STRIP CUTTING IN SHALLOW-SOIL UPLAND BLACK SPRUCE NEAR NIPIGON, ONTARIO. II. REGENERATION IN THE FIRST STUDY AREA

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ABSTRACT

There were no significant differences in black spruce (*Picea mariana* [Mill.] B.S.P.) regeneration among strips 20, 40 and 80 m wide. Regeneration increased from marginally acceptable stocking levels (avg 53%) to desirable levels (avg 65%) during the third year of seeding. With only two years of seeding, scarified strips had better black spruce regeneration than non-scarified strips; after three years of seeding there were no differences between scarified and non-scarified strips. Scarification produces poorer regeneration in peaty drainageways than does non-scarification. Composition has changed from black spruce dominated in the pre-cut forest to a black spruce--white birch (*Betula papyrifera* Marsh.)--trembling aspen (*Populus tremuloides* Michx.) mixedwood in the regenerated first-cut strips. Some silvicultural implications of these findings with respect to improvement of the alternate strip cutting system are discussed.

RÉSUMÉ

Il n'y a pas eu de différences significatives dans la régénération d'épinettes noires (*Picea mariana* [Mill.] B.S.P.) plantées dans des bandes de 20, 40 et 80 m de largeur. La régénération est passée de niveaux de peuplement marginalement acceptables (53%, en moyenne) à des niveaux souhaitables (65%, en moyenne) au cours de la troisième année d'ensemencement. Après seulement deux années d'ensemencement, la régénération était meilleure dans les bandes scarifiées que dans celles qui ne l'étaient pas; après trois ans d'ensemencement, cette différence n'existait plus. Dans les chenaux d'écoulement tourbeux, la scarification donne une régénération inférieure comparativement à la non-scarification. Avant la coupe, c'est l'épinette noire qui était dominante; dans les bandes régénérées de la première coupe on trouvait un mélange d'épinette noire, de bouleau à papier (*Betula papyrifera* Marsh.) et de peuplier faux-tremble (*Populus tremuloides* Michx.). On traite de certaines des implications sylvicoles de ces conclusions, en vue d'améliorer la méthode de coupe par bandes.

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TABLE OF CONTENTS

INTRODUCTION

Upland black spruce (*Picea mariana*[1]) forest on shallow mineral soil over bedrock is a common type in the Precambrian Shield areas of northern Ontario (e.g., Robinson 1974). These sites are among those regarded by the Ontario Ministry of Natural Resources (OMNR) as 'fragile'[2] owing to the shallowness of the mineral soil and its susceptibility to erosion on the frequently irregular and rugged bedrock-controlled topographies. The bedrock close to the surface, and the stoniness of the thin veneer of soils, make for difficult planting conditions and a rather special harvesting-regeneration system is required to minimize erosion and exposure, and to obtain regeneration.

One harvesting-regeneration system that has been used increasingly in this site type, as an alternative to unrestricted clearcutting, is clearcutting in alternate strips (e.g., Robinson 1974, Auld 1975, Marek 1975, Virgo 1975, Fraser *et al.* 1976). The leave strips are left for two or more years to provide a seed source, and some protection from drying by wind and sun, for the first cut strips. Some form of scarification is used to create seedbeds receptive to seed germination and seedling survival. It is well known that the alternate strip clearcut system can be made to work, and to provide successful black spruce regeneration (e.g., Fraser et al. 1976). However, the system has not been used long enough, or with sufficient documentation, for clear guidelines to have evolved. In 1974 a long-term study of alternate strip cutting in shallow-soil upland black spruce was begun by the Canadian Forestry Service in cooperation with Domtar Forest Products and OMNR.

The purpose of this report is to describe, for four assessments (precut, 1, 3 and 5 years after harvest), the natural regeneration occurring in the first cut strips in the first of three study areas. The main factors considered in the experiment were leave time (of residual strips), strip width, and topographic site type. Regeneration results are reported not only for black spruce but also for other important species, and some silvicultural implications are discussed.

STUDY AREA

The study area is located about 30 km east of Beardmore, and 40 km east of Lake Nipigon, in Site Region 3W (Hills 1959) and the Central Plateau Section, B.8, of the Boreal Forest Region (Rowe 1972). The mean daily maximum and

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[1]Nomenclature for vascular species follow that used by Scoggan (1978-1979) and for mosses that used by Ireland *et al.* (1980).

[2] *From* Ontario Ministry of Natural Resources, 8 November, 1975, 'Instructions for the Implementation of Circular T.S. 2.00.05.01 dated 6 October, 1972: Control of Logging Methods on Crown Land.'

minimum temperatures for July are 23 and 11°C, for January, -11 and -23°C (Chapman and Thomas 1968), mean annual growing season is about 158 days, and mean annual precipitation is 737 mm, 55% of which falls between 1 May and 30 September.

The pre-harvest forest, soil, and site conditions have already been described in detail (Jeglum 1980); hence, only a brief description is given here. The first experimental area, the 'Thimble Creek Strip Cut Area', was classed as predominantly 'spruce slope' on the resource inventory maps according to the Domtar site type system. None of the area fell within the category 'shallow soil-rock showing', which is an even more extreme condition of the shallow-soil site. The Thimble Creek area had, nonetheless, quite thin soils over bedrock. In a survey of soil depths (Jeglum 1980), 33% of the probes encountered definite bedrock within 30 cm, and another 48% encountered rock, either bedrock or stone, within 75 cm (maximum depth probed). One type of fragile site has been defined by OMNR as "a shallow site which has less than 12" [30 cm] of mineral soil over bedrock." These sites are usually intermixed with pockets of deeper soil. When the shallow areas represent more than 40% of the forest type, they will be considered fragile and in need of M.H.C. (modified harvest cutting).[3] The above data suggest that these sites fit the OMNR criteria for shallow-soil sites.

[3]See footnote 2.

It is almost certain that the mineral soil depth averaged less than 100 cm, and hence the site would be 'shallow' in the Canadian system of soil classification (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978).

The relief within the study area was about 9 m. Although slopes were generally gradual, there were abrupt cliffs and rock faces throughout the area. In fact, two of the first cut strips could not be completely cut because of an abrupt cliff which cut across the strips, preventing skidder access. In addition, very wet peaty sites prevented complete harvesting of two other strips. The area was so varied and irregular that the aspects at the sample quadrats were more or less equally divided among the four points of the compass. There were some sites in the area that fitted the description of patterned sites (Bedell and MacLean 1952) consisting of bedrock ridges alternating with swampy swales.

Soils in the study area were slightly stony to stony tills, with mainly fine sandy silt or silty fine sand textures. More detailed information on horizon depths and physical and chemical characteristics has already been presented (Jeglum 1980). The sites included a broad range of moisture conditions--uplands ranging from dry to moist, and lowlands which were wet and usually had shallow peat accumulations. The most common topographic positions were lower and upper slopes, followed by drainageways, and finally by crests.

In the pre-harvest condition the most frequently occurring ground vegetation was a continuous mat of Schreber's feather moss *(Pleurozium schreberi)*, often with sparsely distributed herbs and low shrubs such as bunchberry *(Cornus canadensis)* and blueberry *(Vaccinium angustifolium* and *V. myrtilloides)*. On dry crest sites, reindeer lichen *(Cladina* spp.) was common; in wet drainageway sites, Labrador-tea *(Ledum groenlandicum)*, speckled alder *(Alnus rugosa)*, *Sphagnum* spp., and sedges and grasses were abundant; and in areas where hardwoods occurred, broad-leaved herbs such as aster *(Aster* spp.) and bluebell *(Mertensia paniculata)* were abundant.

The forest was predominantly softwood but some of the experimental treatment blocks contained small amounts of mixedwood and hardwood, usually as locally dominant patches. Black spruce was the leading dominant in the majority of the quadrats sampled. Other tree species present in moderate amounts were balsam fir *(Abies balsamea)*, jack pine *(Pinus banksiana)*, trembling aspen *(Populus tremuloides)* and white birch *(Betula papyrifera)*. Very small amounts of white cedar *(Thuja occidentalis)*, white spruce *(Picea glauca)*, tamarack *(Larix laricina)*, black ash *(Fraxinus nigra)*, and balsam poplar *(Populus balsamea)* were also present.

Pretreatment stocking by site type and forest conditions is given in Table 1.

METHODS

Methods have been described in detail in the study establishment report (Jeglum 1980). Therefore, only the essential details are repeated here.

There were 16 strips laid out for each of three strip widths--20 m, 40 m and 80 m (Fig. 1). The strips were approx. 180 m deep, and oriented more or less N-S. Of the 16 of each width, eight were cut in the alternate strip cutting pattern in June and July, 1975 by conventional cut and skid (rubber-tired skidders) tree length (delimbing and detopping before skidding) methods. The leave strips were left for 2 years adjacent to four of the first-cut strips, and for 4 years adjacent to the other four first-cut strips. Leave strips were cut in September 1977, and in September and October 1979.

The first-cut strips were scarified soon after cutting, in July 1975, by two large rubber-tired skidders pulling flanged barrels. The prescription was 'delicate' scarification, designed to scuff off the original mor mat and expose the upper surface of the mineral soil and lower layers of the humus.

An additional eight strips, 40 m wide, were laid out as controls but were not scarified (Fig. 1). The first cut of alternate strips in the control area was in 1975, as it was for the scarified strips. The leave strips were to be cut after two years, as this was the seeding period agreed upon

Table 1. Stocking by site and original forest conditions in the Thimble Creek Strip Cut Area.

Site and forest conditions	Scarified strips						Non-scarified strips
	20 m		40 m		80 m		40 m
	2 yr	4 yr	2 yr	4 yr	2 yr	4 yr	2 yr
No. of quadrats:	100	100	100	100	100	100	100
Company site type							
flat-lowland	0 [a]	0	3	0	0	0	0
softwood slope	100	100	97	100	100	100	100
Topographic site type							
drainageway	12	0	26	1	18	7	17
lower slope	44	32	38	12	57	39	53
upper slope	39	58	29	66	9	42	25
crest	5	10	7	20	16	12	5
Cover type							
softwood	81	80	97	100	95	100	75
mixedwood	17	15	0	0	5	0	5
hardwood	2	5	3	0	0	0	20
Trees (> 10 cm)							
black spruce	25	20	21	8	14	18	27
balsam fir	5	7	4	4	0	0	5
jack pine	2	7	6	2	8	3	0
trembling aspen	0	5	4	2	2	0	1
white birch	1	1	1	3	0	0	1
Saplings (2.5 to 9.9 cm)							
black spruce	1	1	3	5	5	5	1
balsam fir	7	8	8	17	9	0	5
jack pine	0	0	0	0	0	0	0
trembling aspen	0	0	0	0	0	0	0
white birch	0	0	1	0	0	0	0

[a] Values in the table are percentages of quadrats stocked.

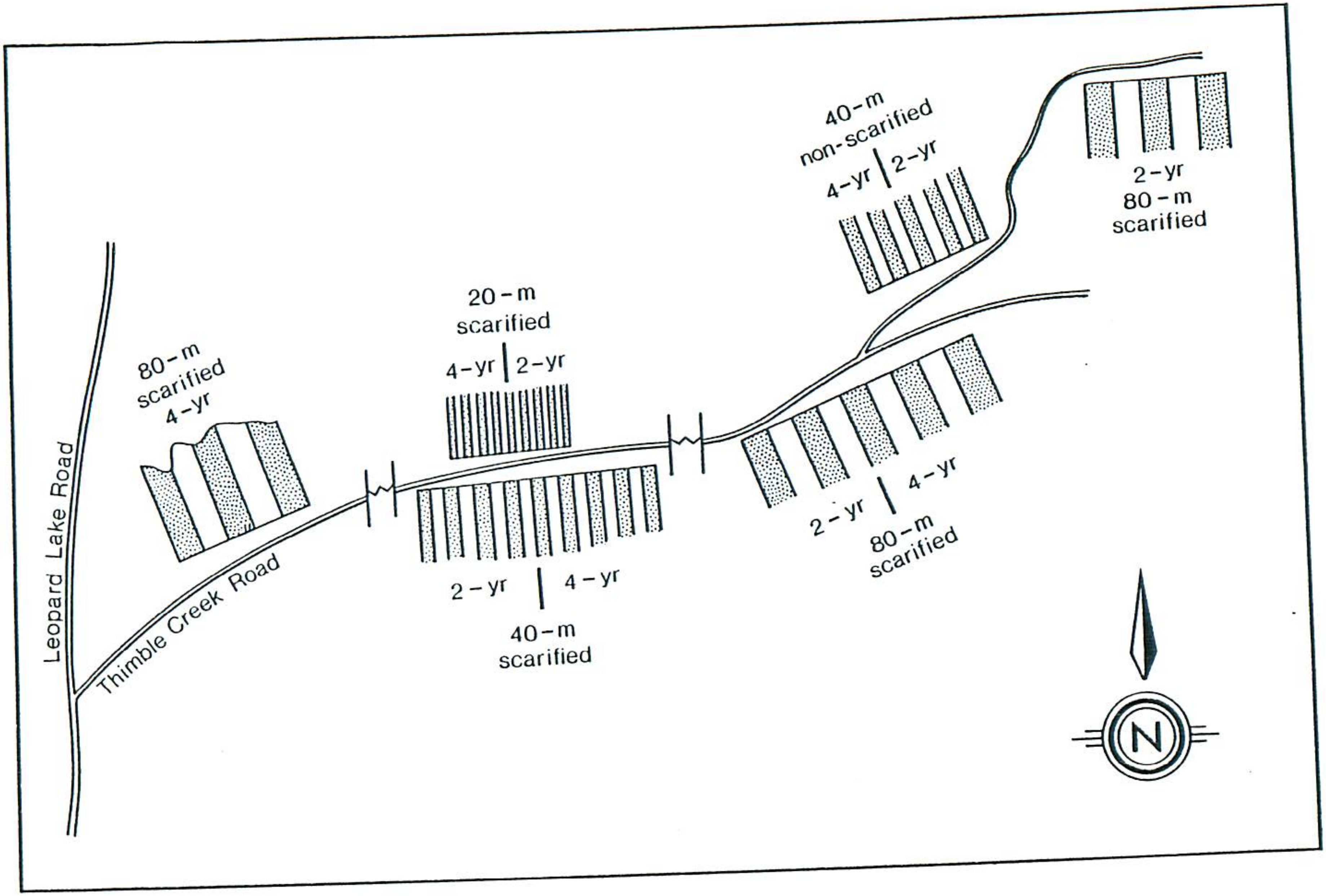

Figure 1. Layout of the alternate strip clearcuts.

by OMNR and Domtar in the operational strip cutting of shallow-soil sites in the same general area (Jeglum 1980).

The 20-m and 40-m strips were located together in blocks; half of each block was designated as 2-year leave and half as 4-year leave (Fig. 1). The 40-m control strips were also in one block. However, the 80-m strips had to be located in three separate blocks because there were no stands of black spruce upland large enough to accommodate all strips of this width within the study area. The total area of all experimental blocks, including buffer strips on the sides of blocks, was on the order of 50 ha.

Five sample lines were laid out across each strip, usually at 30-m intervals. Five quadrats, 2 m x 2 m, were placed at uniform spacing along each line; hence, there were 25 quadrats per strip. Assessments were carried out in 1974 (pre-harvest), and in 1976, 1978 and 1980. In this report only regeneration assessments are reported. These include stocking (= frequency) and density figures for various size classes of seedlings, saplings, and tree-size individuals of tree species.

The original sample of 100 quadrats for the four control strips was too small for reliable estimates of regeneration. Hence, prior to the 1980 assessment, additional quadrats were placed in these strips, for a total of 255. Also, owing to an error during the harvesting in 1977, half of one strip and a buffer strip immediately to the west of the control block were not removed as scheduled during the 1977 harvesting. Hence, two non-scarified strips received an additional 2 years of seeding, and were regarded as 4-year seeded. The other two, more isolated from the seed source, were regarded as 2-year seeded strips.

RESULTS

Black Spruce Regeneration

Stocking of black spruce seedlings in the pre-cut assessment was significantly different in the three strip-width blocks, but similar in the 2-year and 4-year leave blocks, which were usually located adjacent to each other within each strip-width block (Table 2). These differences could not be clearly related to any of the original forest conditions or site conditions for the different blocks.

Stocking dropped from 57% over all in the pre-cut condition to 49% in the first year after cutting and scarification (Table 2). No distinction was made between advance growth and new seedlings in this assessment. However, in a seedling-seedbed relationship assessment, which was done in 0.5- x 2.0-m quadrats nested within the 2- x 2-m quadrats, all seedlings less than 3 cm tall were tallied. With these data it was possible to judge how much of the post-cut regeneration was advance growth and how much was new seedlings. Comparisons of the densities for three seed-

Table 2. The effect of strip width and leave time on black spruce stocking. Data are for all seedlings (<2.5 cm DBH).

Strip width, leave time, and chi² significance levels between 2 yr and 4 yr	Pre-harvest 1974	Year of harvest or assessment and years of natural seeding (+1, ..., +4) 1975	1976 (+1)	1977	1978[a] (+2)	1978[a] (+3)	1979	1980 (+4)	Chi² significance (comparison between pre-harvest and +4)
20-m scarified strips									
2-year leave[b]	59	C1[c]	59	C2[c]	50	-		(51)[d]	NS
4-year leave[b]	52		53		-	67	C3[c]	69	*
Chi²	NS		NS		-	-		**	
40-m scarified strips									
2-year leave[b]	49		48	C2	49	-		(50)[d]	NS
4-year leave[e]	49		38		-	63	C3	61	NS
Chi²	NS		NS		-	-		NS	
80-m scarified strips									
2-year leave[b]	65		34	C2	59	-		(52)[d]	NS
4-year leave[b]	66		56		-	65	C3	63	NS
Chi²	NS		***		-	-		NS	
All scarified strips									
2-year leave[f]	54		47		53	-		(51)[d]	**
4-year leave[g]	58		51		-	65	C3	65	NS
Chi²	NS		NS	-	-	-	***		

[a]Because the 2-yr leave strips were cut in 1977, the assessments in 1978 were done after 2 years of natural seeding for the 2-yr leave strips, but after 3 years of natural seeding for the 4-yr leave strips which were still standing.

[b]Each stocking value in the row is based on 100 quadrats.

[c]C1 = first cut strips, C2= second cut of the 2-yr leave strips, C3= third cut of the 4-yr leave strips.

[d]Values in parentheses are for the 2-yr seeded strips, assessed in 1980 for comparison with the 4-yr seeded strips.

[e]Only 65 quadrats were used in the post-harvest assessments, because 35 were in the ends of two strips that were not cut. (A steep cliff cut off skidder access.)

[f]Each value in the row is based on 300 quadrats.

[g]Each value in the row is based on 265 quadrats.

NS = non-significant
* = significant at the 0.05 level.
** = significant at the 0.01 level.
*** = significant at the 0.005 level.

ling size classes--0 to 2.9 cm tall, 3 to 9.9 cm tall, and 10 cm tall to 2.5 cm DBH--are given in Table 3.

For all species except balsam fir, the numbers of the smallest seedlings, 0 to 2.9 cm tall, were low in the pre-cut assessment (1974), but increased by four times or more by 1976 one year after cutting and harvesting (Table 3). New seedlings undoubtedly accounted for the bulk of this increase. Balsam fir, however, decreased by half between 1974 and 1976, probably because of destruction by forestry operations. It is not known what proportion of this small size class of balsam fir was present in the pre-harvest forest.

In 1974 the 3- to 9.9-cm size class seedlings were more numerous than the 0- to 2.9-cm seedlings for black spruce and white birch and about equal for balsam fir (Table 3). However, by 1976 seedlings in the 0- to 2.9-cm size class were more numerous than those in the 3- to 9.9-cm size class for all species. This reflects both the loss of seedlings in the 3- to 9.9-cm size class as a result of cutting and scarification, and the influx of the 0- to 2.9-cm size class of seedlings.

The number of large seedlings, 10 cm tall to 2.49 cm DBH, decreased to about one-quarter of the original number for all species except trembling aspen (Table 3). Aspen increased in numbers, and this suggests an immediate suckering response following cutting. The increase in number, 0.7 per quadrat, was small, however, in comparison with the number of presumed seed origin (0 to 2.9 cm tall) individuals, 5.0 per quadrat.

The 2-year seeded strips, which were provided with seed from adjacent uncut strips in the spring of 1976 and 1977, had an average of 53% stocking in 1978 (Table 2). This was not significantly different from the 47% stocking in 1976 on the same strips. The 1980 assessment was made to determine whether or not there were any changes after two additional years, during which the only source of seed was distant forested edges. The stocking in 1980 was virtually unchanged from that in 1978. Although there were significant differences between strip widths of the 2-year leave strips after one year, the stocking for three widths was similar by 1978 and remained so in 1980.

The 4-year leave strips provided the adjacent strips with seed for three years (spring 1976-1978) before the summer 1978 assessment (Table 2). These 3-year seeded strips had an overall stocking of 65%, significantly higher (0.005 level) than the 51% for the assessment of the same strips after one year of seeding. Assessments in 1980, after one additional year of natural seeding (1979), revealed no significant change from the 1978 level. Again, although there were significant differences in strip widths for the 1-year seeded assessments, there were no significant differences in strip widths for either the 3-year or the 4-year seeded assessments.

Table 3. Densities of seedlings in three size ranges for 1974 and 1976. All values are mean numbers per 2-m x 2-m quadrat. Data are from the 565 quadrats which were harvested and scarified.

	Seedling size and year of assessment					
	0 to 2.9 cm		3.0 to 9.9 cm[a]		10.0 cm to 2.49 cm DBH	
Species	1974	1976	1974	1976	1974	1976
Black spruce	0.7	2.9	1.9	0.1	1.7	0.4
Balsam fir	2.9	1.6	2.0	0.7	2.0	0.6
Jack pine	0.0	3.3	0.0	0.0	0.0	0.0
Trembling aspen	0.0	5.0	0.1	0.0	0.1	0.8
White birch	0.6	4.0	1.4	0.0[b]	0.5	0.1
All species	4.4	16.8	5.3	0.8	4.4	2.0

[a]Obtained by subtracting individuals in the 0 to 3 cm tally from those in the 0 to 10 cm tally. The number of individuals in the 3.0 to 9.9 cm size range are underestimated, especially for 1976, because in the 0 to 9.9 cm tally, counts were made only up to 9, whereas in the 0 to 3 cm tally, counts of all seedlings were made.

[b]Undoubtedly some white birch seedlings in the 3.0 to 9.9 cm size range survived the cutting and scarification. This value should be greater than 0.0 but less than 1.4.

In the 1978 assessment, comparisons of stocking in strips adjacent to the 2-year leaves and stocking in strips adjacent to the 4-year leaves revealed significant differences: 53% stocking in the former and 65% in the latter (Table 2). These differences were presumed to have been established during the third year of seeding by the 4-year leave strips, in fall 1977 and spring 1978. The numbers of black spruce seedlings less than 3 cm tall in 1978 averaged 5.4 and 3.2 per 2-m x 2-m quadrat in the 4-year and 2-year seeded strips, respectively. This reflects the high influx of seedlings during the third year of seeding. Interestingly, these densities are higher than the 2.9 per 2-m x 2-m quadrat achieved for this size class after the first year of seeding (cf. Table 3). This shows that there was a net increase in new seedlings at least through three years in this study. In the 1980 assessment, there were still seedlings less than 3 cm tall, 2.8 and 0.9 per 2-m x 2-m quadrat in the 4-year and 2-year seeded strips, respectively. The accentuated difference in density suggests that new seedlings were still ingressing during the fourth and final year of seeding by the 4-year leaves.

Data for 2-year and 4-year seeded strips, for both scarified and non-scarified strips, are presented for individual site types in Table 4. The overall stocking in the 2-year leaves was 51% for scarified and 46% for non-scarified (not significantly different). However, upper slope and crest site positions showed significantly higher stockings for the scarified strips, and this suggests a definite advantage in scarifying the drier upland sites when they receive only 2 years of seeding. Lower slope values showed no improvement in scarified strips as compared with non-scarified strips. It is interesting that the values for drainageways, which were the wettest sites, included one of the lowest stockings, 36% for the 2-year scarified strips. In addition, there were relatively low densities for scarified drainageways, for both 2-year and 4-year seeded strips. This suggests that regeneration in drainageways is reduced by scarification.

It is clear that the 4-year seeded strips almost always had higher stocking values than the 2-year seeded strips, both for scarified and for non-scarified strips. There were generally non-significant chi^2 values among site types and also between scarified and non-scarified strips within site types. The non-scarified strips actually had slightly higher stockings on the average.

Regeneration of Other Species

For the different species, changes in regeneration over time on the scarified strips followed different patterns, which were related to the reproductive mechanism(s) inherent in each (Table 5). The pattern for white birch was similar to that for black spruce. Both had moderately high levels in the pre-cut forest, and within a year of cutting and

Table 4. The effects of scarification, leave time and topographic position on black spruce regeneration. Data are for all seedlings (individuals < 2.5 cm DBH) in the fifth-year assessments (1980). Chi^2 values are for comparisons between or among stockings.

	Topographic site types/stocking and density										Chi^2 (among 4 site types)
	Drainageway		Lower slope		Upper slope		Crest		All		
	S[a]	D[a]	S	D	S	D	S	D	S	D	
(1) Scar. 2-year[b]	36	1.6	53	3.2	53	1.9	68	5.1	51	2.7	*
(2) Scar. 4-year[c]	63	1.5	66	3.9	66	4.3	57	4.5	65	4.1	NS
Chi^2 (1:2)	NS		NS		NS		NS		***		
(3) Non-scar. 2-year[d]	100	7.0	50	2.6	31	0.6	46	1.4	46	2.0	**
(4) Non-scar. 4-year[e]	70	6.8	74	9.2	67	6.1	67	2.2	71	7.1	NS
Chi^2 between 3 & 4	NS		*		*		NS		***		
Chi^2 between 1 & 3	***		NS		*		NS		NS		
Chi^2 between 2 & 4	NS		NS		NS		NS		NS		

[a]S = Stocking percentage; D = Density, mean number per 2-m x 2-m quadrat.

[b]Numbers of quadrats for values in the row are 56, 139, 77, 28 and 300.

[c]Numbers of quadrats for values in the row are 8, 79, 143, 35 and 265.

[d]Numbers of quadrats for values in the row are 7, 58, 36, 24 and 125.

[e]Numbers of quadrats for values in the row are 53, 47, 15, 15 and 130.

NS = Non-significant
* = Significant at 0.05 level.
** = Significant at 0.01 level.
*** = Significant at 0.005 level.

Table 5. The effects of leave time on regeneration of the five main species. Data are for all seedlings (< 2.5 cm DBH) and individual scarified strips combined.

Species/stocking density (per 2-m x 2-m quadrat)	Pre-harvest	Year of harvest or assessment/ years of natural seeding (in parentheses)						
	1974	1975	1976 (+1)	1977	1978[a] (+2)	1978[a] (+3)	1979	1980 (+4)
No. of quadrats:	600		565		300	265		265
Black spruce		C1[b] ↓		C2[b] ↓			C3[b] ↓	
Stocking	57		49		53	65		65
Density	4.2		3.4		3.2	5.4		4.1
Balsam fir								
Stocking	70		48		32	33		32
Density	7.2		2.9		1.0	1.6		1.4
Jack pine								
Stocking	1		32		13	20		19
Density	< 0.5		2.6		0.8	0.8		0.6
White birch								
Stocking	36		37		58	58		54
Density	2.5		3.4		8.2	7.7		6.4
Trembling aspen								
Stocking	8		44		44	51		38
Density	0.3		4.5		2.2	3.1		1.7
All species combined								
Stocking	88		87		88	88		87
Density	14.3		16.8		15.5	18.7		14.4

[a] Because the 2-yr leave strips were cut in 1977, the assessments in 1978 were done after 2 years of natural seeding for the 2-yr leave strips, but after 3 years of natural seeding for the 4-yr leave strips which were still standing.

[b] C1 = first cut strips, C2 = second cut of the 2-yr leave strips, C3 = third cut of the 4-yr leave strips.

scarification, about the same levels were achieved, mostly as new seedlings. Both species subsequently exhibited rapid increases in regeneration, white birch after two years of seeding and black spruce after three. Both species dropped slightly in stocking and/or density in the assessment(s) following the peak assessment year.

Balsam fir had the highest pre-cut stocking, 70% (Table 5). This fell to 48% in the first year after cutting, and levelled off to the low 30s in subsequent assessments. Regeneration after cutting was relatively poor in comparison with that of other species, probably because fir does not regenerate as well in open conditions as in shaded forests.

Jack pine had virtually no regeneration in the original forest, but achieved 32% stocking after 1 year (Table 5). However, many of these initial germinants did not survive. By year 5 the density had decreased to about one quarter of the original and stocking was 19%.

Trembling aspen seedlings were relatively infrequent in the original forest (8%, Table 5). There was a large increase in the first year in both stocking and density, primarily as a result of seed germination, but also because of suckering. In subsequent years there was a drop in density, but not in stocking.

Analyses (cf. Table 2) were performed to judge differences between strip widths and leave times for species other than black spruce (data not presented). There were some significant differences, but it was not possible to determine whether they were due to the treatments or to differences in the original forest composition for the different treatment blocks. Often when higher numbers of trees of a species were originally present in a block there tended to be more regeneration to that species in the post-cut assessments.

Further analyses were performed to judge the differences related to scarification and topographic site type (Table 6). Two-year and 4-year leave data were not segregated because there were usually non-significant differences between them within scarified and non-scarified strips.

Jack pine showed significantly lower stocking in the non-scarified strips (Table 6). This may have been related to the fact that this block had a very small jack pine component in the original forest, and that little mineral soil seedbed was available for seedling establishment. White birch showed higher stockings and densities in the scarified strips, largely as a result of differences in upper slope and crest positions. For all conifers, all hardwoods, and all species combined, there were no significant differences between scarified and non-scarified strips for all site types combined.

Table 6. The effects of scarification and topographic position on regeneration of the main secondary species. Data are for all seedlings (individuals <2.5 cm DBH) in the fifth-year assessment (1980). Chi^2 values are for comparisons between or among stockings.

	Topographic site types										
	Drainageway S[a]	(D)[a]	Lower slope S	(D)	Upper slope S	(D)	Crest S	(D)	All S	(D)	Chi^2 (among 4 site types)
Balsam fir											
Scarified[b]	20	(0.4)	22	(0.6)	41	(1.5)	32	(1.1)	30	(1.0)	***
Non-scarified[c]	35	(1.1)	35	(1.9)	41	(1.6)	23	(1.5)	35	(1.6)	NS
Chi^2	NS		*		NS		NS		NS		
Jack pine											
Scarified[b]	3	(0.5)	19	(0.9)	20	(0.7)	13	(0.4)	17	(0.7)	**
Non-scarified[c]	0	(0)	4	(0.1)	4	(<.05)	5	(0.2)	3	(0.1)	NS
Chi^2	NS		***		**		NS		***		
Trembling aspen											
Scarified[b]	30	(1.2)	37	(1.9)	43	(1.6)	43	(1.7)	39	(1.7)	NS
Non-scarified[c]	37	(2.3)	41	(1.8)	47	(1.5)	46	(1.4)	42	(1.9)	NS
Chi^2	NS		NS		NS		NS		NS		
White birch											
Scarified[b]	45	(3.5)	50	(5.0)	60	(6.2)	59	(10.0	55	(5.9)	*
Non-scarified[c]	45	(2.3)	47	(4.7)	41	(1.6)	41	(1.5)	44	(3.0)	NS
Chi^2	NS		NS		*		NS	***			
All conifer											
Scarified[b]	47	(2.3)	68	(5.0)	80	(5.8)	70	(6.4)	71	(5.1)	***
Non-scarified[c]	83	(10.1)	70	(7.9)	69	(3.9)	72	(3.3)	73	(6.9)	NS
Chi^2	***		NS		NS		NS		NS		
All hardwood											
Scarified[b]	61	(5.0)	67	(7.1)	74	(8.0)	73	(12.3)	70	(7.8)	NS
Non-scarified[c]	60	(5.1)	65	(6.6)	69	(3.3)	62	(3.0)	64	(5.1)	NS
Chi^2	NS		NS		NS		NS		NS		
All species											
Scarified[b]	72	(7.3)	86	(12.0)	91	(13.8)	87	(18.7)	86	(12.9)	***
Non-scarified[c]	92	(15.3)	85	(14.5)	78	(7.2)	85	(6.3)	85	(12.0)	NS
Chi^2	***		NS		*		NS		NS		

[a]S = Stocking percentage; D = Density, mean number per 2-m x 2-m quadrat.

[b]Numbers of quadrats for values in this row are 64, 218, 220, 63, and 565.

[c]Numbers of quadrats for values in this row are 60, 105, 51, 39, and 255.

NS = Non-significant
* = Significant at the 0.05 level.
** = Significant at the 0.01 level.
*** = Significant at the 0.005 level.

Comparisons among site types show that for the scarified strips, balsam fir, jack pine, and white birch showed significantly higher stockings, and higher densities, in the upland site types. These higher values were reflected in the values for all conifers and all species. Trembling aspen showed no significant differences among site types, and all hardwoods also showed no significant differences although there were lower values of both stocking and density in the drainageways. For non-scarified strips, there were no significant differences among site types for any species or species group.

Compositional Changes

The pre-cut forest was conifer-dominated, with 89% relative stocking and density in comparison with 11% for hardwoods (Table 7). However, in the post-cut regeneration 5 years after cutting, the proportions have changed dramatically to about half conifers and half hardwoods. This increase in hardwoods is due largely to white birch and trembling aspen.

The relative proportions of black spruce and jack pine have been reduced by half, whereas balsam fir has stayed about the same in the regenerated strips (Table 7). The 4-year leave strips have higher relative stockings and densities for black spruce than do the 2-year leave strips. This reflects the increase in black spruce during the third year of seeding in the 4-year leave strips.

The stocking of seedlings in four height classes in the original forest and at three times after the cut illustrates changes in the structure of the regenerating (4-year seeded, scarified) strips (Table 8). The pre-cut forest showed highest stockings in the lowest height class for black spruce, balsam fir, and white birch, and progressively decreasing stockings for taller height classes. Jack pine and trembling aspen were present in only low quantities in all height classes. During the first year after harvest there was still the same general pattern, with large increases for jack pine and trembling aspen in the lowest height category and high levels for the other species.

By 1978, three years after harvest, there was a net increase of black spruce and white birch in height class 1, and some of the seedlings had grown from height class 1 into 2 and even 3 (Table 8). The relative proportions of seedlings in height classes 1, 2 and 3 reveal the rapid early growth of trembling aspen in comparison with the other species. By 1980, both white birch and trembling aspen had relatively high stockings in height class 3, and the general appearance of the strips was that of hardwood dominance. The stockings of white birch, trembling aspen, black spruce, balsam fir, and jack pine in height class 3 are 32, 28, 11, 11, and 9%, respectively (Table 8). However, if one looks at all seedlings regardless of height, the stockings are 54, 38, 65, 32 and 19%, respectively. Hence, in

Table 7. Composition of the original forest (trees ≥ 10 cm DBH), and of the post-harvest regeneration (seedlings < 2.5 cm DBH), in the fifth year after cutting (1980). Stocking percentage and density (mean number per 2-m x 2-m quadrat) are expressed as relative percentages. Absolute values are given in parentheses.

Species and species group/ stocking and density	Pre-harvest (trees)	Post-harvest (seedlings)			
		Scarified strips		Non-scarified strips	
		2 yr	4 yr	2 yr	4 yr
Number of quadrats:	1400	300	265[a]	125	130
Black spruce					
Stocking	61 (19)	27 (51)	31 (65)	25 (46)	39 (71)
Density	65 (0.24)	24 (2.7)	29 (4.1)	22 (2.0)	53 (7.1)
Balsam fir					
Stocking	13 (4)	15 (29)	15 (32)	20 (37)	17 (32)
Density	14 (.05)	5 (0.6)	10 (1.4)	17 (1.5)	13 (1.7)
Jack pine					
Stocking	16 (5)	8 (15)	9 (19)	3 (6)	0 (0)
Density	14 (.05)	8 (0.9)	4 (0.6)	1 (0.1)	0 (0)
Trembling aspen					
Stocking	6 (2)	21 (40)	18 (38)	24 (44)	22 (40)
Density	5 (.02)	15 (1.7)	12 (1.7)	21 (1.9)	14 (1.9)
White birch					
Stocking	3 (1)	29 (56)	26 (54)	27 (48)	22 (41)
Density	3 (.01)	48 (5.5)	45 (6.4)	39 (3.5)	20 (2.6)
All conifers[b]					
Stocking	89 (25)	48 (65)	53 (77)	49 (66)	57 (79)
Density	89 (.33)	36 (4.2)	43 (6.2)	40 (3.7)	68(10.0)
All hardwoods[b]					
Stocking	11 (3)	52 (71)	47 (68)	51 (69)	43 (59)
Density	11 (.04)	64 (7.4)	57 (8.2)	60 (5.6)	32 (4.6)

[a]In the case of the 40-m 2-year leave strips, only 65 quadrats were used in the post-cut assessments, because 35 were in the ends of two strips that were not cut owing to a steep cliff cutting off skidder access.

[b]All conifers and all hardwoods include minor species in addition to the five main species in this table; hence, density values are slightly higher than the sums of the species in the table.

Table 8. Changes in stocking of seedling height class from the original forest through three subsequent post-harvest assessments. Data for pre-harvest and 1976 assessments were all from the first cut scarified strips, whereas data for the 1978 and 1980 assessments were from the 4-year seeded, scarified strips.

	Seedling size class				
	1	2	3	4	
	0 - 9.9 cm	10 - 49.9 cm	50 - 199 cm	200 - 2.49 cm DBH	All seedlings
Black spruce					
Pre-harvest	41	37	17	5	58
1976[a]	42	13	5	1	49
1978[a]	53	28	7	0	65
1980[a]	48	41	11	1	65
Balsam fir					
Pre-harvest	61	38	27	7	69
1976	41	16	9	2	48
1978	24	17	6	1	
1980	21	20	11	2	32
Jack pine					
Pre-harvest	<.5	<.5	0	<.5	1
1976	32	0	0	0	32
1978	14	12	0	0	20
1980	6	12	9	0	19
Trembling aspen					
Pre-harvest	<.5	5	2	1	8
1976	39	17	7	<.5	44
1978	33	37	22	1	51
1980	12	17	28	2	38
White birch					
Pre-harvest	30	14	5	1	36
1976	34	4	2	<.5	37
1978	53	33	8	0	58
1980	39	38	32	1	54
All					
Pre-harvest	77	63	43	13	87
1976	80	37	20	3	87
1978	78	66	36	2	88
1980	68	67	58	6	87

[a]Numbers of quadrats for pre-harvest, 1976, 1978, and 1980 assessments were 565, 565, 265, and 265, respectively.

these scarified strips black spruce had the greatest stocking, followed by white birch and trembling aspen. However, in terms of density (Table 7), white birch surpassed black spruce, reflecting the large number of germinants of birch in these scarified strips.

DISCUSSION

This study was set up to document the effects of a certain silvicultural prescription--alternate strip clearcutting in shallow-soil upland black spruce with site preparation--on regeneration. It was designed primarily to investigate two key elements of the prescription, specifically (i) width of strips, and (ii) the length of leave time for the residual strips. Two other silvicultural considerations were also included in the study--the influence of (iii) topographic site type and (iv) scarification compared with no scarification. The cutting and scarification in the experimental strips were carried out in the same way as they were (and still are) on operational alternate strip cuts being conducted in the same area (cf. Jeglum 1980). Hence, the experimental results can be applied to fine-tuning and improvement of present practices.

The results suggest that strips up to 80 m are not too wide for obtaining successful levels of regeneration. A similar successful level of black spruce stocking (65%) was achieved for all three strip widths. Hence, if 60 m is the currently favored width, this is quite safely within the range, and it may provide for a slightly higher probability of success. This experiment did not include strips wider than 80 m, so it is not known how wide they can be in upland shallow soil sites in this region of Ontario before regeneration decreases to marginal or failure levels.

This experiment did not address the problem of how to regenerate leave strips. However, since the first cut strips are the ones to regenerate successfully, it may be possible to increase the width of the first cut strips, say to 80 m, and reduce the width of the leave strips to perhaps 40 m. (Reduction of the leave strip widths below 40 m is not advisable, because blowdown increases considerably on narrow leave strips [R. Crossfield and R. Fleming, pers. comm.])[4]. This would increase to two thirds the proportion of the area regenerated, leaving only one third to regenerate when the leave strips are cut.

In this experiment, three years' leave time were necessary to reach a level of black spruce regeneration over 60%. There are a number of possible reasons for the increase in regeneration during the third year of seeding: (1) a higher proportion of moister sites and/or receptive seedbed

[4]Crossfield Environmental Ltd. has conducted a one-year survey of blowdown in strip cuts. The Scientific Authority in this work is R. Fleming, Great Lakes Forest Research Centre.

conditions, (2) weather conditions particularly favorable for maintaining optimum seedbed moisture, (3) a heavy cone crop in the fall of 1977 which provided a large drop of seed and new seedlings in the spring of 1978, and (4) weather conditions particularly favorable for opening cones and shedding seed in the winter and spring of 1978.

With regard to (1) the 4-year seeded strips actually had higher proportions of the *drier* site types, upper slope and crest, than did the 2-year seeded strips (Table 1). A summary of the seedbed conditions showed that mineral soil cover and frequency were about the same for 2-year and 4-year strips. Although the 4-year strips had more H plus Ah, owing to the greater abundance of upland site types, the 2-year strips had more *Sphagnum* moss (living and dead) and peat. Hence, the greater area of one of the more favorable upland seedbeds, H and Ah (cf. Winston 1973)[5], in the 4-year strips is offset by the greater area of one of the most favorable lowland seedbeds, *Sphagnum* (cf. Vincent 1956), in the 2-year strips.

[5]Winston, D.W. 1973. A compara tive antecological study of black spruce, jack pine, lodgepole pine and hybrid pine for direct seeding in northern Ontario. M.S. Thesis, Mich. State Univ., Lansing.

The second possibility, (2) above, was checked by comparing the mean precipitation and Duff Moisture Code of the Canadian forest fire weather index[6] (Van Wagner 1974, Anon. 1976), for 10-(11-) day intervals for May through September, 1975 to 1978 inclusive (Fig. 2). Precipitation during May, 1978 was higher than in preceding years. The relatively high precipitation in May, 1978 could explain the influx of seedlings. In addition, the Duff Moisture Code suggests that May, 1978 was a particularly favorable month. It is noted that the fall of 1977 was also favorable for precipitation and duff moisture. The sequence of two good seasons in a row may have been significant.

The third possibility, (3) above, was checked through the OMNR Nipigon District Office. There was not a good general cone crop from the period following the cut in 1975 until the fall of 1979, which was too late to explain the increase noted in the summer assessments of 1978. However, it is possible that the 1975 cutting plus scarification,

[6]Values obtained from the OMNR weather station at Jellicoe, 15 km from the study area, except for some data for May, 1976, 1978 and 1979, obtianed from the Atmospheric Environment Service, Environment Canada weather station at Geraldton, some 50 km ENE of the study area.

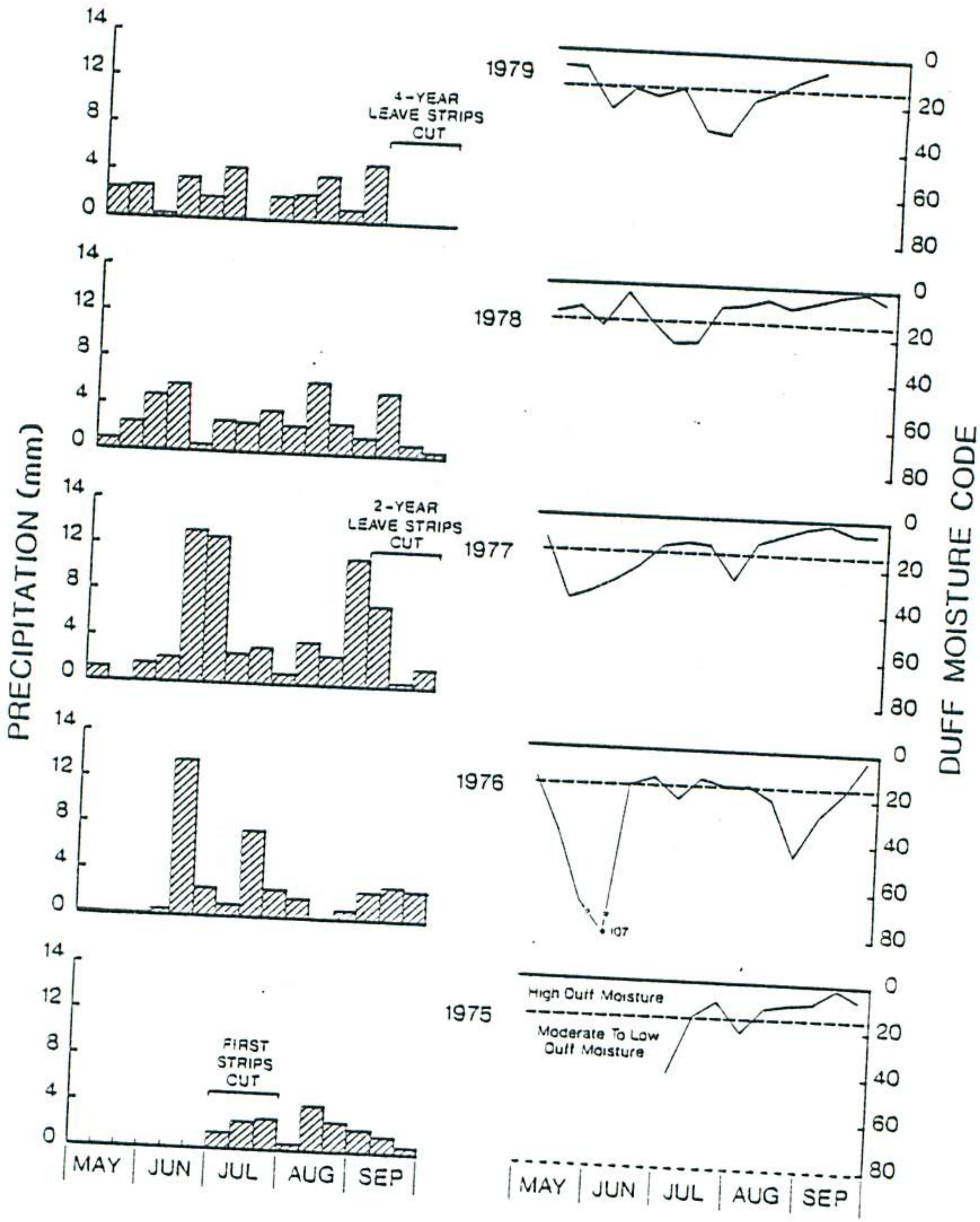

Figure 2. Mean precipitation and Duff Moisture Code (DMC) for 10- (11-) day intervals during the period of the experiment. Low DMC is associated with high duff moisture. A line is drawn arbitrarily at DMC 15 to indicate high duff moisture above, and moderate to low duff moisture beneath.

which undoubtedly injures black spruce root systems located largely in the duff and uppermost layers of mineral soil, could have stimulated a stress crop of cones. The stress crop of reproductive buds could have been formed in 1976, and a crop of cones produced in the fall of 1977.

The final possibility (4) is that some weather conditions may have been particularly favorable for the release of seed between summer 1977 and summer 1978. Haavisto (1978) has noted that a high proportion of seed was released in spring on one lowland black spruce site. Haavisto[7] speculates that continuous periods of clear weather, as indicated by hours of bright sunshine, in late winter and early spring--associated with cold nights and warm days--may be favorable for opening cone scales. Strong spring winds would then shake out the seed. It is interesting that there was relatively low precipitation, and presumably periods of clear weather, during the winter and early spring of 1978.

It will be clear from the above that the success of any one year of operational strip cutting will vary depending on subsequent variations in seedfall and weather. Since it took three years for successful regeneration of black spruce in this experiment, and since there can be good and poor weather years for regeneration from seed, it is suggested that a fixed 2-year leave period may often be too short to achieve successful levels of regeneration (equal to or greater than 60% stocking). Three or four years will probably yield, on the average, better results.

[7]V.F. Haavisto, Forestry Officer, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. pers. comm.

A surprising result of this experiment is that scarification with barrels did not yield any better results, after three years of seeding, than did the non-scarified strips. Part of the explanation could be that more advance growth was destroyed in the scarified than in the non-scarified strips. Another explanation could be that scarification appears to yield poorer regeneration in drainageways, possibly because of the deep rutting and churning of peat by skidder tires in the summer cut operation. The wet holes and wet black muck created by this disturbance may be unsuitable seedbeds, and the rapid colonization of such seedbeds by dense sedges and grasses offers considerable competition to black spruce seedling establishment. In addition, the harvesting process alone, which utilized wheeled skidders, may have provided enough tire scuffing and compaction for good regeneration. Finally, the non-scarified control strips were located in a rather low protected site, generally lower than the other blocks, and they had a higher proportion of lower slope and drainageway sites than did most of the other blocks (Table 1). All of these unknowns indicate that one should be cautious about overemphasizing the good regeneration obtained on the non-scarified sites in this trial. The conventional wisdom of scarifying uplands to produce seedbed should not be discarded until additional trials indicate that it is not necessary.

There is some indication in the data that scarification of peat and drainageway sites should be avoided if at all possible. Lower slope positions may also be moist enough, and have enough receptive seedbed, that scarification is not necessary. If there is abundant advance growth in the pre-cut forest, it may be sufficient to strip cut, ensuring that there is not too much slash, and then wait for natural seeding to occur on the scuffed surfaces and grooves created by the harvesting machines. It may even be possible to develop modified harvesting procedures which will create more receptive seedbed during the harvesting process.

The change in composition from conifer in the original mature forest to mixedwood in the regenerated strips is a common occurrence in boreal cutovers (e.g., Ellis and Mattice 1974, Clemmer and Atkins 1980[8]). It cannot be inferred, however, that the composition of the fifth-year regeneration will remain the same as the stand develops. The different tree species will mature at different rates, and it is possible that trembling aspen, white birch and jack pine will die out, leaving a black spruce-dominated forest in the long term. On the other hand, it is quite possible that the stands may still be mixedwood by the time of the next harvest, especially with the increasing need for wood and consequent shortened rotations. Jovic (1981) describes mixedwood stands in the Geraldton District, located north and east of the Nipigon District, noting that most are 80 to 120 years old. One of the mixedwood conditions in both the Geraldton and Nipigon Districts is black spruce-white birch on shallow soils. These stands may represent the kind of forest into which the regenerated strip cuts will develop.

With the present harvesting system, hardwood reproduction may be favored, inadvertently, over that of black spruce. Only the conifers are cut, and the trembling aspen and white birch are usually left standing, thus providing a seed source to the cutovers. In addition, aspen roots sucker prolifically. If it is desired to reduce the hardwood composition in the regenerating strips, then the aspen and birch should be cut from the first strips at the same time as the conifers. This would not prevent the hardwoods in the leave strips from seeding, but would at least reduce the numbers of parent trees by half. Also, the hardwoods left in the leave strips might not produce as much seed because they would not be exposed and stressed to produce heavy

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[8]Clemmer, E., and Atkins, T. 1980. St. Lawrence Licence cutover assessment final report. Ontario Ministry of Natural Resources, Nipigon District, Nipigon, Ontario. A regeneration assessment for cutovers in the area encompassing the location of the present study.

seed crops as would single trees or groups of trees left in cutovers. Treatment of the cut aspen stumps with a biocide must be undertaken soon after cutting to discourage suckering.

As an alternative, herbicides can be (and are being) applied to those areas with too much hardwood after the strips have been regenerated. However, this may be too late to effectively discourage the hardwoods, and perhaps it is better to discourage the hardwoods at harvest time by cutting, rather than to fight a rearguard action after the seedlings are well established.

The manager may decide to accept the change in composition, on the assumption that more utilization of hardwoods will be the rule by the next harvest and/or simply because resources are limited. Whether the increased hardwood composition will be deleterious to black spruce growth, or will benefit the spruce by providing some shade and also a better nutrient supply, *viz.* nutrient pumping and leaf fall, is not known. It is not known either how well the hardwoods will grow on these shallow-soil sites or whether they will provide good wood or fibre at the next harvest. These are some of the questions that need to be answered after further study of second-growth forests in boreal cutovers.

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