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POST-CUT BURNING AND BLACK SPRUCE REGENERATION

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ABSTRACT

Experimental post-cut burning for black spruce (*Picea mariana* (Mill.) B.S.P.) regeneration was tried in conjunction with natural seeding, artificial seeding, and direct planting. So far, the best results approaching a full spruce stocking were produced by post-cut burning in aid of natural seeding on moist to wet lowland peat sites. Due to reasonable operational costs, ecological compatibility, and consistently acceptable regeneration involved, this particular method is now being extensively used on some areas in the post-cut management of lowland spruce. None of the methods tested on fresh to somewhat moist upland sites produced similarly acceptable regeneration, mainly because both burning and consequent seedbed improvements were inadequate on such sites. This paper provides a brief overview of the current uses of post-cut burning, and then deals specifically with successful black spruce regeneration following lowland burns of two different prescriptions.

INTRODUCTION

Black spruce (*Picea mariana* (Mill.) B.S.P.) usually fails to regenerate in adequate numbers after cutting, mainly because most of the loose, surface forest-floor materials remain undisturbed. The surface materials, consisting often of feather moss (*Pleurozium schreberi* (Brid.) Mitt., occasionally with some *Hylocomium splendens* (Hedw.) B.S.G. and *Ptilium crista-castrensis* (Hedw.) De Not.) and/or various plant litter, are subject to rapid losses of moisture when exposed to increased solar radiation and ventilation (Chrosciewicz 1978, 1980). This alone makes them extremely poor media for seed germination and seedling survival, and the situation is further aggravated by substantial post-cut

additions of fresh litter and of logging slash (Heinselman 1957, 1959; Jarvis and Cayford 1961, 1967; Chrosciewicz 1976, 1978, 1980). On such seedbeds, not many of the black spruce seeds that are normally shed by cones in slash on the ground, or are dispersed from cones on residual trees nearby, would have a chance to start a new stand unless mechanical scarification, or controlled burning of the right prescriptions, are carried out to rectify the situation.

These unfavorable post-cut conditions occur both on uplands with mineral soil substrata and on lowlands with organic, or peat, soil substrata. Only where the forest floor on some lowlands predominantly consists of the seemingly always moist *Sphagnum*, the seedbeds may be sufficiently receptive to black spruce regeneration without corrective treatments (Jarvis and Cayford 1961, 1967; Mueller-Dombois 1964; Johnson 1971, 1977; Chrosciewicz 1976; Haavisto 1979; Aksamit and Irving 1983), providing that some of the faster-growing varieties of that moss do not smother the freshly germinated seedlings (LeBarron 1948; Roe 1949; Heinselman 1957, 1959; Losee 1961). In any case, both the living *Sphagnum* and the peat materials derived from *Sphagnum* are nutritionally deficient, and because of this their value as seedbeds may be much less than normally expected (Wilde 1958; Jeglum 1981; Munson and Timmer 1989). Indications are, however, that even this condition, as well as the overall productivity of lowland sites, can be substantially improved by post-cut burning (Mueller-Dombois 1964; Chrosciewicz 1976; Armson 1977), preferably in aid of natural regeneration.

Black spruce is known to regenerate very well on suitable fire-produced seedbeds, particularly where natural seed source is available either in the form of seed trees or as uncut portions of the stand next to the burn (Heinselman 1957, 1959; Dickson and Nickerson 1958; Horton and Lees 1961; Johnson 1971; Chrosciewicz 1976). Controlled fires for silvicultural purposes usually burn the slash, aerial parts of vegetation, surface moss and litter, and depending on site and weather, varying quantities of the underlying

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mor or peat. The organic materials remaining after such fires normally include charred stumps and other large pieces of wood, partially burned mor or peat, and unburned plant roots in the residual mor or peat. These conditions are usually adequate for planting the spruce, and if the fires burn deep enough into the mor or peat, they can be favorable also for the reproduction of spruce by either direct or natural seedling. In the latter case, the heat of fires usually helps in seed dissemination by partially opening the otherwise semi-serotinous cones on standing parent trees (Chrosiewicz 1976, 1978, 1980).

As an alternative to mechanical scarification, post-cut burning of clear-cut strips and patches of various sizes was tested on both uplands and lowlands in anticipation of natural seeding from adjoining black spruce stands (Heinselman 1959; Johnson 1971; Haavisto 1979; Aksamit and Irving 1984; Jeglum 1987), and followed either by artificial broadcast and spot seeding (Richardson 1969, 1972; Johnson 1971; Aksamit and Irving 1984) or by direct planting just on uplands (Zasada *et al.* 1987; Arnup 1989). Post-cut burning under black spruce seed trees was also tested on both uplands (Robinson 1970) and lowlands (Chrosiewicz 1976).

The outcome of these tests were highly variable and often inconclusive in terms of black spruce regeneration, particularly on upland sites with respect to natural and artificial seeding. The burning prescriptions for the uplands were simply ineffective in the improvement of seedbeds as the relatively high moisture contents of the forest-floor materials at the time prevented the fires from penetrating sufficiently deep into the mor humus. The black spruce stocking by 4 m² quadrats that resulted from these upland burning and seeding tests was totally inadequate at 11-39% (Richardson 1969, 1972; Robinson 1970; Jeglum 1987). The development and growth of planted black spruce on some other burned uplands, however, were quite satisfactory (Zasada *et al.* 1987; Arnup 1989), with the young tree survival being about 68-92% (Zasada *et al.* 1987). Further research is needed to develop suitable burning prescriptions specifically for seedbed improvements on the upland black spruce sites.

The results pertaining to post-burn natural and artificial seeding on lowland sites were considerably better than those on uplands. Summer burning on clear-cut 70-101 m wide strips in anticipation of natural seeding from uncut strips, as well as that on 13-26 ha clear-cut patches followed by broadcast seeding of black spruce with about 247 000 seeds/ha, produced 91% and 80%

black spruce stocking 2-6 years later (Johnson 1971). Burning on 40 m wide clear-cut strips in aid of natural seeding also from adjoining uncut strips produced 68% black spruce stocking 4 years later in one area, and 86% black spruce stocking 14 years later in another area (Haavisto 1979). This successful spruce regeneration on lowland sites was attributed to the fact that the burns exposed moist *Sphagnum* from under the slash in some places and at the same time produced other favorable seedbeds by consuming dry feather moss in other places. Burning piled slash in winter was found less practical and more costly than burning scattered slash in summer (Johnson 1971).

In 1967, two burning operations were carried out on one of the lowland cutover sites at latitude 49°34'N and longitude 95°56'W, some 97 km east-southeast of Winnipeg, Manitoba. The objective was to determine whether the predominantly poor feather moss, litter, and slash seedbeds could be sufficiently improved to induce prompt and adequate black spruce regeneration from residual seed sources on the site. The initial results have been published elsewhere (Chrosiewicz 1976), and this report describes the overall outcome of the treatments after 22 growing seasons.

THE SITE

Generally, the site matched Mueller-Dombois' (1964) habitat description as an "oligotrophic (nutritionally poor), very moist, feather moss-*Sphagnum* type on peaty gleysol". It was situated on a gentle transition gradient between a well drained upland and a poorly drained muskeg. The ground was characterized by 25-46 cm high peaty hummocks and intermittent depressions. The upper peat, extending to a depth of about 25 cm below depressions, was mostly a fibrous moss debris that had changed little since accumulation. Immediately below this material was about 41 cm of well decomposed mucky peat, which in turn overlaid a fine-textured mineral gleysol. The average depth to water table between hummocks was about 30 cm, and the soil moisture regime according to Hills' (1955) classification was 6 (Chrosiewicz 1976), or somewhat wet.

Before cutting, the site supported a 100-year-old black spruce forest, averaging 5387 trees/ha. More than a third of the trees were merchantable, with pulpwood yields of nearly 233 m³/ha. A very few, widely scattered tamarack (*Larix laricina* (Du Roi) K. Koch) grew along with the spruce. The peaty hummocks and depressions were covered by a continuous carpet of moss. About 88% of this carpet was formed by feather moss and the remaining 12% was *Sphagnum*. The

Sphagnum moss occurred in variable-sized colonies that were randomly interspersed throughout the feather moss cover. The overall ground cover by other plants consisted of 10% for various low creeping shrubs and some herbs, 10% for grasses and sedges, and 20% for medium shrubs. Layering was uncommon on this site, and black spruce regeneration originally consisted of 84 seedlings/ha, growing mostly on *Sphagnum* (Chrosiewicz 1976).

A portion of the forest was harvested in the winter of 1964-1965, and the resulting cutover became treatment sections A and B, 2.4 ha and 3.6 ha in area, respectively. The cutting operations removed merchantable timber, and all that remained on these two sections by the time of burning in the spring of 1967 were bare (without needles) logging slash and some 1977 trees/ha that were still standing. These trees were either under-sized or defective ones that loggers could not use. The slash was 25-64 cm deep and provided an intermittent ground cover totalling 52%. Underneath the slash, fallen needles formed a litter mat up to 8 cm thick. Another 2.0 ha portion of the forest was harvested in the winter of 1967-1968, and this cutover, called section C, was kept intact as a control for sections A and B. The conditions resulting from the cutting operations were nearly identical on all three sections (Chrosiewicz 1976).

METHODS

Burning

The individual treatment sections were enclosed by a plowed fire guard 61 cm wide. Section A was burned between 11:20 and 16:40 CST (Central Standard Time) on May 17, 1967, and section B was burned between 10:00 and 15:00 CST on May 29, 1967. Each burn began as a U-shaped backfire and was completed by a series of successive strip head fires. The average flame height for both burns was about 1 m, with occasional trees candling up to 12 m. After normal mop-up operations, the burned sections were patrolled for several days (Chrosiewicz 1976).

Daily weather data for 12:00 CST were obtained from the nearest provincial stations at Hadashville (rainfall) and East Braintree (cloud cover, air temperature, relative humidity, wind speed at 10 m height, and wind direction), 11 and 24 km away from the burning site, respectively. By using these data, various moisture codes (FFMC, fine fuel moisture code; DMC, duff moisture code; DC, drought code) and fire behavior indices (BUI, buildup index; ISI, initial spread index; FWI, fire weather index) for each of the two burns were determined (Chrosiewicz 1976) by standard

methods (Canadian Forestry Service 1984). The noon weather, moisture codes, and fire indices on days of burning are shown in Table 1.

The burns were conducted under different degrees of desiccation in the upper peat materials so that, in terms of peat consumption, "light" and "moderate" degrees of burn were obtained. Winds at noon on both days were identical in speed, but May 29 was somewhat warmer and slightly drier than May 17. On both days, fine components of slash, surface litter, feather moss, winter-cured grass, sedge, and herbs were sufficiently dry (FFMC 91) to sustain comparable rates of fire spread (ISI 10). Based on 20 random measurements preceding each burn, the peat under feather moss in more exposed situations was dry to a depth of about 3 cm on May 17 (DMC 22, DC 55) and to a depth of about 8 cm on May 29 (DMC 46, DC 104). This meant that considerably more dry fuel was available to the spreading fire on May 29 (BUI 45) than on May 17 (BUI 21). The total production of thermal energy per unit length of fire front was, therefore, correspondingly greater on May 29 (FWI 21) than on May 17 (FWI 15). Further down the peat profile, the moisture content markedly increased until the materials became completely saturated near the water table. The latter condition provided an effective barrier to excessively deep burning (Chrosiewicz 1976).

The depths of each burn were measured at 40 observation points: 20 on feather moss hummocks and 20 in feather moss depressions. Special steel pins were used to mark the surface of moss or litter at the different points before burning. The pins were placed at random along centre lines traversing each burn. Materials with *Sphagnum* cover were excluded from these measurements because, with their usually high moisture content, they were extremely poor indicators of the overall burning conditions (Chrosiewicz 1976).

Seedbed and Regeneration Surveys

The conditions after burning on sections A and B, and after cutting on section C, were surveyed by means of parallel transects, 20 m apart. The individual transects consisted of single rows of 4 m² quadrats, and there were four such transects traversing the middle portion of each section. This resulted in a sampling intensity which for the total section areas ranged between 2.2% and 3.4%. The transects were extended into the residual black spruce forest to provide means for assessing the conditions before cutting (Chrosiewicz 1976).

The individual quadrats within the transects were used, when applicable, for mapping to scale various

categories of seedbeds, for making total counts of trees by species and classes of seedbeds, for measuring diameters and/or heights of dominant trees by species on each stocked quadrat, for measuring height growth of dominant black spruce, and for estimating total plant cover by species and groups of species. Seedbeds were surveyed shortly after the treatments, and Table 2 shows their distribution. Otherwise, there were two major surveys along the same transects: the first one was carried out to assess black spruce regeneration after 5 growing seasons, and the second one was carried out to assess the regeneration of all tree species present after 22 growing seasons. The tree species in the second survey included black spruce, white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.), tamarack, white cedar (*Thuja occidentalis* L.), jack pine (*Pinus banksiana* Lamb.), trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), and paper birch (*Betula papyrifera* Marsh.). The results of the first regeneration survey have already been published (Chrosiewicz 1976), and the results of the second survey are presented in this report: regeneration stocking in Table 3, regeneration density in Table 4, regeneration height in Table 5, and black spruce height growth in Table 6. One-way analyses of variance and t-tests were used in making comparisons of mean height growth rates between the treatment sections A, B, and C by tree diameter classes.

RESULTS AND DISCUSSION

Fuel Consumption and Seedbeds

The fires destroyed slash, surface litter, and aerial parts of vegetation, including feather moss and some *Sphagnum*. Varying quantities of peat underneath the feather moss and litter were also destroyed, but stumps and discarded logs remained in their partially burned state. The fires killed residual trees by completely burning the smaller ones and by scorching all others. However, clusters of cones in the upper portions of the scorched crowns were untouched by the flames, resulting in good dispersal of seeds after burning (Chrosiewicz 1976).

The depths of burn into the peat varied from superficial in some of the moister situations to greater than average next to some of the drier stumps and logs. As a result of different degrees of desiccation in the upper peat materials, the depths of burn averaged 8 cm for hummocks and 5 cm for depressions on section A, and 18 cm for hummocks and 10 cm for depressions on section B (Table 2). Burning exposed about 95% of the

peat on both sections; the remaining 5% consisted of unburned materials such as 1% *Sphagnum* moss, 3% feather moss, and 1% slash-plus-litter on section A and 3% *Sphagnum* moss, 1% feather moss, and 1% slash-plus-litter on section B. Although the seedbed conditions were improved on both sections, the degree of improvement was directly related to the depth of burn into the peat, greater on section B and lesser on section A. Section B had also, by chance, somewhat greater residual *Sphagnum* cover (Chrosiewicz 1976). In contrast, inferior post-cut seedbeds were much in evidence on section C. About 93% of the section area was characterized by unfavorable conditions, 52% as a result of slash-plus-litter cover, and 41% as a result of feather moss cover. Favorable seedbeds were scarce on this section since only 6% of the area was covered by *Sphagnum* and another 1% had its peat exposed by logging (Table 2) (Chrosiewicz 1976).

Black Spruce Regeneration

Toward the end of the fifth growing season, black spruce stocking by 4 m² quadrats was 94% on the moderately burned section B, 70% on the lightly burned section A, and 35% on the unburned control C. The numbers of trees associated with this stocking were 39 856, 7598, and 4690/ha, respectively (Chrosiewicz 1976). Later on, the black spruce stocking increased and its density decreased, until after 22 growing seasons, they were 98% with 31 536 trees/ha on section B, 80% with 6203 trees/ha on section A, and 52% with 4162 trees/ha on control C (Tables 3 and 4). With mean heights of 3.49 m on section B, 3.10 m on section A, and 2.23 m on control C (Table 5), the dominant black spruce trees indicated the same preferential differentiation between the three sections as did both the black spruce stocking (Table 3) and the black spruce density (Table 4). This, however, could not be verified in terms of mean height growth of dominant black spruce trees. When grouped into strict diameter classes, the within-group differences in height growth between the treatment sections A, B, and C, were all consistently not significant (NS) at $p < 0.05$ in each of the last three growing seasons, the 20th, the 21st, and the 22nd. Otherwise, the annual rates of mean height growth were quite impressive, particularly for the black spruce trees with large mean diameters (Table 6). Regardless of the rather high stocking and density values, there were numerous black spruce trees that had their tops above all competing vegetation and, therefore, freely growing in full sunlight at excellent annual rates. In fact, height growth rates above 0.5 m per year were quite common, with 0.65 m as the maximum recorded.

Table 1. Weather, moisture codes, and fire indices on days of burning.

Items	Treatment sections	
	Lightly burned A	Moderately burned B
Date of burn	May 17, 1967	May 29, 1967
Noon weather		
Cloud cover (%)	90	70
Air temperature (°C)	22	24
Relative humidity (%)	32	31
Wind speed (km/h)	14	14
Wind direction	W	SE
Codes and indices ^a		
FFMC (fine fuel moisture code)	91	91
DMC (duff moisture code)	22	46
DC (drought code)	55	104
BUI (buildup index) ^b	21	45
ISI (initial spread index)	10	10
FWI (fire weather index)	15	21

^a For definitions of the terms used see Canadian Forestry Service (1984) and Van Wagner (1987).

^b Formerly known as ADCMC (adjusted duff moisture code).

Table 2. Post-treatment inventory of seedbeds.

Items	Treatment sections		
	Lightly burned A	Moderately burned B	Unburned control C
Depths of burn measured (n)	40	40	-
Mean depths of burn			
Hummocks (cm)	8	18	-
Depressions (cm)	5	10	-
4 m ² quadrats sampled ^a (n)	133	293	167
Area burned (%)	95	95	-
Area by seedbeds			
Exposed peat ^b (%)	95	95	1
Sphagnum moss (%)	1	3	6
Feather moss (%)	3	1	41
Slash-plus-litter (%)	1	1	52

^a Used for mapping to scale various classes of seedbeds.

^b Includes fractions of decayed wood.

Table 3. Regeneration stocking after 22 growing seasons.

Tree species	4 m ² quadrats stocked (%) ^a		
	Lightly burned A	Moderately burned B	Unburned control C
Black spruce	80	98	52
White spruce	1	28	5
Balsam fir	13	49	25
Tamarack	10	5	7
White cedar	1	2	0
Jack pine	2	0	0
Trembling aspen	27	66	17
Balsam poplar	2	34	1
Paper birch	1	4	4
Any tree species	87	99	68

^a 4 m² quadrats sampled: 133 in A, 293 in B, and 167 in C. Presence of trees was noted by species on all quadrats.

Table 4. Regeneration density after 22 growing seasons.

Tree species	Living trees (stems/ha) ^a		
	Lightly burned A	Moderately burned B	Unburned control C
Black spruce	6 203	31 536	4 162
White spruce	19	1 015	120
Balsam fir	357	2 312	838
Tamarack	320	154	195
White cedar	19	43	0
Jack pine	38	0	0
Trembling aspen	1 278	4 352	898
Balsam poplar	38	1 502	15
Paper birch	19	128	150
Any tree species	8 291	41 042	6 378

^a 4 m² quadrats sampled: 133 in A, 293 in B, and 167 in C. Trees were counted by species on all quadrats.

Table 5. Regeneration height after 22 growing seasons.

Tree species	Mean heights of dominant trees (m) ^a		
	Lightly burned A	Moderately burned B	Unburned control C
Black spruce	3.10 (107)	3.49 (287)	2.23 (87)
White spruce	3.91 (1)	2.26 (81)	2.10 (8)
Balsam fir	0.81 (17)	0.44 (145)	1.29 (41)
Tamarack	6.10 (13)	7.72 (16)	1.28 (12)
White cedar	0.07 (1)	0.14 (5)	-
Jack pine	3.80 (2)	-	-
Trembling aspen	6.64 (36)	4.99 (193)	5.15 (29)
Balsam poplar	7.10 (2)	4.62 (100)	1.50 (1)
Paper birch	5.70 (1)	4.82 (11)	5.69 (7)

^a Heights of tallest trees were measured, one per species per stocked 4 m² quadrat. Values in parentheses show the actual numbers of trees so measured.

Regeneration of Companion Tree Species

The rather tall jack pine and the tiny white cedar occurred sporadically after burning on sections A and B. Tamarack trees, with their large sizes being particularly impressive following the burns, were widely scattered throughout the new stands on sections A and B, and on the control C. Balsam fir, which was somewhat shorter on the burned sections A and B than on the control C, occurred as a partial understory on all three sections. The presence of white spruce was numerically much greater on section B than on the other two sections, but the species heights were comparable on the B and C sections (Tables 3-5).

Among the hardwoods, trembling aspen was the numerous companion of black spruce, and was more so than balsam poplar and white birch put together (Tables 3 and 4). All three species were, on the average, much taller than the spruce (Table 5), but this did not appear to have any adverse effect on the growth of spruce (Table 6). In fact, the three hardwood species were numerically much more prominent on section B than elsewhere in the project (Tables 3 and 4), but no significant differences were detected in the growth of black spruce between sections A, B, and C (Table 6).

A similar conclusion can be reached when considering the competition from shrubs. Clumps of willow (mostly *Salix bebbiana* Sarg.), about 4 m tall, were nearly always constant companions of the regenerating black spruce, much more so on section B than on section A, and relatively little on control C. Moreover green alder (*Alnus crispa* (Ait.) Pursh), 4 m tall, and sometimes

even speckled alder (*Alnus rugosa* (Du Roi) Spreng. var. *americana* (Regel) Fern.), 5 m tall, occurred sporadically and so they both somewhat increased the already existing competition. Here again, no significant differences could be detected in the growth of black spruce between the sections A, B, and C (Table 6).

In terms of the combined regeneration of all tree species present after 22 growing seasons, the overall stocking and corresponding stand densities were as follows: 99% with 41 042 trees/ha on section B, 87% with 8291 trees/ha on section A, and 68% with 6378 trees/ha on control C. It is premature as yet to speculate which of the treatment sections, A or B, would eventually yield a greater return in usable pulpwood weight, or volume, and by how much in this respect would the control C then lag behind each of the two other sections. Considerably more time will be required before sufficient evidence presents itself to provide concrete answers to these important questions.

THE STATUS OF POST-CUT BURNING

Although the post-cut use of burning for silvicultural purposes is increasing in Canada, much of this is done prior to planting and relatively little prior to direct seeding which, in fact, shows a decline (Kuhnke 1989). There are no reliable statistical data that would, at present, indicate how much of this burning activity is taking place specifically prior to planting or direct seeding of black spruce. Similarly, there are absolutely no data on how much of the post-cut burning is done across Canada in aid of natural black spruce regeneration; the general impression is that, in this respect, much less is done in Canada than in

Table 6. Black spruce height growth by treatment sections and tree diameter classes.

Treatment sections	DBH classes (cm)	Trees measured ^a (n)	Mean DBH ^b (cm)	Mean heights ^b (m)	Mean height growth (m) ^b		
					20th growing season	21st growing season	22nd growing season
A	≤1.0	8	0.6 ± 0.3 NS	1.58 ± 0.23 NS	0.09 ± 0.04 NS	0.14 ± 0.12 NS	0.15 ± 0.13 NS
B	≤1.0	8	0.7 ± 0.2 NS	1.70 ± 0.22 NS	0.11 ± 0.04 NS	0.10 ± 0.04 NS	0.13 ± 0.06 NS
C	≤1.0	5	0.7 ± 0.3	1.63 ± 0.25	0.13 ± 0.06	0.15 ± 0.10	0.16 ± 0.08
A	1.1-3.0	20	2.1 ± 0.5 NS	2.77 ± 0.57 NS	0.20 ± 0.10 NS	0.18 ± 0.11 NS	0.21 ± 0.11 NS
B	1.1-3.0	118	2.2 ± 0.6 NS	2.98 ± 0.60 NS	0.18 ± 0.08 NS	0.19 ± 0.09 NS	0.22 ± 0.09 NS
C	1.1-3.0	9	2.1 ± 0.6	2.62 ± 0.44	0.19 ± 0.07	0.20 ± 0.10	0.23 ± 0.13
A	3.1-5.0	21	4.1 ± 0.5 *	4.29 ± 0.52 NS	0.30 ± 0.10 NS	0.32 ± 0.15 NS	0.30 ± 0.14 NS
B	3.1-5.0	100	3.8 ± 0.6 NS	4.17 ± 0.55 NS	0.27 ± 0.08 NS	0.31 ± 0.08 NS	0.34 ± 0.08 NS
C	3.1-5.0	12	3.7 ± 0.8	4.01 ± 0.71	0.29 ± 0.09	0.31 ± 0.11	0.32 ± 0.11
A	5.1-7.0	14	5.8 ± 0.5 NS	5.30 ± 0.67 NS	0.37 ± 0.10 NS	0.36 ± 0.12 NS	0.43 ± 0.07 NS
B	5.1-7.0	16	5.5 ± 0.4 NS	5.45 ± 0.58 NS	0.37 ± 0.09 NS	0.38 ± 0.10 NS	0.38 ± 0.13 NS
C	5.1-7.0	10	5.8 ± 0.5	5.39 ± 0.42	0.34 ± 0.11	0.42 ± 0.08	0.38 ± 0.10

^a Included are dominant, undamaged trees with measurable diameters at 1.30 m (breast height).

^b Differences between means (with ± standard deviations) are either significant (*) or not significant (NS) at $p < 0.05$.

northern Minnesota, for example (Aksamit and Irving 1984). Poor results, high operational costs, and other compelling reasons (Jeglum 1987) may be responsible for this lack of interest in strip burning on black spruce uplands. There is no doubt, however, that this situation can be in time rectified by the development and use of more suitable burning prescriptions than those tried so far on the uplands. It was said not too long ago that "black spruce peatland management (particularly the regeneration aspect of it) is in many respects still in the Dark Ages" (Virgo 1975). This report shows that by now much more is known about the problem and how to solve it. The post-cut burning methods that are designed specifically for the lowlands in aid of natural black spruce regeneration are dependable, ecologically compatible, and cost-effective when compared with other methods serving the same purpose.

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REFERENCES

- Aksamit, S.E., and Irving, F.D. 1984. Prescribed burning for lowland black spruce regeneration in northern Minnesota. *Can. J. For. Res.* 14:107-113.
- Armson, K.A. 1977. *Forest soils*. University of Toronto Press, Toronto, Ontario.
- Arnup, R. 1989. Growth response in black spruce - mechanical site preparation versus prescribed burning. *Ont. Min. Nat. Resour.*, Toronto, Ontario. On Line 5(1):6-7.
- Canadian Forestry Service. 1984. *Tables for the Canadian Forest Fire Weather Index System*. Environ. Can., Hull, Quebec. For. Tech. Rep. 25 (4th ed.).
- Chrosiewicz, Z. 1976. Burning for black spruce regeneration on a lowland cutover site in southeastern Manitoba. *Can. J. For. Res.* 6:179-186.
- Chrosiewicz, Z. 1978. Silvicultural uses of fire in mid-western Canada. *In*: D.E. Dubé (compiler). *Fire ecology in resource management. Workshop proceedings*. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-210. pp. 37-46.
- Chrosiewicz, Z. 1980. Some practical methods of securing adequate postcut forest reproduction in Canada. *In*: M. Murray and R.M. Van Weldhuisen (editors). *Forest regeneration at high latitudes. The proceedings of an international workshop*. U.S. Dep. Agric., For. Serv., Pac. Northwest For. Range Exp. Stn., Portland, Oregon. Gen. Tech. Rep. PNW-107. pp. 49-52.
- Dickson, W.A., and Nickerson, D.E. 1958. Factors affecting natural regeneration on cutover and burned-over lands, Newfoundland. *Can. Dep. North. Aff. Natl. Resour., For. Branch, For. Res. Div., Ottawa, Ontario*. S. & M. 58-3.
- Haavisto, V.F. 1979. Some considerations for regenerating black spruce on peatlands in the Northern Clay Forest Section, Ontario. *Can. Dep. Environ., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario*. Rep. 0-X-295.
- Heinselman, M.L. 1957. Living *Sphagnum* found most favorable seedbed for swamp black spruce in Minnesota study. *U.S. Dep. Agric., For. Serv., Lake States For. Exp. Stn., St. Paul, Minnesota*. Tech. Note 504.
- Heinselman, M.L. 1959. Natural regeneration of swamp black spruce in Minnesota under various cutting systems. *U.S. Dep. Agric., For. Serv., Washington, D.C. Prod. Res. Rep.* 32.
- Hills, G.A. 1955. Field methods for investigating site. *Ont. Dep. Lands For., Res. Div., Maple, Ontario*. Site Res. Man. 4.
- Horton, K.W., and Lees, J.C. 1961. Black spruce in the foothills of Alberta. *Can. Dep. For., For. Res. Branch, Ottawa, Ontario*. Tech. Note 110.
- Jarvis, J.M., and Cayford, J.H. 1961. Regeneration following various methods of cutting in black spruce stands in Manitoba. *For. Chron.* 37:339-349.
- Jarvis, J.M., and Cayford, J.H. 1967. Effects of partial cutting, clear-cutting and seedbed treatment on growth and regeneration in black spruce stands in Manitoba. *Pulp Pap. Mag. Can.* 68:WR 362-367.

- Jeglum, J.K. 1981. Black spruce seedling growth and nutrition on *Sphagnum* and feather moss peats from a northern Ontario peatland. Can. Dep. Environ., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. Rep. 0-X-326.
- Jeglum, J.K. 1987. Alternate strip clearcutting in upland black spruce. II. Factors affecting regeneration in first-cut strips. For. Chron. 63:439-445.
- Johnson, W.F. 1971. Broadcast burning slash favors black spruce reproduction on organic soil in Minnesota. For. Chron. 47:33-35.
- Johnson, W.F. 1977. Manager's handbook for black spruce in the north central States. U.S. Dep. Agric., For. Serv., North Central For. Exp. Stn., St. Paul, Minnesota. Gen. Tech. Rep. NC-34.
- Kuhnke, D.H. 1989. Silviculture statistics for Canada: an 11-year summary. For. Can., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-301.
- LeBarron, R.K. 1948. Silvicultural management of black spruce in Minnesota. U.S. Dep. Agric., Washington, D.C. Cir. 791.
- Losee, S.T.B. 1961. Results of group cutting for black spruce regeneration at the Abitibi Woodlands Laboratory. Can. Pulp Pap. Assoc., Montreal, Quebec. Woodl. Sect. Index 2086 (F-2).
- Mueller-Dombois, D. 1964. The forest habitat types of southeastern Manitoba and their application to forest management. Can. J. Bot. 42:1417-1444.
- Munson, A.D., and Timmer, V.R. 1989. Site-specific growth and nutrition of planted *Picea mariana* in the Ontario Clay Belt. I. Early performance. Can. J. For. Res. 19:162-170.
- Richardson, J. 1969. Seedspotting three spruce species on prescribed burns. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab., St. John's, Newfoundland. Inf. Rep. N-X-37.
- Richardson, J. 1972. Direct seeding on a prescribed burn in western Newfoundland. Can. Dep. Environ., Can. For. Serv., Nfld. For. Res. Cent., St. John's, Newfoundland. Inf. Rep. N-X-82.
- Robinson, A.J. 1970. Logging by the seed tree system and prescribed burning to encourage black spruce regeneration. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab., St. John's, Newfoundland. Inf. Rep. N-X-42.
- Roe, E.I. 1949. *Sphagnum* moss retards black spruce regeneration. U.S. Dep. Agric., For. Serv., Lake States For. Exp. Stn., St. Paul, Minnesota. Tech. Note 321.
- Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Gov. Can., Can. For. Serv., Ottawa, Ontario. For. Tech. Rep. 35.
- Virgo, K. 1975. Practical aspects of regeneration on Ontario's Clay Belt peatlands. In: Black Spruce Symposium. Can. Dep. Environ., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. Symp. Proc. 0-P-4, pp. 265-276.
- Wilde, S.A. 1958. Forest soils - their properties and relation to silviculture. Ronald Press Co., New York.
- Zasada, J.C., Norum, R.A., Teutsh, C.E., and Densmore, R. 1987. Survival and growth of planted black spruce, alder, aspen and willow after fire on black spruce/feather moss sites in interior Alaska. For. Chron. 63:84-88.