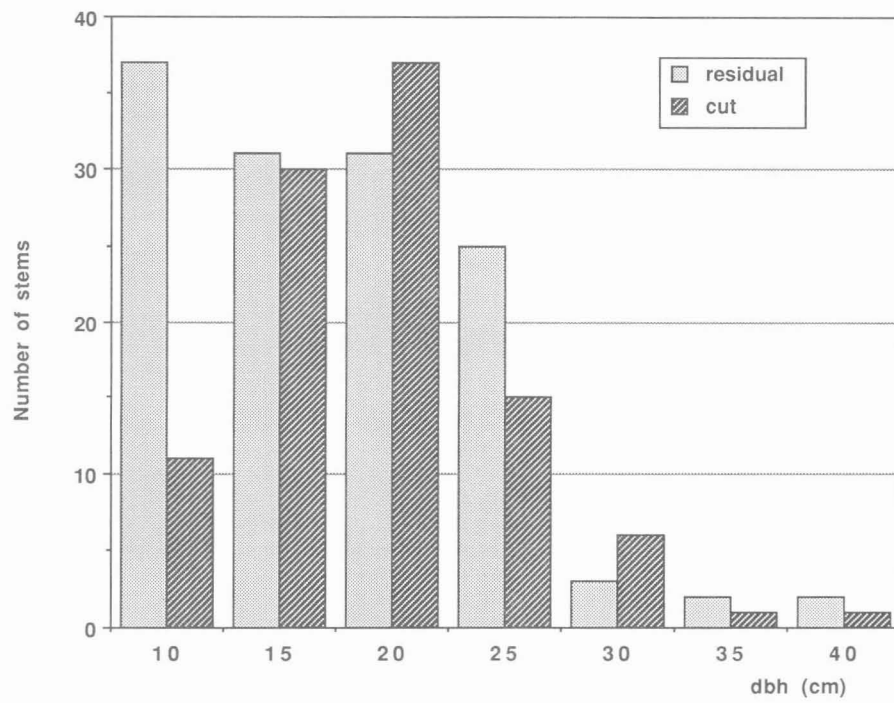
Figure 10.   Diameter distribution of Plot 2 after cutting.
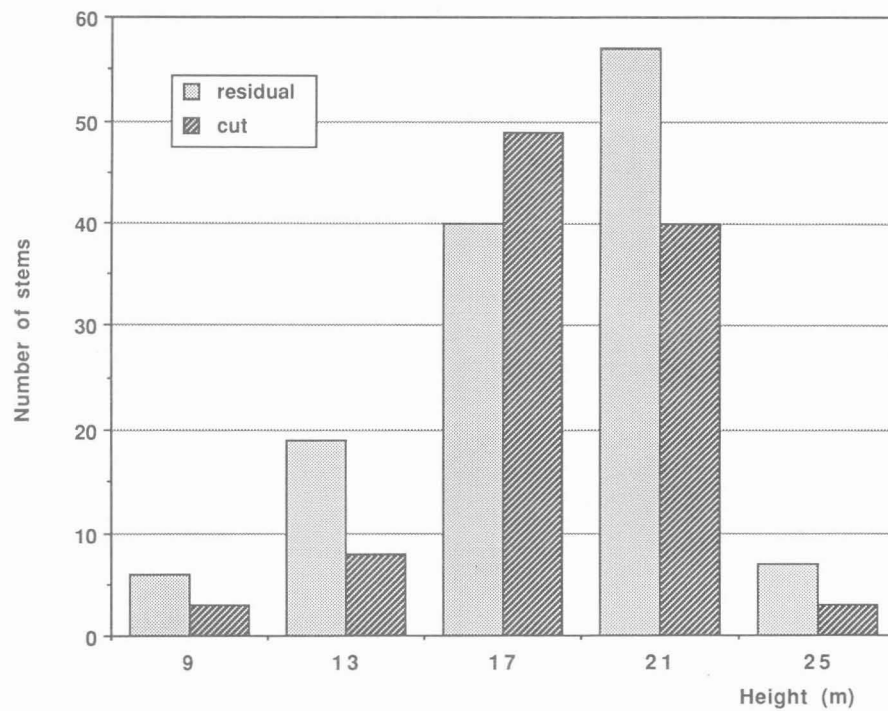
Figure 11.   Vertical distribution of Plot 2 after cutting.
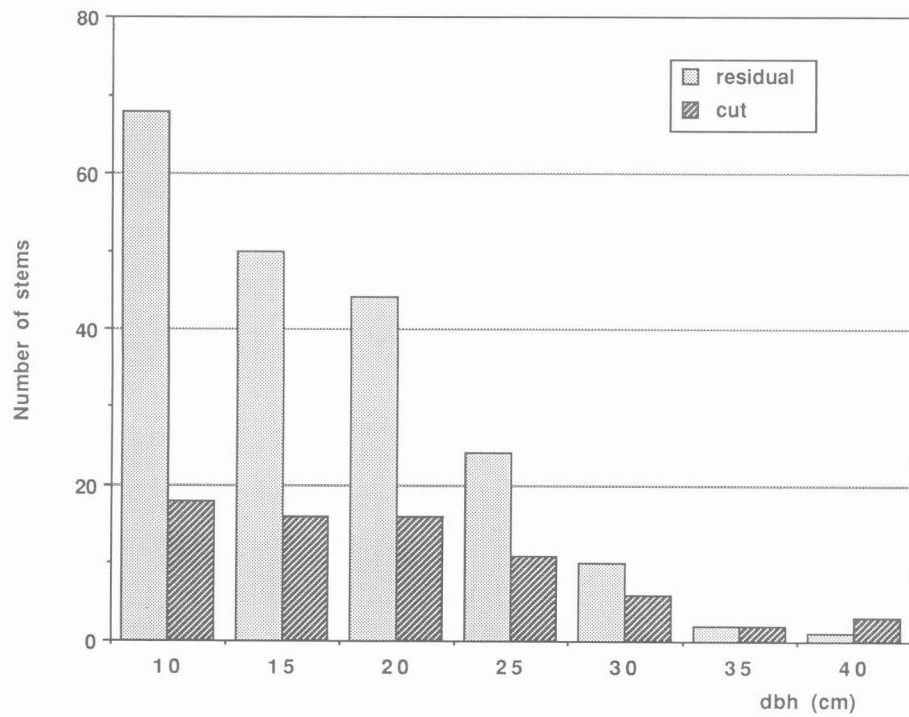
Figure 12. Diameter distribution of Plot 3 after cutting.
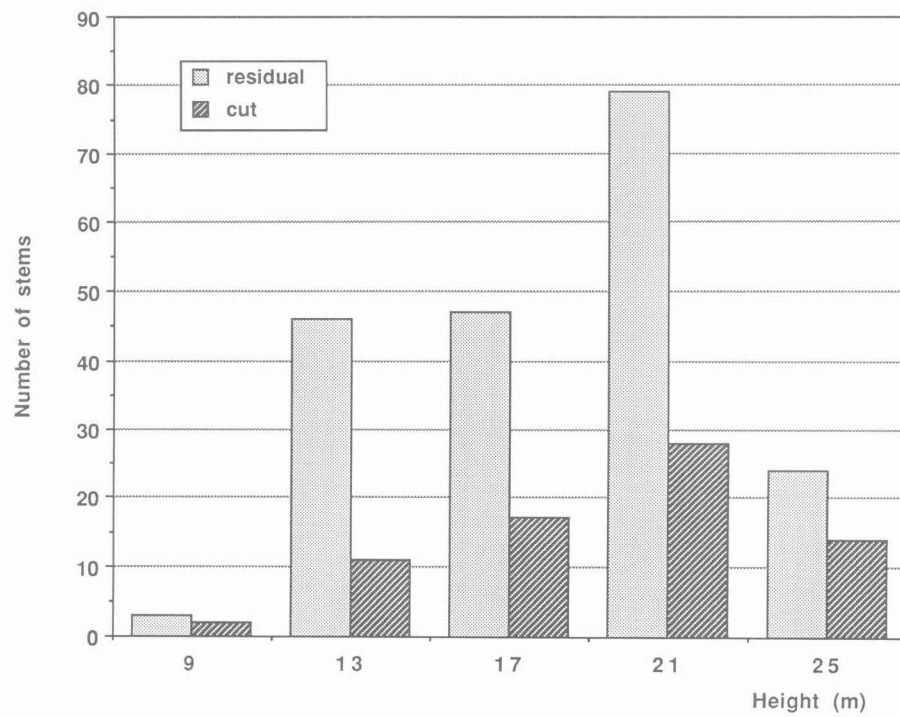
Figure 13. Vertical distribution of Plot 3 after cutting.

Status of stands in 1992

In the spring of 1992, an inventory was carried out on the three plots by measuring diameters at breast height, total heights and radial increments. The inventory (Table 3) indicated lower mortality on stems in plots 1 and 2 and higher mortality in Plot 3.

Table 3. Inventory of plots in the spring of 1992

| Plot	n	$dbh_{o.b.}$ (cm)	h (m)	g (m^2)	$v_{o.b.}$ (m^3)	R.D. (%)
Plot 1						
Inventory	150	19.8	18.8	4.597	40.95	23
Mortality	13	11.8	16.3	0.141	1.14	
Difference between 1987 and 1992, live stems				0.661	7.03	
Plot 2						
Inventory	112	21.0	19.9	6.631	34.02	6
Mortality	17	10.5	13.8	0.147	1.02	
Difference between 1987 and 1992, live stems				0.568	7.12	
Plot 3						
Inventory	162	20.4	19.5	5.302	49.22	40
Mortality	37	11.8	15.3	0.408	3.02	
Difference between 1987 and 1992, live stems				0.319	5.07	

Note: Variables are defined in Table 1.

For the period from 1987 to 1992, the difference between the two inventories showed that in Plot 1 the annual increment rate was 4.2% for basal area and 5.2% for volume growth. The comparison of inventories for Plot 2 indicates an annual growth rate of 4.3% for basal area and 7.2% for volume. Comparison of inventories for Plot 3 yielded an annual growth rate of 1.6% for basal area and 2.3% for volume. Also noteworthy was the increase in the relative density of plots, based on the chart by Roach, compared with 1987 residual density.

Effect of thinnings on radial increment

To assess the effect of thinning on radial growth, all living trees were sampled in the spring of 1992 (except for one sugar maple in Plot 1, which was injured) using a Pressler borer. Radial increment was measured on core samples for the 4-year period before thinning and for the 4-year period after thinning, for a total of 423 measurements (Table 4).

Certain species, such as black cherry and red maple, were not included in the statistical analysis because of the very small number of measurements.

Table 4. Number of trees sampled by species and plot

Plot	SM	BE	YB	WAS	BA	RM	CH	Total
1	103	27	15	0	0	3	1	149
2	95	12	4	0	0	0	1	112
3	114	0	12	26	8	2	0	162
Total	312	39	31	26	8	5	2	423

Plot 1 - thinning from above

In Plot 1, analysis of variance indicated no significant interaction between the thinning and species factors, which means that the effect of thinning from above was the same for all species studied in this plot. The test on the thinning factor yielded the conclusion that the increase of 0.239 mm.yr^{-1} in radial increment after thinning was significant (p = 0.0001).

Figure 14 clearly illustrates the absence of interaction between the thinning and species factors for Plot 1. The reaction of sugar maple, beech and yellow birch to thinning from above was an increase in radial growth of 0.257 mm.yr^{-1}, 0.190 mm.yr^{-1} and 0.205 mm.yr^{-1} respectively.

Plot 2 - combined thinning

For Plot 2, analysis of variance made it possible to conclude that there was a significant interaction (p = 0.026) between the thinning and species factors. This result indicates that species react differently to combined thinning (Figure 14) and justifies the use of a separate statistical treatment for each tree. Given that the thinning factor had only two modalities

(before and after thinning) measured on the same trees, the appropriate statistical treatment was the paired "t" test.

Combined thinning in Plot 2 resulted in no significant reaction in radial increment for the three species studied (sugar maple, yellow birch and beech). The observed decrease of -0.312 mm.yr^{-1} for yellow birch, although considerable, remains statistically non-significant (p = 0.24) due to the small number of stems (4). In the case of sugar maple, the observed increase in radial increment was practically negligible and statistically non-significant (0.060 mm.yr^{-1}, p = 0.074). Combined thinning brought a 0.206-mm.yr^{-1} increase in radial increment for beech; however, given the small number of stems involved (12), we cannot conclude that this increase is statistically significant (p = 0.055) at the 5% level.

Plot 3 - selective thinning

The analysis of variance made it possible to find a significant interaction (p = 0.043) between the thinning and species factors. This indicates that species react differently to selective thinning (Figure 14) and justifies a separate statistical treatment for each species.
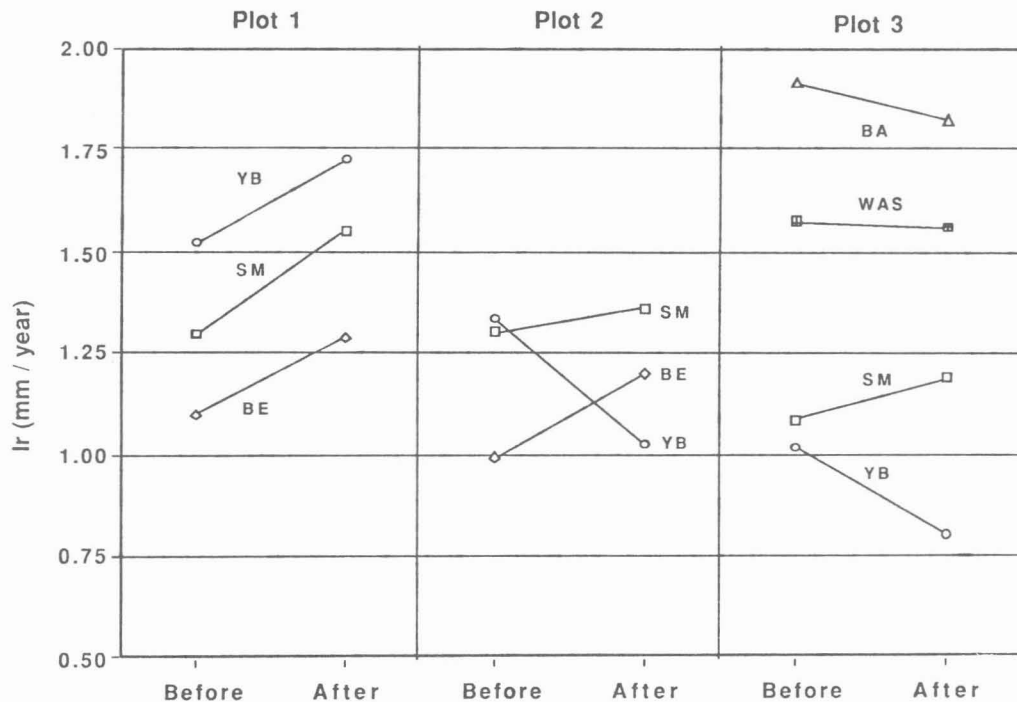
Figure 14. Radial increment (i$_r$) before and after thinning, by plot and species (YB - yellow birch, SM - sugar maple, BE - beech, WAS - white ash; BA - basswood).

Following selective thinning, paired "t" tests made it possible to find a significant decrease (p = 0.017) in radial increment for yellow birch with a decline of 0.218 mm.yr^{-1} and a significant increase of 0.102 mm.yr^{-1} (p = 0.009) in radial increment for sugar maple.

For white ash and basswood, paired "t" tests yielded the conclusion that silvicultural treatment was not significant, with negligible decreases in radial increment of 0.013 mm.yr^{-1} (p = 0.89) and 0.092 mm.yr^{-1} (p = 0.55) respectively.

Effect of thinnings - summary

Examination of the reaction of species to thinning (Table 5) yielded some important points.

Table 5. Summary of thinnings by species and plot

Plot	Species	Number of stems	q	diff. (mm/yr)
1	YB	15	1.16	0.205
1	SM	103	1.25	0.257
1	BE	27	1.23	0.190
1	all	145	1.24	0.239
2	YB	4	0.85	-0.311
2	SM	95	1.07	0.060
2	BE	12	1.27	0.206
2	all	111	1.09	0.062
3	YB	12	0.80	-0.218
3	SM	114	1.11	0.102
3	WAS	26	0.99	-0.013
3	BA	8	1.00	-0.092
3	all	160	1.07	0.050

Note :   q = i_r after treatment / i_r before treatment;
diff. = i_r after treatment - i_r before treatment.

For yellow birch, thinning from above in Plot 1 caused a significant 16% increase in radial growth, while in plots 2 and 3, combined and selective thinnings brought respectively 15% and 20% decreases in radial increment. However, it should be borne in mind that the decrease associated with combined thinning was not statistically significant.

This demonstrates that yellow birch is unable to progress in a fixed social hierarchy and reacts to individualization treatments (Marquis and Ernst 1991). In fact, the only positive reaction of this species in the dominant position in Plot 1 clearly proves this.

The reaction of sugar maple was positive on the whole; increases were observed in radial growth of 25% from thinning from above, 7% from combined thinning and 11% from selective thinning. The results in terms of radial increment in sugar maple confirmed those obtained by Roberge (1975) in the Dudswell forest.

Intensive thinning from above in Plot 1 and selective thinning in Plot 3 was successful in significantly stimulating radial growth, while intensive combined thinning in Plot 2 failed to produce the anticipated effect.

Beech showed a positive reaction to both thinning from above and combined thinning, with a 23% increase in radial growth in Plot 1 and 27% in Plot 2. Even though the increase was not significant at the 5% level (p = 0.055) for combined thinning, these results confirm the tolerance to shade and great adaptability to type of silvicultural treatment of beech as compared with sugar maple and yellow birch.

The absence of reaction to selective thinning of basswood and white ash suggests, on the one hand, that there was no crown expansion in these light-demanding species in the overstory to stimulate radial growth (Stroempl 1983) and that, on the other hand, individualization of these species must be done sufficiently early and repetitively to achieve the desired effect (Marquis and Ernst 1991).

While the effect of thinnings was relatively easy to assess in Plot 1 due to a simple stand hierarchy, the exercise became much more difficult in Plots 2 and 3 because of the complex hierarchical structures.

CONCLUSION

Thinning from above as well as combined and selective thinnings were carried out in three experimental plots with an intensity of thinning by volume cut of 44%, 50% and 35%.

Examination of the effect of thinnings showed that beech and sugar maple displayed an increase in radial increment in all plots where they were present.

Analysis of variance, however, showed that these increases were not always statistically significant. For beech, thinning from above resulted in a significant increase in radial

increment. For combined thinning, the increase in radial increment was greater than for thinning from above, but not statistically significant. This result is most likely due to the smaller number of stems in Plot 2. Sugar maple reacted significantly to selective thinning and to thinning from above, while the smaller increment following combined thinning was not significant.

The reaction of yellow birch to treatments was mixed, while analysis of variance detected a significant increase following thinning from above and a significant decrease following selective thinning.

In the case of ash and basswood, no change was noted in radial increment following selective thinning.

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