STRIP CUTTING IN SHALLOW-SOIL UPLAND BLACK SPRUCE NEAR NIPIGON, ONTARIO
IV. SEEDLING-SEEDBED RELATIONSHIPS

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ABSTRACT

Seedbed materials and conditions influencing regeneration from natural seeding were studied in the precut forest and in alternate strip clearcuts 1, 3, and 5 years after cutting and scarification. Seedbeds very receptive to black spruce regeneration are live sphagnum moss, sphagnum peat, mineral plus organic mixed, mineral B and C horizons, and pioneer moss. Moderately receptive seedbeds include live feather moss, dark upland humus, dark peat and muck, F-horizon, Ae-horizon, dead sphagnum moss, and aquatic moss. Windthrow in the precut forest and scarification after cutting are disturbances that remove dry surface litter, moss and upper F-horizons, and expose underlying receptive seedbeds. Sheltered microniches and depressions are important for obtaining regeneration by natural seeding. The best overall index of seedbed receptivity was a sum of percentage cover of specific receptive materials estimated within 1 year after scarification.

Stocking and density for black spruce seedlings were 65% and 4.39, respectively, in 2-m x 2-m quadrats, after 4 years of natural seeding and with a mean receptive seedbed of 13.9% per quadrat. Seedling density in the fifth year was significantly influenced by receptive seedbed and leave time, but not significantly influenced by width of strip, location in strip, or site type.

There was considerable graminoid development on dark peat and muck and on sphagnum moss. Receptive upland seedbed was positively correlated with cover values for broad-leaf trees and pioneer moss, and density of black spruce and white birch seedlings. Sphagnum moss was strongly correlated with density of black spruce seedlings. Drainageways and lower slopes had more black spruce seedlings than upper slope and crest sites in 1976. However, in 1980, the levels in drainageways were low.

RÉSUMÉ

Une, trois et cinq années après la coupe et la scarification, on a étudié la nature des lits de germination et les facteurs de régénération d'un ensemencement naturel, dans la forêt préalablement coupée et dans des coupes rases alternées. Les lits de germination qui conviennent très bien à la régénération de l'épinette noire sont constitués de sphaignes vivantes, de tourbe de sphaigne, de sol minéral mélangé à du sol organique, des horizons minéraux B et C et de mousse pionnière. Les lits qui conviennent modérément comprennent les hypnacées vivantes, l'humus foncé des hautes terres, la tourbe foncée et la tourbe évoluée, les horizons F et Ae, les sphaignes mortes et les mousses aquatiques. Le déracinement par le vent dans la forêt préalablement coupée et la scarification qui suit la coupe sont des causes de perturbation qui enlèvent la litière superficielle sèche, la mousse et les horizons supérieurs F et mettent au jour les lits de germination sous-jacents favorables. Les microniches et les dépressions abritées sont importantes pour la régénération naturelle. Le meilleur index global de la réceptivité des lits de germination était la somme des pourcentages de recouvrement des matières favorables respectives, estimés moins d'un an après la scarification.

Après quatre ans d'ensemencement naturel, le taux d'occupation et la densité des épinettes noires était de 65% et de 4.39 respectivement dans les quadrats de 2 m x 2 m, à un taux moyen de lits de germination favorable de 13.9%. La densité des semis au cours de la cinquième année a subi l'influence notable de la nature du lit de germination et du nombre d'années pendant lesquelles on avait laissé subsister les bandes épargnées, mais non de la largeur des bandes, de leur emplacement ou du type stationnel.

If y a eu une croissance considérable de plantes apparentées aux graminées sur la tourbe foncée, la tourbe évoluée et les sphaignes. Il y avait corrélation positive entre les lits favorables à la germination, sur les hautes terres, et le recouvrement des feuillus et de la mousse pionnière ainsi que la densité des semis d'épinette noire et de bouleau à papier. Il y avait une forte corrélation entre les sphaignes et la densité des semis d'épinette noire. Dans les voies de drainage et sur le bas des pentes, on comptait davantage de semis d'épinette noire que sur le haut des pentes et sur les croupes, en 1976, tandis qu'en 1980, les taux étaient faibles dans les voies de drainage.

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INTRODUCTION

Studies of alternate strip clear-cutting as a system of harvesting and regenerating black spruce *(Picea mariana)* [1] by natural seeding on shallow-soil uplands near Nipigon have been in progress since 1974 (Jeglum 1980, 1982, 1983; Fleming and Crossfield 1983). In order to obtain successful regeneration of black spruce from natural seeding, three requirements must be satisfied: there must be an adequate supply of viable seed; there must be some protection of the cutover from excessive heating and drying, especially on upland sites; and there must be enough favorable seedbed present, in terms of percentage cover and distribution, to obtain satisfactory levels of stocking and density (cf. Roe et al. 1970).

In order to achieve regeneration on shallow-soil upland black spruce areas in the Nipigon Forest District, the alternate strip clear-cutting system was prescribed (Robinson 1974, Marek 1975). The silvicultural prescription included 'delicate' scarification of the first cut strips as soon after cutting as possible in order not to delay regeneration. This scarification was intended to expose enough receptive seedbed to achieve fully satisfactory levels of stocking and density. At the same time the delicate scarification would minimize the scraping off and/or erosion of the thin layers of soil that cover the bedrock.

The specific objectives of this study were: (1) to describe changes in seedbed conditions from just before to 5 years after cutting, in shallow-soil, upland black spruce; (2) to determine which seedbeds are favorable to black spruce regeneration by seed; (3) to develop an index of receptive seedbed; and (4) to assess the relative importance of seedbed to regeneration of black spruce in comparison with strip width, position in strip, leave time and topographic site position.

STUDY AREA

The area has been described previously in detail (Jeglum 1980). This study is based on the first of three replicated study areas. It is located close to Thimble Creek on the Domtar Forest Products Limits, about 30 km east of Beardmore, and 40 km east of Pijitawabik Bay (Lake Nipigon). It is in Site Region 3W (Hills 1960) and the Central Plateau Section, B.8, of the Boreal Forest Region (Rowe 1972). In the precut forest, black spruce was dominant, and Schreber's feather moss *(Pleurozium schreberi)* was abundant. Other species present in lesser amounts were balsam fir *(Abies balsamea)*, jack pine *(Pinus banksiana)*, white birch *(Betula papyrifera)*, and trembling aspen *(Populus tremuloides)*.

The area is a mix of lowland and upland conditions in shallow-soil bedrock-controlled topography. Because of topographic variations, there was not the same distribution of sites among scarified strips and control strips. Scarified quadrats were distributed as follows: 11% on drainageways, 39% on lower slope, 39% on upper slope, and 11% on crest. The control quadrats consisted of a higher proportion of lower, moister sites--24%, 41%, 20% and 15% for the same sequence of sites. The drainageways were wet with usually shallow accumulations of peat. Seven percent of the Thimble Creek area had organic soils 40 cm deep or deeper (cf. organic soils, Canada Soil Survey Committee, Subcommittee on Soil Classification 1978). The upland sites were covered with variable depths of shallow rocky till over bedrock.

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[1] Nomenclature and author citations for vascular species follow those used by Scoggan (1978/79) and for mosses, those used by Ireland et al. (1980).

METHODS

Research methods have been described in detail (Jeglum 1980). Only the essential details need be repeated. In the Thimble Creek Area, 16 strips were laid out for each of three strip widths--20 m, 40 m, and 80 m. The strips were approximately 180 m deep, oriented more or less north-south. Alternate strips were cut in June and July of 1975 by conventional cut and skid of tree lengths using rubber-tired skidders. For each strip width, eight strips were cut and eight were left as leave strips.

The silvicultural prescription for the area was to reduce slash, to scuff off the organic mor mat, and to expose the upper surface of the mineral soil and lower layers of the mor mat. To achieve this, the first-cut strips were scarified in July, 1975 by rubber-tired skidders pulling flanged barrels and anchor chains. In scarifying, two skidders were used with different spacings between barrels (1.5 and 2.3 m) and different-sized barrels.

The leave strips (second-cut 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 September and October, 1979.

Eight additional 40-m strips were added as controls that were not to be scarified. Two of the leave strips were cut after 2 years and the other two after 4 years to provide the same two leave treatments as were used in the scarified strips.

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, giving 25 quadrats per strip, and 1400 quadrats in all 56 strips. Several lines of quadrats were added to the control strips in 1979 to bolster the original number of quadrats.

Summer assessments (from late June to the end of July) were carried out in 1974 (precut), and at 1 year (1976), 3 years (1978), and 5 years (1980) after the cut. The seedbed assessments were done in 0.5 m x 2 m quadrats, oriented crosswise to the long axes of the strips.

Percentage cover estimates were made in the 0.5-m x 2-m quadrats for numerous vegetational categories (Table 1) and non-living ground materials, soil horizons or mixtures of materials, and conditions (Table 2). Cover of any particular category was judged continuous if spaces between constituent pieces of it were less than 2.5 cm wide. Cover estimates were made in the following categories: less than 1%; 1 to 5%; >5 to 15%; >15 to 25%...etc....; >85 to 95%; >95 to 100%. In the analyses, cover classes were converted to the midpoints of the ranges.

Seedlings less than 10 cm tall of each species in the 0.5-m x 2-m quadrat, up to a maximum of nine, were counted. The presence of seedlings of this size was noted in the 2-m x 2-m quadrats. Seedlings of each species in greater height classes were counted, up to nine, in the 2-m x 2-m quadrats.

A detailed study of seedling-seedbed relationships was also performed. For this the total numbers of 'small' seedlings of seed origin occurring on different ground material types were counted in the 0.5-m x 2-m quadrats. The criterion for choosing 'small' seedlings was sometimes height, sometimes age. For these small seedlings, 'special' seedbed conditions were also recorded--e.g., on a scraped surface created by skid-

Table 1. Field and ground layer vegetation in precut condition and first-cut scarified strips (all strip widths combined). Values in the table are mean cover percentage, and frequency percentage (within parentheses).

Vegetation component	Year of assessment			
	Precut	Postcut-scarified		
	1974	1976	1978	1980
No. of quadrats	1400	565	565	565
Broad-leaf trees[a]	2.4 (38)	8.0 (59)	10.6 (73)	7.8 (70)
Shrubs	19.2 (76)	6.7 (76)	12.2 (81)	20.5 (94)
Graminoids[b]	3.7 (26)	1.6 (40)	9.7 (53)	11.4 (55)
Herbs	18.8 (91)	5.7 (80)	13.2 (86)	11.5 (88)
Mosses, total	60.0 (100)	11.3 (96)	13.2 (96)	6.5 (91)
Feather moss, live[c]	53.7 (97)	4.4 (41)	9.9 (89)	2.9 (51)
Feather moss, dead	0.8 (54)	5.5 (83)	1.5 (58)	0.8 (63)
Sphagnum moss, live	3.8 (15)	0.9 (11)	2.0 (12)	1.3 (10)
Sphagnum moss, dead	+ (4)	0.2 (7)	+ (2)	.1 (3)
Aquatic moss[d]	0.5 (11)	0.1 (10)	0.4 (10)	+ (+)
Pioneer moss[e]	0.6 (17)	0.1 (9)	1.0 (39)	1.6 (57)
Moss on wood	2.3 (87)	0.3 (21)	1.1 (46)	0.2 (15)
Lichen on ground	1.1 (11)	0.5 (10)	1.8 (90)	0.7 (19)
Lichen on wood	1.3 (98)	0.5 (76)	0.9 (87)	0.4 (58)

[a]Cover values for broad-leaf tree species are for all size classes, including residual trees; frequencies are only for sapling and seedling-sized individuals.

[b]Graminoid cover including living and dead leaves and culms.

[c]Feather mosses are a group of dry upland mosses occurring in mats in shade beneath conifers. They include Schreber's feather moss *(Pleurozium schreberi)*, step moss *(Hylocomium splendens)*, plume moss *(Ptilium crista-castrensis)*, and manystalked broom moss *(Dicranum polysetum)*.

[d]Aquatic mosses include *Mnium* spp. *(sensu lato)*, and *Drepanocladus* spp.

[e]Pioneer mosses include juniper hair-cap moss *(Polytrichum juniperinum)*, awned hair-cap moss *(P. piliferum)*, common hair-cap moss *(P. commune)*, purple-fruiting heath moss *(Ceratodon purpureus)*, cord moss *(Funaria hygrometrica)*, and silky pendulous thread moss *(Pohlia nutans)*.

Table 2. Non-living seedbed material or condition above and on the ground in precut condition and first-cut scarified strips (all strip widths combined). Values in the table are mean cover percentage, and frequency percentage (within parentheses).

Seedbed material/ condition	Year of assessment			
	Precut	Postcut-scarified		
	1974	1976	1978	1980
No. of quadrats	1400	565	565	565
Material				
Slash	5.8 (76)	20.3 (100)	21.3 (99)	10.2 (78)
Logs (⩾10 cm diam.)	3.8 (33)	4.8 (39)	4.3 (35)	4.3 (36)
Stumps	0.4 (9)	2.1 (47)	2.2 (39)	1.8 (36)
Stems, wood, bark on ground[a]	2.9 (93)	9.4 (100)	7.3 (97)	5.5 (77)
Rotten wood[b]	3.9 (71)	8.1 (94)	9.6 (92)	5.6 (72)
Needle litter[c]	10.2 (99)	31.5 (100)	26.4 (99)	9.3 (80)
Broad-leaf litter	16.4 (98)	5.6 (90)	7.9 (93)	6.7 (90)
F-horizon	0.4 (13)	7.2 (67)	14.1 (83)	6.4 (65)
H, Hi, Ah-horizon	(2)	0.9 (22)	1.8 (19)	0.2 (5)
Ae-horizon	+ (1)	0.3 (16)	0.2 (7)	0.2 (3)
B + C-horizon	+ (2)	0.3 (14)	0.2 (8)	0.2 (6)
Mixed min. + org.	+ (1)	1.0 (17)	0.3 (7)	0.1 (1)
Min. over org.	+ (1)	0.1 (1)	+ (1)	+ (1)
Sphagnum peat	+ (+)	0.5 (4)	0.1 (2)	+ (1)
Dark peat, muck	0.4 (6)	2.4 (16)	1.0 (8)	0.5 (6)
Rock	0.3 (5)	1.2 (24)	2.0 (22)	1.8 (22)
Water	1.1 (9)	2.7 (11)	1.9 (9)	0.1 (1)
Totals (excluding slash)	39.8+	78.1	79.3+	42.7+
Condition				
Tire track	0.0 (0)	9.9 (34)	3.3 (10)	2.3 (9)
Scrape line	0.0 (0)	3.3 (5)	1.1 (11)	0.5 (4)
Windthrow scar	2.7 (10)	0.5 (2)	0.5 (2)	0.3 (1)

[a] 'Stems, wood and bark' includes pieces 1 to 10 cm in diameter.

[b] 'Rotten' wood was defined as any wood surface that was soft or spongy to the touch in any degree.

[c] Needle litter includes fine twigs and woody pieces less than 1 cm in diameter on the ground.

der tire or barrel, in a windthrow scar, or in a microdepression or sheltered niche beside a stump, stem, rock, or other elevated object[2].

To judge relationships between seedlings and seedbed, correlation matrices were obtained between the number of black spruce in a quadrat (seedlings less than 10 cm tall) and the percentage cover of each seedbed material or condition. This was done for 11 data sets. The data sets were assessments for various year and treatment combinations (Table 3).

Another non-statistical method was developed to judge relationships --i.e., 'ratio analysis' (cf. Jarvis and Cayford 1961). This was based on the principle that if there are no differences among seedbeds for receptivity of seed germination, the relative number of seedlings found on each seedbed should be in the same proportion as the percentage covers for the various seedbeds. The relative percentage of seedlings on each ground material in the quadrat was divided by the relative percentage cover for that material. Only ground materials were used (Table 4). Graminoid cover was included because seedlings were found to germinate in the graminoid thatch and litter that develop closely appressed to the ground surface. Elevated materials such as slash (regarded as stems and branches elevated above the ground), broad-leaf tree cover, shrub cover and herb cover were not used, because they do not provide a substrate on which seedlings can germinate. Also, general ground disturbance conditions were not used because they are composites of specific materials already included.

[2]Small seedlings were < 10 cm in the precut data, ⩽3 cm in the 1976 data, ⩽3 years in the 1978 data, and ⩽5 cm in the 1980 data (Table 3). Small seedlings were used in this special study so that the seedbed and special conditions would not have changed, or would have changed very little.

Table 3. Description of the data sets for seedling-seedbed relationships.

Data set	No. of 1-m² quadrats	Assessment criterion (ht or age)	No. of seedlings assessed
Precut '74	1400	< 10 cm	402
Postcut			
'76 Scar	565	⩽ 3 cm	409
'76 Con	100	⩽ 3 cm	173
'78 Scar 2Y	300	⩽ 3 yr	226
'78 Scar 4Y	265	⩽ 3 yr	361
'78 Con 2Y	50	⩽ 3 yr	27
'78 Con 4Y	50	⩽ 3 yr	79
'80 Scar 2Y	300	⩽ 5 cm	300
'80 Scar 4Y	265	⩽ 5 cm	186
'80 Con 2Y	125	⩽ 5 cm	31
'80 Con 4Y	130	⩽ 5 cm	155

Scar = scarified.
Con = controls, non-scarified.
2Y = first-cut strip seeded 2 years.
4Y = first-cut strip seeded 4 years.

Table 4. Relation of small black spruce seedlings to ground materials (all strip widths combined). Criteria for 'small' are in Table 3.

	Percentage of seedlings						
		Postcut					
	Precut	Scarified			Controls		
	1974	1976	1978	1980	1976	1978	1980
No. of quadrats	1400	565	565	565	100	100	255
No. of seedlings on seedbeds	357	409	559	195	173	98	169
Graminoid	–	–	0.4	5.6	–	5.1	10.1
Feather moss, live	47.6	4.4	27.5	25.6	5.8	28.6	24.3
Feather moss, dead	2.5	0.7	0.2	0.1	0.6	1.0	0.6
Sphagnum moss, live	4.5	8.1	12.7	10.3	18.5	6.1	21.3
Sphagnum moss, dead	–	0.2	1.0	–	1.7	2.0	–
Pioneer moss	–	–	–	–	–	–	–
Aquatic moss	0.6	–	0.5	–	–	1.0	1.2
Moss on wood	10.4	–	–	–	–	–	–
Lichen on wood	2.0	–	–	–	–	13.3	–
Lichen on ground	–	–	0.2	2.6	–	–	–
Logs (⩾10 cm diam.)	–	–	–	–	–	–	–
Stumps	–	–	–	–	–	–	–
Stems, wood, bark on ground	–	2.0	0.5	–	0.6	–	–
Rotten wood	4.8	5.4	4.3	1.5	6.4	1.0	4.7
Needle litter	17.6	24.9	24.5	13.8	14.5	11.2	6.0
Broad-leaf litter	4.8	1.0	6.3	21.0	0.6	–	4.7
F-horizon	2.5	9.0	13.8	12.3	12.1	18.4	23.1
H, Hi, Ah-horizon	–	8.6	1.1	0.5	2.9	3.1	1.2
Ae-horizon	–	–	–	3.0	2.3	–	0.6
B + C-horizon	2.2	5.1	3.6	3.1	2.3	1.0	–
Mixed min. + org.	0.6	7.3	2.7	0.5	4.6	5.1	–
Min. over org.	–	–	–	–	–	–	–
Sphagnum peat	–	4.2	0.5	–	4.0	3.1	–
Dark peat, muck	–	19.1	0.2	–	23.1	–	2.4
Rock	–	–	–	–	–	–	–
Water	–	–	–	–	–	–	–
Totals	100.1	100.0	100.0	99.9	100.0	100.0	100.2

RESULTS

Changes in Vegetation

Before the cut, the most important understorey layers were feather mosses, shrubs, and herbs (Table 1). Other vegetational categories in relatively high abundance included broad-leaf trees, graminoids, living sphagnum moss, and moss on wood.

In the first year after cutting and scarification (1976), almost all vegetative layers decreased in cover percentage (Table 1). However, broad-leaf trees and dead feather moss increased. Most frequency values either were similar to the precut levels or decreased. Increases occurred in broad-leaf trees, graminoids, and dead feather moss.

Between 1976 and 1978, all vegetation components increased, except for dead feather moss and dead sphagnum moss (Table 1). Large increases occurred for shrubs, herbs, and live feather mosses, and broad-leaf trees and graminoids exceeded their precut levels by 1978.

In 1980, shrubs, graminoids, and pioneer mosses had higher cover levels than in 1978 (Table 1). The pioneer mosses are those mosses developing on disturbed surfaces, particularly mineral soil, but also on scraped organic surfaces (see footnote e, Table 1).

Changes in Non-living Materials and Conditions

Ground materials and conditions changed dramatically from precut to postcut-scarified (Table 2). Because of logging and scarification, subsurface soil horizons were exposed, and virtually all non-living ground materials increased, except for broad-leaf litter. The largest increases were in slash (branches and stems elevated above the ground surface), stems, wood and bark on the ground, rotten wood, needle litter, F-horizon, dark peat, and water. Of course, logs and stumps increased. Of the general categories of disturbance, tire tracks and scrape lines showed large increases. Windthrow scars decreased, being masked and difficult to distinguish from the disturbances caused by logging and scarification.

As expected, comparisons of 1976, 1978, and 1980 data showed relatively constant values for stumps and logs (Table 2). There were general decreases in the covers and/or frequencies for most ground surfaces. The totals for all ground surface materials (slash excluded, graminoid, moss and lichen included) for 1974, 1976, and 1978 were 105, 92, and 105% respectively (Tables 1 and 2). However, for 1980 the totals dropped to 62%. Clearly, there were underestimates in 1980 for several of the ground surface materials. This drop could be explained partly by the development of low vegetation such as blueberry *(Vaccinium angustifolium)*, creeping snowberry *(Gaultheria hispidula)* and twinflower *(Linnaea borealis)*. Also, the assessors in 1980 could have underestimated certain materials that might mature or change over time, becoming less easy to classify. For example, needle litter decreased from 26% in 1978 to 9% in 1980.

Seedling-Seedbed Relationships

The relative density of 'small' black spruce seedlings (see footnote 2) recorded on specific seedbeds is given in Table 4. In the precut forest, seedlings became established most frequently on living feather moss, needle litter, and moss on wood. Other materials on which they frequently occurred were living sphagnum moss, rotten wood, and broad-leaf litter.

In the postcut strips, the seedbeds favoring regeneration seemed to be similar for scarified and control strips. The main seedbeds were living feather moss, living sphagnum moss, needle litter, F-horizon, and dark peat and muck. Numerous other seedbeds were also utilized. It is intereresting that, although moss on wood had a relatively high percentage of black spruce seedlings in the precut, it had none recorded in the postcut condition.

In the assessment of the relation of species to special conditions, the importance of disturbance for the creation of receptive seedbeds becomes apparent. Three special conditions are presented in Table 5: 1) windthrow scars; 2) a combination category including tire marks, barrel grooves and scrape lines; and 3) microniches and depressions beside stumps, stems, logs, and rocks. In the precut condition windthrows and microdepressions were both important to seedling establishment. In the postcut condition, logging and scarification became important. When all seedling-seedbed assessments for 11 data sets were combined, 37% of all seedlings were classified as being in disturbance or special microsites--9% in windthrow scars, 11% in tire track or scrape lines, and 16% in microniches or microdepressions.

Seedbed Receptivity

The relative receptivities of various seedbeds to black spruce are suggested in Table 4, but the relative abundances of the various seedbeds are not taken into account. To obtain an indication of the relative receptivities of various seedbeds, the densities of seedlings should be rated relative to the cover percentage of the seedbed materials. This was accomplished by correlation analysis and ratio analysis (Table 6).

In the precut assessments there were significant positive correlations ($P < 0.05$) for pioneer moss, the H-Hi-Ah-horizons, the F-horizon, needle litter, stumps, moss on wood, and mineral over organic (Table 6). There was a negative correlation for broadleaf litter. Neither feather moss nor sphagnum moss (live or dead) had significant r values.

The results of both correlation analysis and ratio analysis for the postcut results were used to classify seedbeds as to their relative receptivities (Table 6). 'Very receptive' seedbeds had numerous positive 'r' values and ratios. These included living sphagnum moss, mineral+organic mixed, sphagnum peat, B+C-horizon, and pioneer moss. 'Receptive' seedbeds had one or more positive r values and ratios. Most of the other exposed horizons were included here, as well as live feather moss, dead sphagnum moss and aquatic moss. 'Non-receptive' seedbeds had numerous significant negative values of one or both indices. Some seedbeds showed no consistent relationship with seedlings, either positive or negative.

Developing an Index for Receptive Seedbed

A single number to represent total receptive seedbed (by percentage cover) per quadrat is necessary for analyzing the importance of seedbed. Five indices were derived from the data and analyzed to determine which was best correlated with black spruce regeneration. The indices were as follows:

1. DISTCON - 'disturbance conditions', derived by adding the covers for tire ruts, scrape lines, and windthrow scars[3];

2. DISTMAT - 'disturbance materials', derived by adding all exposed subsurface soil horizons--dark peat and muck, sphagnum peat, F-horizon, H+Hi+Ah-horizon, Ae horizon, B+C-horizon, mineral+ organic mixed, and mineral over organic;

3. DISTMAX - 'disturbance maximum', the larger of DISTCON and DISTMAT;

4. RECEP - 'receptive', derived by adding all attributes classified as very receptive or receptive (Table 6), but also including mineral over organic and excluding living feather moss (explained in the following text); and

5. MAXALL - 'maximum of all', the maximum of all the above indices.

Mineral over organic was included in RECEP because other mineral surfaces were found receptive (Table 2).

A summary of the mean cover percentages and frequencies over the 4 years of assessments is given in Table 7. In the precut condition mean covers and frequencies were relatively low, and MAXALL was highest, followed by RECEP. After cutting, all values increased greatly, MAXALL achieving over 20% mean cover. DISTCON may sometimes have had overly high estimates, as when a quadrat was rated as 100% disturbed when actually only a portion of it was. This explains the highest mean values for MAXALL, which was the maximum for each quadrat among all the different seedbed estimates. In 1980 all values were considerably lower than in 1976 and 1978, probably because of the difficulty of accurately assessing ground surfaces covered by vegetation, and because of underestimates of certain ground materials.

Black spruce seedling (< 10 cm) densities in the 0.5-m x 2-m quadrats (Table 7) rose from 0.55 to 0.83, then to 0.92, and then dropped to 0.48. Frequencies showed a similar trend. The main reason for this drop was that some seedlings grow out of the 0- to 9.9-cm height class into taller classes (Jeglum 1982).

Correlations of black spruce seedlings (< 10 cm) were performed with the five indices of seedbed (Table 8). This was done for various combinations of seedbed (S) and regeneration (R) data for different years of assessment: S76R76, S78R78, S80R80, S76R78, and S76R80. Consistently higher r values were found when the 1976 seedbed estimates were used with 1976, 1978, and 1980 regeneration data. This suggests that the first-year seedbed assessment was the most accurate for correlation with subsequent regeneration. Among the five indices of seedbed, RECEP had the highest correlation with black spruce seedlings in four out of five cases. MAXALL was next best after RECEP, with usually only slightly lower r values.

When living feather moss cover was added to RECEP, the r values between RECEP and black spruce seedlings were reduced in four of the five cases shown in Table 8. For this

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[3]The estimates for the three types of disturbance condition were mutually exclusive and did not overlap. Scrape lines were lines of disturbance which had been caused by either logging or scarification, but did not show definite tire ruts or marks.

Table 5. Relation of small black spruce seedlings to special ground surface conditions (all strip widths combined).

	Seedling in special condition (% of all seedlings recorded)			
	Windthrow scar	Tire tracks, scrape lines[a]	Microniche or depression	All special conditions
Precut '74	12	0	6	18
Postcut				
'76 Scar[b]	1	28	6	35
'76 Con	10	12	6	28
'78 Scar 2Y	5	4	38	47
'78 Scar 4Y	4	3	29	36
'78 Con 2Y	4	11	41	56
'78 Con 4Y	9	0	49	58
'80 Scar 2Y	24	7	8	39
'80 Scar 4Y	17	15	29	61
'80 Con 2Y	23	6	6	35
'80 Con 4Y	5	28	3	36
All data sets (%)	9	11	16	37

[a]Tire tracks are distinct tire-caused ruts. Scrape lines are indistinct lines of either logging or scarification which are compacted and scraped, but are not distinct tire ruts.

[b]Scar = scarified; Con = control, non-scarified; 2Y = 2-year seeded strips; 4Y = 4-year seed strips.

reason feather moss was not included in the RECEP index.

Dark peat + muck was also questionable for inclusion in RECEP. Although it provides a good germination medium, seedling survival is poor owing to graminoid competition, frost heaving, and flooding (cf. Jeglum et al. 1983). When dark peat + muck was excluded from RECEP, the r value between it and black spruce seedlings was reduced below that for the S76R76 combination shown in Table 8. This suggests that it was an important component of RECEP. The r values for the other four combinations of years were changed very little by excluding dark peat + muck. For this reason it was retained in the RECEP index.

Relative Importance of Seedbed

A number of analyses of variance were performed with a one-way ANOVA in the BMDP statistical programs (Engelman 1981), so that the relative importance of seedbed could be judged. With this

Table 6. Relation of black spruce seedlings to ground materials, as interpreted from correlation analysis and 'ratio analysis'.

	Precut: significance of r[a]	Postcut: no. of significant values in 10 data sets			
		r values[b]		Ratio analysis[c]	
		+	-	+	-
VERY RECEPTIVE					
Sphagnum moss, live	NS	5	0	9	0
Mixed min. + org.	NS	5	0	5	0
Sphagnum peat	NS	3	0	5	0
B + C-horizon	NS	3	0	5	0
Pioneer moss	+	8	0	—[d]	—[d]
RECEPTIVE					
Feather moss, live	NS	1	0	8	0
H, Hi, Ah-horizon	+	1	0	6	1
Dark peat, muck	NS	3	0	3	2
F-horizon	+	1	0	3	0
Ae-horizon	NS	1	0	3	0
Sphagnum moss, dead	NS	3	0	3	2
Aquatic moss	NS	2	0	1	0
NON-RECEPTIVE					
Needle litter	+	0	2	1	3
Logs	NS	0	0	0	10
Stumps	+	0	0	0	10
Stems, wood, bark	NS	0	1	0	10
Lichen on wood	NS	0	0	1	9
Lichen on ground	NS	0	0	1	8
Feather moss, dead	NS	0	0	1	8
Moss on wood	+	0	0	0	4
Rotten wood	NS	0	0	1	4
Rock	NS	2	0	0	4
Water	NS	1	0	0	6
NO CLEAR RELATION					
Graminoid cover	NS	3	0	2	8
Broad-leaf litter	-	3	0	1	5
Min. over org.	+	1	0	0	0

[a]Correlations between number of seedlings <10 cm tall and the cover estimates for seedbed categories in 0.5-m x 2-m quadrats. The signs + or - indicate significance at 5% level. NS = not significant.

[b]Correlations between number of seedlings < 10 cm and cover estimates for seedbed categories in 0.5-m x 2-m quadrats. In the table are the numbers of r values in the 10 postcut data sets that were significantly positive or negative (cf. Table 3).

[c]Number of ratios that were 'significantly' positive (⩾2.0) or negative (⩽0.5) in the 10 postcut data sets (cf. Table 3).

[d]Not recorded consistently.

Table 7. Quantitative levels for five summation indices for favorable seedbed, and for black spruce seedlings <10 cm tall (all strip widths combined).

	Precut 1974		Postcut 1976		Postcut 1978		Postcut 1980	
	C[a]	F[a]	C	F	C	F	C	F
No. of quadrats	1400		665		665		665	
DISTCON	2.7	(10)	12.7	(35)	5.3	(20)	2.9	(11)
DISTMAT	1.0	(19)	12.8	(79)	17.4	(87)	7.6	(70)
DISTMAX	3.2	(22)	19.7	(80)	19.7	(88)	9.4	(71)
RECEP	5.8	(43)	14.3	(82)	20.4	(92)	10.7	(84)
MAXALL	7.8	(45)	20.9	(84)	22.5	(93)	12.3	(84)
Black spruce[b]	0.55	(22)	0.83	(30)	0.92	(32)	0.48	(19)

[a]C = percentage cover, means in 0.5-m x 2-m quadrats; F = percentage frequency in 0.5-m x 2-m quadrats.
[b]Values given under C columns for black spruce are mean numbers per 0.5-m x 2-m quadrat.

program any number of groups can be defined as single-factor treatments or combinations of factors, depending on the objectives for testing for differences. Five factors were included:

1. RECEPTIVE SEEDBED, four classes -- 0%, 0.1 to 4.9%, 5% to 19.9%, and equal to or greater than 20% (cover by quadrat);

2. SEEDING TIME, two classes -- 2 years and 3 years;

3. STRIP WIDTH, four classes -- 20 m, 40 m, 40 m controls, and 80 m;

4. DISTURBANCE BY SCARIFICATION, two classes -- scarification and no scarification; and

5. SITE TYPE, four classes -- drainageway, lower slope, upper slope, and crest.

The dependent variable was numbers of black spruce seedlings <10 cm tall in the 0.5-m x 2-m quadrats. Analyses were done with 1976 seedbed data, and 1978 regeneration data, since this latter assessment included strips which had both 2 and 3 years of seeding. Also, the regeneration in the <10 cm height class had achieved its highest levels in 1978.

When each factor was considered separately, only two showed significant F-values -- receptive seedbed ($P < 0.0000$) and seeding time ($P < 0.0002$). This suggests that, of the factors tested, seedbed is the most important. ANOVAs were run for the treatment combinations for all possible pairs of factors--e.g., 1:2, 1:3, 1:4, 2:3, etc. Whenever receptive seedbed was in the pair there was a significant difference ($P < 0.0000$) among treatment combinations with both F tests. For combinations of leave time with strip width, disturbance, or

Table 8. Correlations of black spruce seedling (<10 cm tall) number with five summation indices for favorable seedbeds for five data set combinations. All correlations based on n = 665.

	r, black spruce < 10 cm tall with seedbed percentage				
	S76R76[a]	S78R78	S80R80	S76R78	S76R80
DISTCON	0.17**	-0.00 NS	0.05 NS	0.14**	0.09*
DISTMAT	0.29**	.08*	0.07 NS	0.33**	0.29**
DISTMAX	0.27**	0.07 NS	0.10*	0.26**	0.18**
RECEP	0.36**	0.20**	0.20**	0.36**	0.35**
MAXALL	0.32**	0.18**	0.22**	0.29**	0.23**

[a]S = seedbed data for the year that follows; R = regeneration data for the year that follows.

NS = not significant.

* = significant at 5% level.

** = significant at 1% level.

site type, there were always significant differences as well (at least P <0.003). This confirms the overriding importance of receptive seedbed and leave time on regeneration.

The same ANOVA as outlined above was run with receptive seedbed (RECEP) as the variable rather than black spruce density. Naturally, RECEP had a very significant F-value for the four classes of RECEP. There were no significant differences in relation to seeding time and width. This indicated that RECEP was similar across all categories in each of these factors.

It was desired to test the difference between five positions of quadrats in strips. The five positions were the lines of five quadrats closest to the east forest edge, between east and central, central, between central and west, and closest to the west forest edge. Separate ANOVAs were carried out for position in strip, for each of three different strip widths. Scarified and non-scarified strips of the 40-m width were combined, because there were no significant differences found between them in the previous analyses and there were not enough quadrats to justify separating them. The 1976 regeneration assessment data (seeded 1 year) were used in order to obtain a high enough number of quadrats to represent each strip position.

None of the three strip widths had significant differences in seedling density or in receptive seedbed (Table 9). However, visual inspection reveals that the 20-m strips had lower densities in the rows of quadrats immediately adjacent to the forested strips, and this seemed to correspond to lower receptive seedbed values. The scarification in these narrow strips was light at the margins and more intense in the centers, probably because of overlap in the scarification passes in the centres. There were no other clear relationships

Table 9. Black spruce seedling (<10 cm tall) mean number and receptive seedbed cover in five different positions in strips, in each of three strip widths. Based on seedbed and regeneration assessed in 1976, including scarified and non-scarified strips.

	Strip width					
	20 m[a]		40 m[a]		80 m[a]	
Position in strip	Mean No.	RECEP (% C)	Mean No.	RECEP (% C)	Mean No.	RECEP (% C)
Far east	0.50	11.1	0.96	16.1	0.40	14.4
East	1.20	17.2	0.77	14.8	0.40	14.7
Central	0.73	18.6	1.15	11.2	0.88	13.1
West	0.80	16.7	0.83	12.7	0.95	17.7
Far west	0.58	11.3	0.92	11.8	1.25	14.1
P (F)	0.18 NS	0.11 NS	0.88 NS	0.48 NS	0.17 NS	0.85 NS

[a]Number of quadrats in each mean were 40, 53, and 40 for 20-m, 40-m, and 80-m strips, respectively.

NS = not significant at 5% level.

between seedling density and mean cover of receptive seedbed.

To emphasize the importance of receptive seedbed and seeding time, stocking and mean density for all black spruce up to 2.5 cm DBH in the the 2-m x 2-m quadrats were plotted in terms of receptive seedbed classes using the receptive seedbed values from the 0.5-m x 2-m quadrats (Fig. 1 and 2). There were clear, direct relations of stocking and density to percentage cover of receptive seedbed. Inspection of the curves for 3 and 4 years of seeding indicates that the 60% and 70% stocking levels were achieved for receptive seedbed cover levels of >3 to 5% and >5 to 15%, respectively.

The proportion of quadrats in the 1976 assessment occurring in each of the 10 classes of RECEP shown in Figures 1 and 2 was 18, 10, 11, 7, 20, 13, 10, 6, 3, and 2%, respectively. The highest proportions of quadrats were associated with 0%, >5 to 15%, and >15 to 25% RECEP--that is, 18, 20, and 13% of the quadrats, respectively.

The overall stocking and mean densities achieved after different seeding periods are shown in Table 10. There were two main influxes of seedlings, one during the first year, the other during the third. The first influx occurred when receptive seedbeds were first utilized. The second was probably related to favorable weather conditions (Jeglum 1982). After each of the surges in regeneration, there was a reduction in numbers, because of seedling mortality. However, the stocking levels stayed almost the same in spite of the drop in mean numbers.

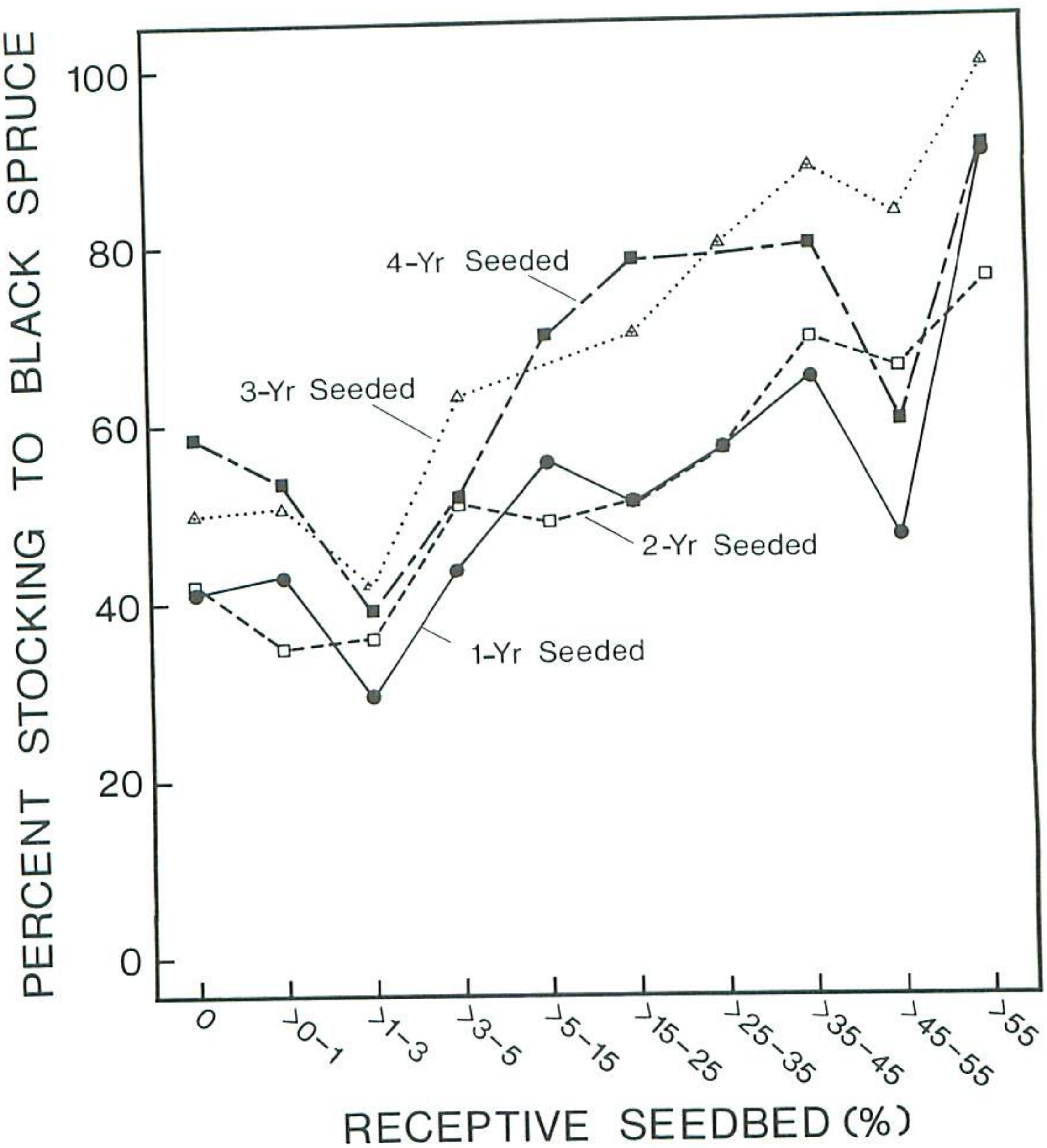

Figure 1. Stocking of black spruce seedlings (<2.5 cm DBH) in 10 classes of receptive seedbed. Stocking is in 2-m x 2-m quadrats.

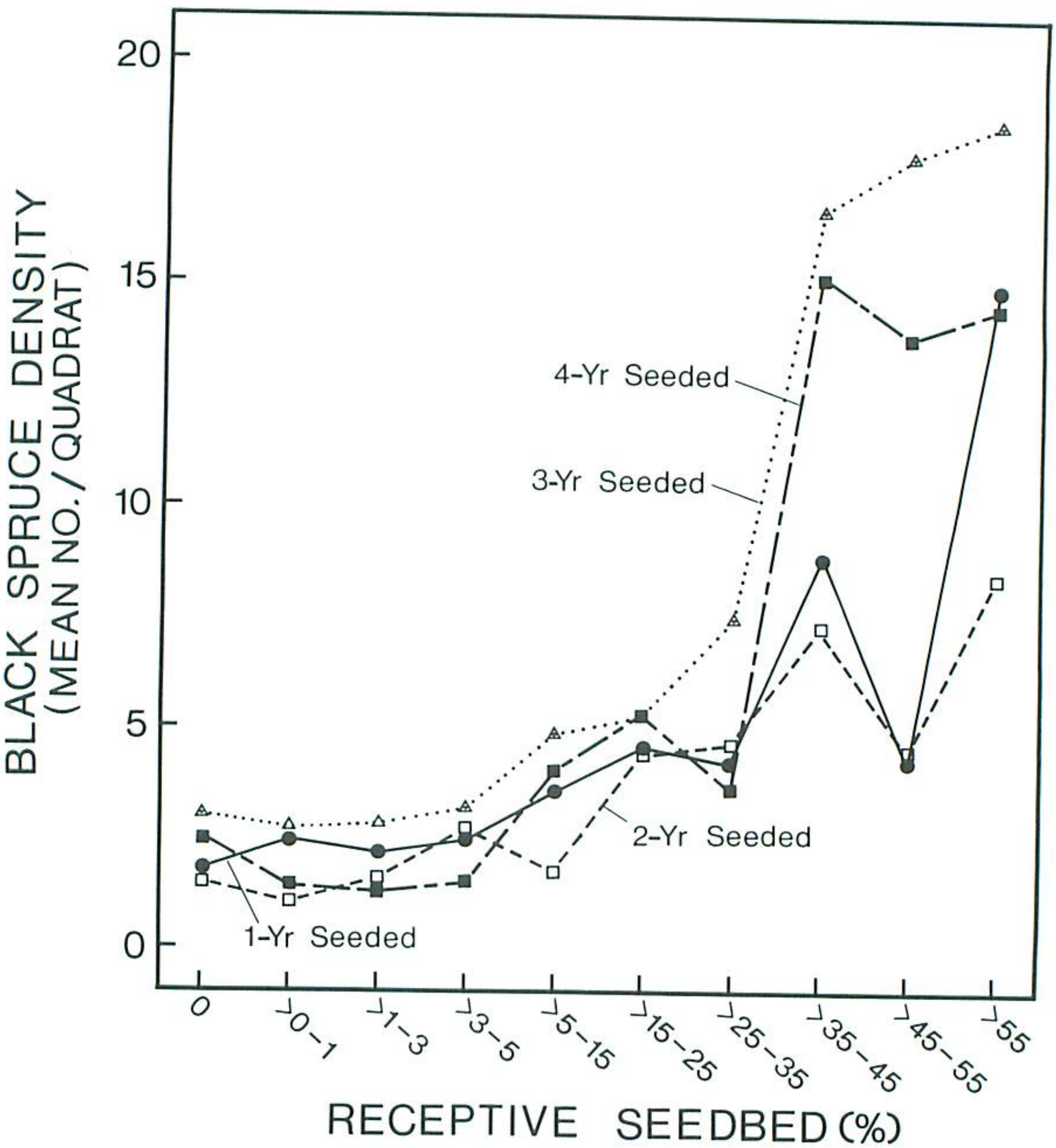

Figure 2. Density of black spruce seedlings (<2.5 cm DBH) in 10 classes of receptive seedbed. Stocking is mean number per 2-m x 2-m quadrats.

Table 10. Stocking (%) and mean number of all black spruce seedlings (<2.5 cm DBH) in 2-m x 2-m quadrats after 1, 2, 3 and 4 years of seeding by adjacent forested strips (all strip widths combined).

No. of years of seeding	No. of quadrats	Stocking (%)	Mean no.
1	665	49	3.75
2	350	49	3.00
3	315	63	5.58
4	315	65	4.39

The stocking and density levels achieved after 4 years of seeding are those achieved with 13.9% mean cover per quadrat of receptive seedbed. The 2-year seeded strips had 15.0% cover of receptive seedbed.

Relation of Main Seedbed Types to Vegetation Regrowth

Seedbed data from 1976 were correlated with vegetational data for 1980 to investigate whether seedbed influences types of vegetative regrowth (Table 11). 'Receptive upland' was the sum of all non-living receptive upland seedbeds--H+Hi+Ah-horizon, F-horizon, Ae-horizon, B+C-horizon, mineral+organic mixed, and mineral over organic (cf. Table 6). It was negatively correlated with total shrubs, but positively correlated with living feather moss, broad-leaf trees, and pioneer moss. Numbers of black spruce and white birch seedlings (<10 cm), the two main regenerating species, were strongly favored by receptive upland as well.

'Dark peat and muck' strongly favored the development of grasses and sedges, as well as living sphagnum moss. Broad-leaf trees, pioneer mosses and several other categories of vegetation are not significantly related to peat and muck.

'All sphagnum moss' in 1976 was strongly correlated with living sphagnum moss in 1980. All sphagnum moss also strongly favored graminoids and black spruce. Negative correlations were obtained between all sphagnum moss and total herbs, and all sphagnum moss and broad-leaf trees.

RECEP synthesizes the overall relationship of receptive seedbed to vegetational development. Negative significant relations for shrubs, herbs, and feather moss indicate generally lower amounts of these categories on receptive seedbed. Strong positive correlations for living sphagnum moss, pioneer moss, black spruce, and white birch are reflections of positive correlations in one of the previous three categories. Broad-leaf trees are reduced to nonsignificance on RECEP because, even though favored by upland receptive seedbeds, they are not favored by lowland seedbeds. Feather moss has a significant negative correlation with RECEP, probably because of its higher abundance in quadrats with lower disturbance, and hence lower values of RECEP.

Table 11. Correlations of 1980 vegetational categories (percentage cover) and numbers of seedlings (< 10 cm tall) with some composite seedbed categories derived from 1976 seedbed estimates. All correlations based on n = 665.

Vegetation category	Seedbed category: Receptive upland	Dark peat, muck	All sphagnum moss	RECEP - all receptive
Total shrubs	-0.09*	0.03NS	-0.02NS	-0.09*
Total graminoids	-0.07NS	0.38**	0.22**	0.22**
Total herbs	-0.02NS	-0.06NS	-0.08*	-0.08*
Feather moss, live	0.08*	-0.05NS	-0.07NS	-0.12**
Sphagnum moss, live	0.02NS	0.16**	0.47**	0.27**
Broad-leaf trees	0.13**	-0.04NS	-0.08*	0.06NS
Pioneer moss	0.21**	-0.05NS	-0.03NS	0.15**
Black spruce	0.31**	0.01NS	0.14**	0.33**
White birch	0.17**	-0.03NS	-0.02NS	0.13**

* = significant at 5% level.
** = significant at 1% level.
NS = not significant at 5% level.

Seedbed-Topography Relations

The main receptive seedbed categories of upland and lowland were summarized for the four topographic site types (Table 12). In the precut assessment most of the receptive seedbeds were not abundant. However, sphagnum moss was abundant in drainageways and lower slopes and this was reflected also in the RECEP covers and frequencies.

After cutting and scarification, receptive upland naturally increased the most in the upland site positions, and dark peat and muck increased primarily in drainageways and lower slopes. Sphagnum moss decreased considerably because of the scarification disturbance, but still achieved its highest levels in the two moister site types. RECEP achieved its highest level in drainageways because of the high values for dark peat and muck, and sphagnum moss.

The levels of natural black spruce regeneration were related to topographic site type, because of the relation of site type to RECEP (Table 12). The lowest levels of RECEP and regeneration were in crest and upper slope, the highest levels in lower slope and drainageways.

DISCUSSION

Changes in Vegetation and Seedbed Conditions

In the postcut-scarified strips there was initially a high amount of slash and of exposed subsurface horizons (Table 2). Vegetation was generally reduced by the disturbances (Table 1). However, dead feather moss was abundant owing to exposure and drying of living feather moss, and broad-leaf trees increased rapidly in the first year.

As time passed, vegetation quickly increased (Table 1; cf. Ellis and Mattice 1974). By the fifth year, considerable regrowth had occurred and much of the ground surface, probably more than 50%, was covered by vegetation. Broad-leaf tree species (7.8%), shrubs (20.5%), herbs (11.5%), and graminoids (11.4%) were the chief competition for the small, slow-growing black spruce seedlings.

Besides vegetation ingrowth and competition, other changes occurred to some of the receptive seedbeds that probably reduced their receptivity. One was the development of crusty surfaces on exposed F, H-Hi-Ah black humus, mineral soil, and sphagnum moss surfaces. This development appeared to be in microsites that initially were favorable to seedling development. The crusts gradually developed a grey or green cast, and the older ones sometimes produced the fruiting bodies of lichens (cf. *Cladonia* or *Cladina)* and tended to crack and form polygonal features upon drying. It appears that when seedbed has developed to this stage, it is no longer receptive to seedlings.

Since vegetation regrows so rapidly, and since seedbeds become less receptive with time, it is important to have black spruce seed on the seedbeds very early after the cut. The level of stocking should be enough to provide more than desirable levels, which are about 60% (cf. Robinson 1974). This is so that compensation can be made for mortality or stagnation of growth of a certain proportion of the seedlings as a result of competition. It is important to establish high enough levels of black spruce so

Table 12. Quantitative relations of some composite seedbed categories to four topographic site types before cutting, and after cutting and scarification on 1400 quadrats for 1974, 565 for 1976 (all strips combined).

Seedbed Category		Precut 1974				Postcut-scarified 1976			
		D[b]	L[b]	U[b]	C[b]	D	L	U	C
Receptive upland	C[a]	1.3	1.0	1.3	1.7	6.0	10.4	10.8	14.3
	F[a]	(23)	(28)	(28)	(30)	(48)	(80)	(75)	(78)
Dark peat, muck	C	1.4	0.5	0.1	0.0	9.8	2.6	0.7	0.0
	F	(27)	(6)	(1)	(1)	(58)	(19)	(5)	(0)
All sphagnum	C	13.4	5.4	0.5	0.7	5.7	2.0	0.4	.1
moss	F	(59)	(20)	(4)	(4)	(53)	(18)	(4)	(6)
RECEP	C	16.0	6.8	1.9	2.4	21.4	14.9	11.8	14.3
(All receptive)	F	(74)	(43)	(29)	(32)	(94)	(88)	(76)	(78)
Black spruce	No.[a]	1.9	2.3	2.0	3.2	4.6	3.5	1.9	3.0
10 cm tall	F	(42)	(40)	(37)	(43)	(63)	(39)	(39)	(38)

[a] C = mean percentage cover; F = percentage frequency; No. = mean number. All expressions based on 0.5-m x 2-m quadrats, except frequency and numbers of black spruce, based on 2-m x 2-m quadrats.

[b] D = drainageway; L = lower slope; U = upper slope; C = crest.

that eventually, perhaps in 10 or 15 years, the black spruce will begin to shade out the competing vegetation. Also, as the canopy begins to close, a carpet of feather moss and some sphagnum moss in lower places will develop. This layer of mosses and moss peat may provide a favorable substrate for black spruce root growth, in terms of temperature, moisture, and nutrient cycling and supply.[4] In addition the mosses, if moist enough, will favor layering when lower branches of black spruce seedlings and saplings touch the ground surface. It has also been suggested that a tighter spacing may make less probable the physical damage to stems and branches when there are heavy wet snowfalls.[5]

Stocking and Density

An important question about fine-tuning of strip cutting is: What levels of stocking and density are optimum for black spruce stand development? The first-cut, scarified strips achieved desirable levels of stocking (65%) and density per ha (10,250) by the fifth year of assessment. Jack pine was also present but less abundantly (19% stocking and 1500 per ha). These levels met the 'desirable' standards given by Robinson (1974), and were achieved with about 14% of receptive seedbed exposure. Even with these levels it was clear that there would be significant competition to the black spruce from the more rapidly growing trembling aspen and white birch. The regenerating strips had over 30% stocking to aspen, and over 50% to white birch. The problem of species composition shifts and competition for black spruce has been considered elsewhere (Jeglum 1982, 1983).

It is thought that the 65% stocking level obtained in this study area is not high enough to allow black spruce to dominate the site fully. It is suggested that levels should be 80% or higher. It is possible that the 65% level of stocking may increase if the lower branches of the black spruce touch the ground, layer, and fill in the gaps. Such layering has been observed in some older regenerating strips on a moist lower slope position at about 15 years (near Jean Lake). However, these strips were quite narrow and the initial stocking of the first-cut strips was much higher, probably close to 100%. As well, the site was a relatively moist lower slope. Whether layering will occur on drier site positions, or with all levels of competition and litter fall, or with lower levels of initial stocking, requires further study.

Seedling-Seedbed Relationships

In this study black spruce seedlings were recorded as coming in commonly on live feather moss. However, only one significant r value (feather moss cover with black spruce density) was obtained (Table 6). In the undisturbed, non-compacted, exposed condition feather moss is a very poor seedbed (e.g., Vincent 1966, Jeglum 1979). In the compacted state, where the F-horizon beneath the living moss is compressed, water retention is better and feather moss becomes a better seedbed. Vincent (1966) showed this for foot-trampled feather moss in the precut forest, but he obtained poor regeneration from seed for this treatment in the cutovers. In the study reported here the logging-scarification disturbance probably served to compact the feather moss and underlying F-horizon to a much greater degree than in Vincent's study.

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[4] Clemmer, E. 1977. On the processes regulating the growth of black spruce stands in northern Ontario. M.ScF. Thesis, Univ. New Brunswick.

[5] George Marek, Beardmore, Ontario, pers. comm.

In the present study, the skidder wheels and the flanged barrels scraped moss off the surface and compacted the underlying F-horizon. There was not much ripping and tearing to expose 'fluffy' F-horizon, which would not have been a good seedbed. For a more accurate index of receptive seedbed in future work, conditions of compacted and non-compacted feather moss and F-horizon could be distinguished and the compacted types added to RECEP.

Protection from drying by the adjacent leave strips probably served to maintain moisture in the compacted feather mosses and F-horizon so that they provided sufficient moisture long enough for seeds to germinate and seedlings to become established. Experiments with narrow strips in narrow strip cuts showed some regeneration establishment on relatively undisturbed feather moss (Losee 1966). In the present study, seedlings were common on feather moss in the precut forest.

The rating of a seedbed (Table 6) as nonreceptive or as having no consistent positive or negative relationship does not mean that seedlings never occur on that seedbed. Certainly seedlings can and do germinate on needle litter, logs, stumps, stems, wood, bark, moss on wood, or rotten wood (mainly dry). However, the probability of seedlings germinating on these types is low, as indicated by the negative values obtained for either r values or ratio analysis.

The 'rotten' wood category in this study included any wood pieces more than 1 cm in diameter that were even slightly soft and yielded to finger pressure. This was mainly a dry soft wood. The type of rotten wood that is very receptive is usually moist or wet, and usually well decomposed. This type should be distinguished in future assessments for total receptive seedbed.

Index for Receptive Seedbed

The best composite index for receptive seedbed of those that were tested was 'RECEP'--the arithmetic sum of the individual cover estimates for specific seedbed types that were shown to be positively correlated with seedlings. This index was best for fresh seedbeds, when estimates were obtained soon after scarification. With the passage of years, seedbed materials become less distinct, and also become covered with litter or vegetation.

In deriving the RECEP summation, addition of living feather moss usually reduced the magnitudes of the r values between RECEP and black spruce seedling numbers. Hence, feather moss was excluded from the RECEP index. When dark peat + muck was excluded from RECEP, the r values decreased in the 1976 comparison. When dark peat + muck was excluded in later years the r values changed very little. Because of this, dark peat + muck was retained in RECEP.

It has been observed that dark peat + muck is a poor seedbed for survival owing to graminoid competition, frost heaving, erosion, and flooding (cf. Jeglum et al. 1983) and it could be argued that it should be excluded from RECEP. However, the category 'dark peat + muck' includes much variation, and it probably should be subdivided in future assessments into at least two categories--the very wet, 'soupy' mucks, and the less decomposed, sometimes woody peats. The mucks probably have poorer seedling germination and survival than the peats, but this needs to be verified.

The results of this report suggest that it is best first to determine which seedbed materials (abiotic and biotic) are receptive with the particular harvesting-scarification technique employed. The materials receptive with one harvesting-scarification technique and on a particular site in a particular climatic-physiographic region, may not all be receptive under another set of conditions. For example, compacted feather moss may be receptive if the strips are narrow enough, the site conditions are predominantly moist, or the climate sufficiently humid. Hence, for accuracy the index of receptive seedbed for regeneration by seed should be tailored to the specific set of harvesting-scarification-site conditions being addressed. For the best percentage estimates, the assessment of seedbed should be done as soon after scarification as possible, before seedbeds have changed or become covered with litter and vegetation. It may, however, be necessary to wait for a year for the seedbed to settle, if considerable mixing has occurred.

Seedbed-Topography Relations

There was clearly a direct relationship between seedbed and topographic site type (Table 12). The highest level of receptive seedbed was in the drainageways because of the abundance there of dark peat + muck and sphagnum moss. In addition, the highest levels of black spruce regeneration, initially, were associated with the drainageways with their high levels of receptive lowland seedbed. However, even though regeneration was better in 1976 on drainageways, this relationship was reversed by 1980 (Jeglum 1982). The regeneration may have been reduced as a result of competition and smothering by grasses and sedges, which tend to develop profusely on the dark peat and sphagnum moss seedbeds. As well, seedlings on dark peat + muck are susceptible to mortality because of frost heaving and flooding, and because they may be overgrown by sphagnum moss.

Scarification

Scarification and the provision of receptive seedbed are among the most important elements of the silvicultural prescription. A study of spruce and fir reproduction in the 'mixedwood slope type' of northwestern Ontario (Hughes 1967) showed that scarified strip cuts had 10 times as many naturally seeded spruce and five times as many fir as nonscarified strips. The levels of stocking of spruce on nonscarified and scarified strips were 9% and 49%, and densities were 62 and 618 per ha, respectively. (These cutover strips included fresh and moist moisture regimes.)

There was concern at the time of scarification in this experiment that the techique was not producing enough seedbed exposure. However, fully satisfactory regeneration was obtained with 13.9% exposure of receptive seedbed, and 4 years of natural seeding.

It is suggested that scarification should be carried out as soon after cutting as possible. This differs from the opinion of Hughes (1967) that scarification should be done 2 or 3 years after cutting to allow for some slash deterioration. It is felt that this delay would allow the vegetation to become too well developed, and that competition control would be more difficult. Naturally, slash should be minimized to allow for more effective scarification. If the stand density is low so that little slash results, conventional cut and skid may be acceptable. This will keep a certain quantity of the nutrients on the site. However, if the stand is dense, then full-tree logging may be preferable to lessen the slash loading and maximize the effectiveness of scarification.

Riley (1980) conducted aerial seeding studies for jack pine on a well drained outwash till, with seeding rates of ca. 50,000 seeds/ha. He recommended a 20/20/40/20 distribution of percentages of quadrats to achieve the following levels of exposure of receptive seedbed--0 to 5%, 6 to 15%, 16 to 35%, and 36 to 100%, respectively. Riley felt this could be achieved operationally, and would result in an overall receptive seedbed level of approximately 25%.

The definition of receptive seedbed in Riley's study was not the same as in this study. For example, RECEP in this study included living sphagnum moss and F-horizon regardless of depth over mineral soil. In addition, natural black spruce regeneration in strip cuts on shallow soil does not employ the same silvicultural system as direct seeding jack pine on drier, deeper, sandy soils. Although the receptive seedbed types and microniches may be similar in both species, jack pine can utilize somewhat drier seedbeds because of its faster rate of germination and root establishment. In addition, the relative rates of natural seeding with strip cutting in black spruce are much higher than those of direct seeding with jack pine. Nonetheless it is interesting to compare the distribution of quadrats in this study with that in Riley's standards. These were 46, 20, 23, and 11%, respectively, for the ranges given above. Even though the scarification achieved in this study was relatively light in comparison with recommended standards for jack pine, desirable levels of regeneration were achieved. Undoubtedly the explanation is the much higher rate of natural seeding, and the protection afforded by leave strips, when strip cutting is used.

The probabilities of achieving desirable, marginally acceptable, or failure levels of regeneration with strip cutting in upland black spruce are not well established. A survey of regeneration in clearcuts and strip cuts in the Nipigon area (Fraser et al. 1976) found desirable and marginally acceptable levels in 14 and 63% of the strip cuts, and in 6 and 30% of the clearcuts surveyed. Failure levels were observed in 23 and 64% of the samples of strip cuts and clearcuts, respectively. This was with a sample of 80 plots. It is likely that the proportion of plots achieving desirable levels in strip cuts could have been even higher if scarification had been better, i.e., if more receptive seedbed had been exposed. Scarification in the strips was less intensive, and probably less seedbed was exposed than in the present study in which more emphasis was placed on achieving good scarification coverage.

Predictability of Regeneration

Seedfall is dependent on the cones in the adjacent forested strips. It is known that the cones of black spruce shed seed gradually over many years, and that some proportion of this seed is viable even in relatively old cones (LeBarron 1948; Haavisto 1975, 1982). Hence, even if there has not been a recent cone crop, the older cones will provide viable seed for regeneration. Of course, if there are few cones of any age on the trees, natural regeneration by strip cutting would be a poor bet.

Another difficulty with prediction of regeneration levels in strip cutting is the variability of the weather. One of the key factors in the success of regeneration by seed is the amount and distribution of rainfall (Arnott 1974). In a previous report dealing with this same study area (Jeglum 1982), rainfall distribution and the buildup index (part of the fire weather index) both indicated favorable moisture conditions during the third fall and spring after cutting. This seemed to be the main reason for the rise in regeneration between the two-year seeded and three-year seeded regeneration assessments.

With data from this study it would have been possible to predict, by using weighted average techniques, both density and stocking of black spruce after 1, 2, 3 or 4 years of natural seeding in other strip cuts with similar seed supply, widths, physiographic and soil features, and weather patterns. However, it is risky to assume that the same or even very similar sets of conditions can in fact be achieved. To a large degree it is the weather factor that cannot be predicted. Just what constitutes a good weather year for natural seeding has not been well defined in terms of recorded influx of natural regeneration (e.g, Jeglum 1982). Hence, it was decided not to develop such predictions until the results of other experiments are available, along with weather correlations, to provide a stronger basis for them.

RECOMMENDATIONS

1. Scarification should be carried out as soon as possible after harvest to give natural regeneration an advantage over competing vegetation.

2. Assessment of seedbed should be carried out within one year of scarification, to obtain accurate cover estimates of seedbed types.

3. To obtain a good index of seedbed receptivity, it is recommended that the individual cover estimates be added together for all receptive seedbed types, both living and non-living.

4. Receptivity of various seedbeds will vary depending on the harvesting-scarification treatment, site conditions, degree of exposure, species being regenerated by seed, and climatic region in which the cutting occurs. It is recommended that preliminary studies of seedling-seedbed relationships, or verification of receptive seedbeds reported here, be done for different climatic regions, harvesting-scarification techniques, site conditions, and species being regenerated, to fine-tune the definition of receptive seedbed.

5. Definition of seedbed categories should be based on material types, subdivided as judged necessary to reflect potentially different conditions of moisture-retaining ability.

6. Seedlings are often associated with special microsites or conditions that provide shelter and preserve substrate moisture. Scarification procedures that provide numerous microniches with small depressions, microhummocks and hollows, and other shelterings, are preferable to those that create large expanses of smooth open surfaces.

7. Scarification of drainageways and lowlands with organic soils should be avoided wherever possible to reduce the exposure of wet, dark peat and muck. Exposure of these surfaces is probably acceptable in lower slope (shallow peat) positions.

8. Scarification should provide an exposure of at least 14% mean cover of receptive seedbed, with a good distribution of scarification to reduce the proportion of plots with no receptive seedbed or only small amounts.

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