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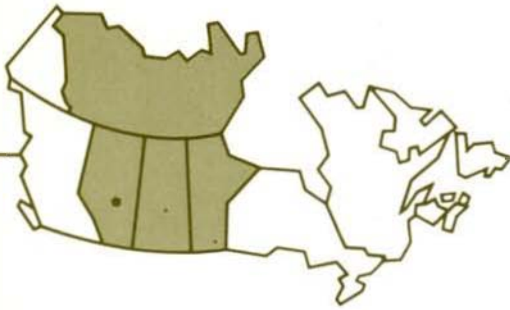
Forest regeneration on burned, planted, and seeded clear-cuts in central Saskatchewan

Z. Chrosciewicz



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Cover photo: Jack pine 14 years after postburn planting of conventional 2+2 nursery stock; approximate spacing 1.8 × 1.8 m.

FOREST REGENERATION ON BURNED, PLANTED, AND SEEDED CLEAR-CUTS IN CENTRAL SASKATCHEWAN

Z. Chrosciewicz

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ABSTRACT

Fall and spring planting and seeding of jack pine (*Pinus banksiana* Lamb.) and fall seeding of white spruce (*Picea glauca* (Moench) Voss) were operationally tested on four burned, clear-cut areas in central Saskatchewan. Hand planting of conventional 2 + 2 nursery stock at 1.8-m spacing and uniform broadcast seeding of 0.56 kg of seeds (viability 65%) per hectare were the standard postburn treatments. After eight growing seasons, jack pine stocking by 4-m^2 quadrats averaged 47% (range 24–70%) on planted area sections, 24% (range 22–27%) on seeded area sections, and 12% (range 6–18%) on controls, all differing from each other significantly at $P < 0.05$. The differences in mean pine stocking between the fall and the spring applications of both planting and seeding were not significant ($P > 0.05$). A fall seeding of white spruce along with jack pine was the least successful treatment as it produced stocking of 12% for pine and nearly 0% for spruce. Combining with natural forest regeneration, the treatments resulted in the formation of mixed forest stands in which aspen (*Populus tremuloides* Michx.), jack pine, and black spruce (*Picea mariana* (Mill.) B.S.P.) predominated.

RESUME

Quatre parterres de coupe incendiés du centre de la Saskatchewan ont été plantés et ensemencés en pins gris (*Pinus banksiana* Lamb.) à l'automne et au printemps et ensemencés en épinettes blanches (*Picea glauca* (Moench) Voss) à l'automne. Les plantations ont été faites à la main avec du matériel classique de pépinière (2 + 2) à un écartement de 1,8 m, et les graines ont été semées en plein de façon uniforme à raison de 0,56 kg par hectare (viabilité de 65%). Aprés huit saisons de croissance, la densité du pin gris déterminée par quadrats de 4 m^2 était en moyenne de 47% (intervalle de 24 à 70%) dans les sections plantées, de 24% (22 à 27%) dans les sections ensemencées et de 12% (6 à 18%) dans les sections témoins, toutes les différences étant significatives à $P < 0,05$. Les différences quant à la densité relative moyenne du pin entre les traitements faits à l'automne et au printemps n'étaient pas significatives ($P > 0,05$) tant pour la plantation que pour l'ensemencement. Le traitement le moins efficace a été un ensemencement effectué à l'automne en épinettes blanches et en pins gris qui a donné une densité relative de 12% pour le pin et de près de 0% pour l'épinette. Combinés à la régénération forestière naturelle, les traitements ont entraîné la formation de peuplements de forêt mixte dans lesquels le peuplier faux-tremble (*Populus tremuloides* Michx.), le pin gris et l'épinette noire (*Picea mariana* (Mill.) B.S.P.) prédominaient.

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INTRODUCTION

Controlled burning was introduced to central Saskatchewan in 1970 as an optional treatment testing its postcut uses in reduction of slash fire hazard and preparation of sites for either planting or seeding jack pine (*Pinus banksiana* Lamb.)[1] and white spruce (*Picea glauca* (Moench) Voss). Following and coincidental with a series of preliminary experimental tests (Chrosciewicz 1978c, 1983a), several larger operational burns were conducted in 1971 at latitudes 53°53′–55′N and longitudes 104°57′–58′W, about 31–36 km by road northeast of Candle Lake, Saskatchewan. Information on these operational burns as well as resulting guidelines for the safe, effective, and economic use of fire in future operations have been published (Chrosciewicz 1978a). Numerous experimental and operational treatments with planting and seeding the pine and spruce were put in place following the larger burns (Figs. 1–5). The results of experimental planting (Ball and Kolabinski 1986) and those of experimental seeding (Chrosciewicz 1987) were published elsewhere; this report provides information on the outcome of somewhat similar treatments at the operational level.

THE CLEAR-CUT AREAS

The burns were conducted on four clear-cut jack pine areas named Center East, Center West, South, and North (Fig. 1) and consisting of 15.6, 33.4, 27.6, and 17.5 ha, respectively. The mineral soil materials were deep, loamy glacial tills containing, by volume, 1–35% stones. The tills varied in texture from sandy loam to sandy clay loam, with about 8–25 cm of silty sand in upper soil horizons. With the exception of a few wet spots that occurred in occasional depressions, the predominant soil moisture regimes (Hills 1955) were 2 (fresh) on Areas Center East and Center West and 2 (fresh) to 3 (moderately moist) on Areas South and North (Chrosciewicz 1978a).

The original stands were over 80 years old, with pine pulpwood yields of about 190–270 m³/ha. They were clear-cut between 1968 and 1971. Residual slash ranged in depth from 0.1 to 0.7 m and had an intermittent ground cover totalling 78–85%. Mor-type raw humus, or duff, consisted mostly of semifermented moss and litter materials and ranged in depth on all four areas from 1 to 17 cm. It remained predominantly undisturbed, but some mineral soil was exposed during logging operations mainly along skidways, landing places, and access roads (Chrosciewicz 1978a).

Among the plant species common on all fresh to moderately moist sites were Schreber's moss (*Pleurozium schreberi* (Brid.) Mitt.), bunchberry (*Cornus canadensis* L.), blueberry (*Vaccinium myrtilloides* Michx.), Labrador tea (*Ledum groenlandicum* Oeder), fireweed (*Epilobium angustifolium* L.), grass (*Calamagrostis canadensis* (Michx.) Nutt. with some *Elymus innovatus* Beal.), and willow (*Salix bebbiana* Sarg.). Common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.) was present mostly on the fresh sites, while strawberry (*Fragaria virginiana* Duchesne), sweet coltsfoot (*Petasites palmatus* (Ait.) Gray), raspberry (*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.), and green alder (*Alnus crispa* (Ait.) Pursh.) were particularly more abundant on the moderately moist sites. The total moss cover was consistently 80–90%. Above it, the other species provided a combined cover of about 30–50% on the fresh sites and 80–100% on the moderately moist sites. A few small, widely scattered clumps of trembling aspen (*Populus tremuloides* Michx.) were present within the areas, and these remained uncut (Chrosciewicz 1978a).

METHODS

Burning

The four areas were burned between July 21 and August 5, 1971. Duff Moisture Code ratings[2] associated with the individual burns varied from 20 to 40 so that different degrees of raw humus (duff) consumption were obtained, while high Fine Fuel Moisture Code ratings of 88–90 assured sustained ignition of fine

[1]Species nomenclature follows Scoggan (1957) for vascular plants, Crum et al. (1973) for mosses, Benoit (1975) for insects, and Banfield (1974) for mammals.

[2]For definitions of the different ratings, see Van Wagner (1974).

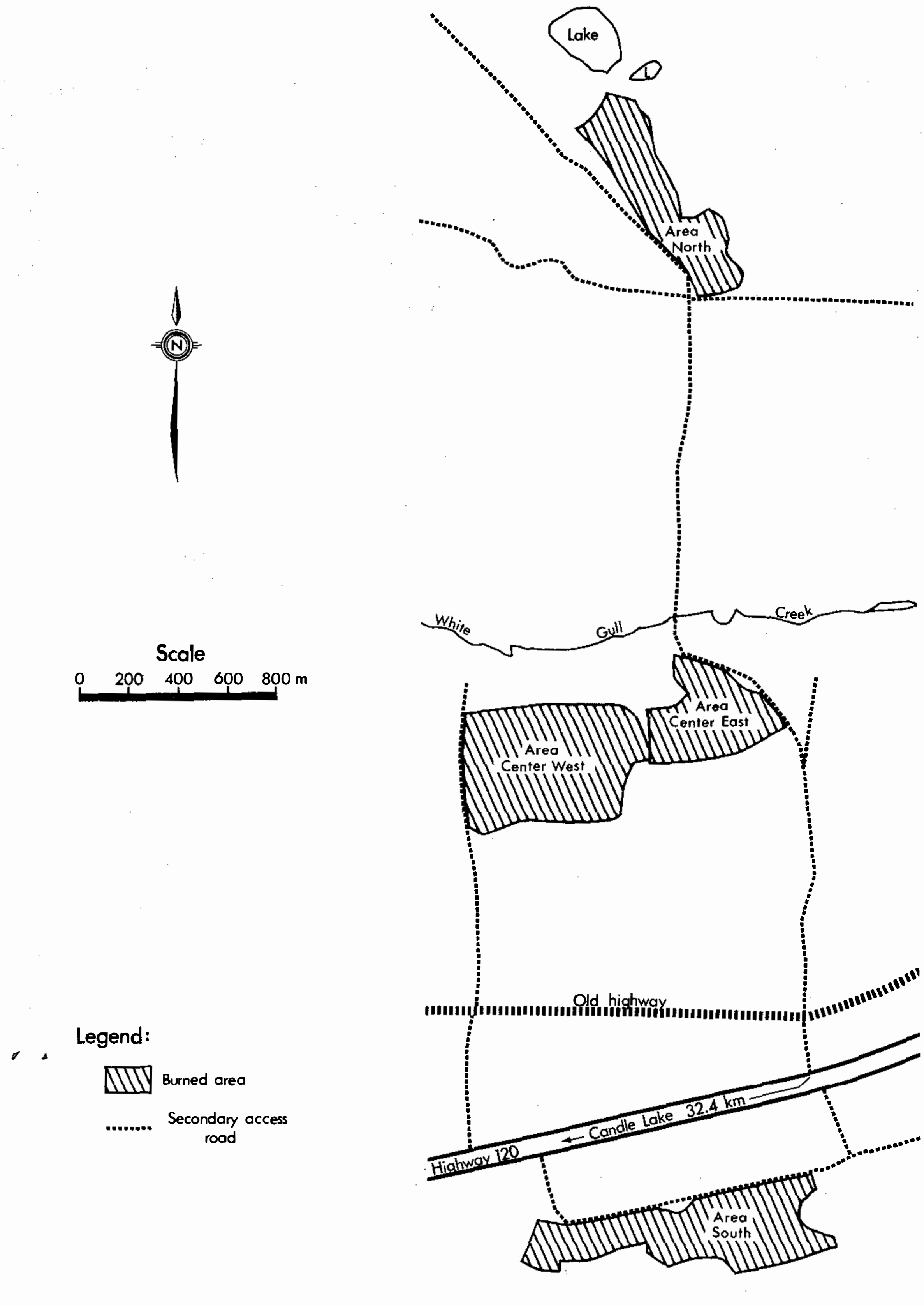


Figure 1. Location of operational burns by area.

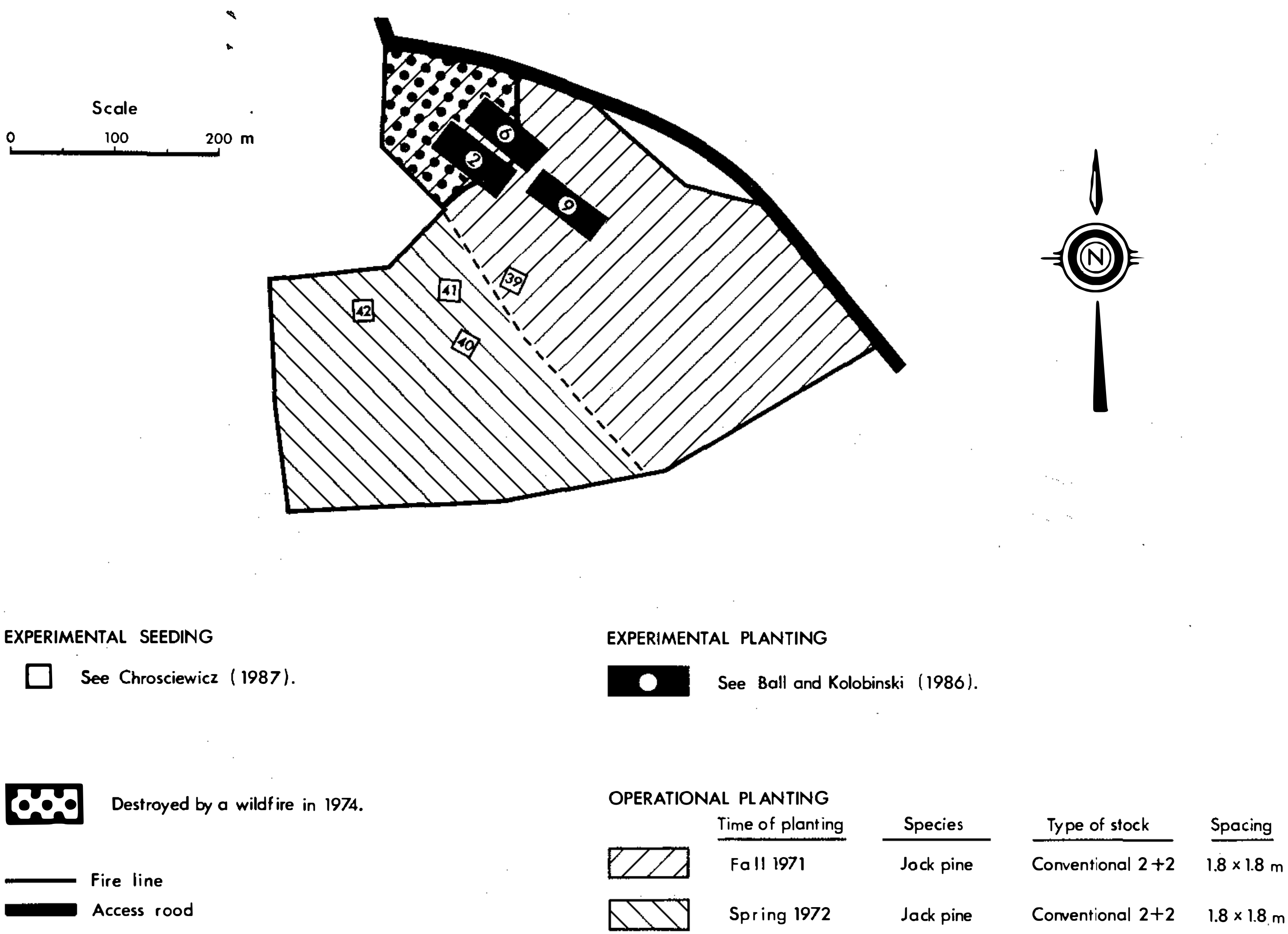
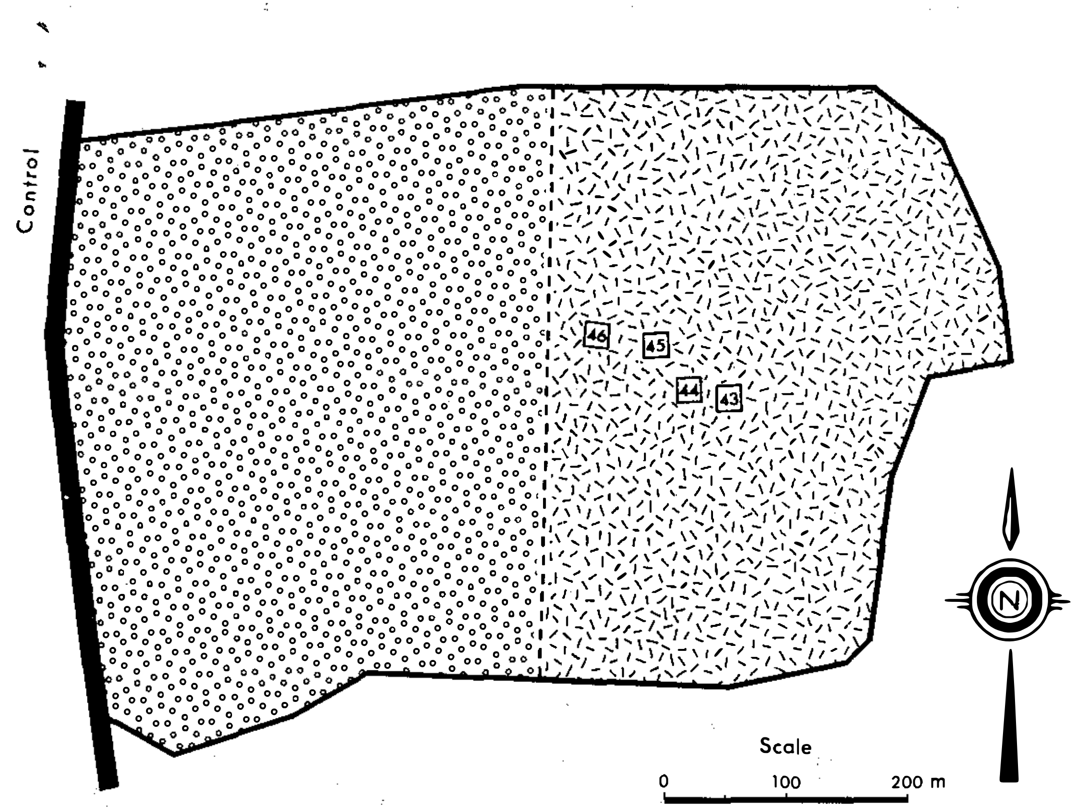


Figure 2. Location of postburn treatments on Area Center East (Date of burn: July 21, 1971).



EXPERIMENTAL SEEDING

☐ See Chrosciewicz (1987).

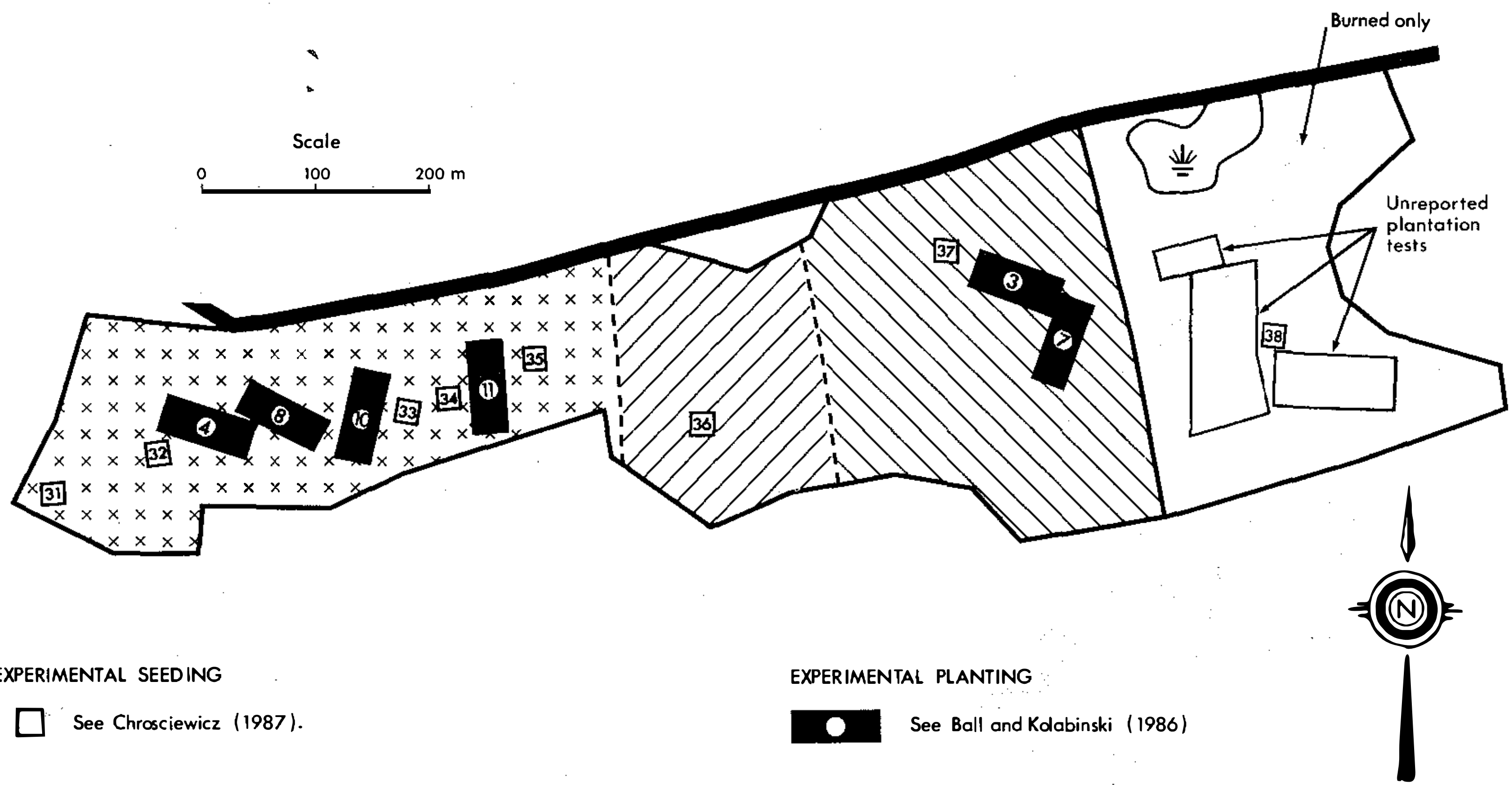
—— Fire line

▬ Access road

OPERATIONAL SEEDING

Time of seeding	Species	Amount of seed	Seed viability
Fall 1971	Jack pine	0.56 kg/ha	65%
Spring 1972	Jack pine	0.56 kg/ha	65%

Figure 3. Location of postburn treatments on Area Center West (Date of burn: July 23, 1971).



EXPERIMENTAL SEEDING

☐ See Chrosciewicz (1987).

EXPERIMENTAL PLANTING

▬●▬ See Ball and Kolabinski (1986)

OPERATIONAL SEEDING

	Time of seeding	Species	Amount of seed	Seed viability
××××	Fall 1971	Jack pine and white spruce	Mixed 0.42 and 0.14 kg/ha	65%

OPERATIONAL PLANTING

	Time of planting	Species	Type of stock	Spacing
////	Fall 1971	Jack pine	Conventional 2+2	1.8 x 1.8 m
\\\\	Spring 1972	Jack pine	Conventional 2+2	1.8 x 1.8 m

—— Fire line

▬▬ Access road

Figure 4. Location of postburn treatments on Area South (Date of burn: August 3, 1971).

EXPERIMENTAL SEEDING

☐ See Chrosciewicz (1987).

OPERATIONAL SEEDING

	Time of seeding	Species	Amount of seed	Seed viability
(dashes symbol)	Fall 1971	Jack pine	0.56 kg/ha	65%
(dots symbol)	Spring 1972	Jack pine	0.56 kg/ha	65%

EXPERIMENTAL PLANTING

■ See Ball and Kolabinski (1986).

OPERATIONAL PLANTING

	Time of planting	Species	Type of stock	Spacing
(forward hatch symbol)	Fall 1971	Jack pine	Conventional 2+2	1.8 × 1.8 m
(back hatch symbol)	Spring 1972	Jack pine	Conventional 2+2	1.8 × 1.8 m

Fire line

Access road

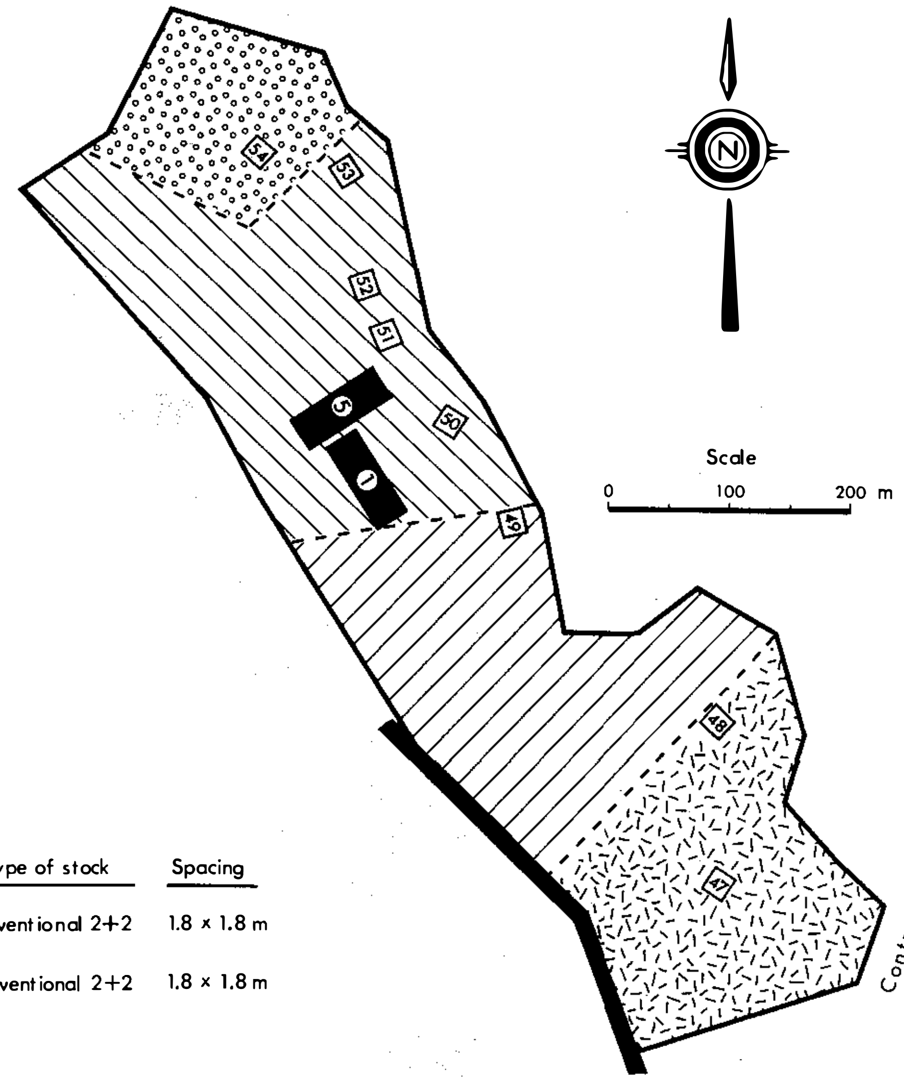


Figure 5. Location of postburn treatments on Area North (Date of burn: August 5, 1971).

surface and aerial fuels. The burns were also characterized by Drought Code ratings of 128–168, Buildup Index ratings of 29–50, Initial Spread Index ratings of 6–12, and Fire Weather Index ratings of 11–23 (Chrosciewicz 1978a). All these ratings were determined from direct weather observations with the aid of standard tables (Canadian Forestry Service 1976).

Postburn Treatments

Operational planting and seeding were conducted in October 1971 and during the last three weeks of May 1972 (Table 1). Jack pine conventional, bare-root 2 + 2 nursery-grown stock was planted at an approximate spacing of 1.8 × 1.8 m in both fall and spring on sections of Area Center East (7.09 and 6.11 ha), Area South (3.74 and 7.33 ha), and Area North (4.95 and 5.44 ha) (Figs. 2, 4, and 5). Fall and spring broadcast seeding of jack pine at a standard rate of 0.56 kg/ha was done on sections of Area Center West (15.79 and 17.46 ha) and Area North (4.28 and 2.06 ha) (Figs. 3 and 5). A section of Area South (6.62 ha) was also broadcast seeded with a mixture of 0.42 kg/ha jack pine seeds and 0.14 kg/ha white spruce seeds (Fig. 4). All tree seeds used had a viability of about 65%. In every case, small controlled lots of seeds were intermixed with standard quantities of rye (*Secale cereale* L.) grain, which by itself had a low viability. This procedure provided the necessary bulk for even distribution. A Cyclone seeder was used to spread the mixtures evenly at the desired rate.

One of the sections of Area South was reserved exclusively for various experimental planting and seeding tests, and no operational planting or seeding was carried out on it to fill the remaining spaces (Fig. 4).

Sampling

Twenty-four 0.04-ha plots were used to assess fuel and forest floor conditions. These were randomly located in groups of four plots per major site within individual areas. Consequently, there were four plots each on Areas Center East and Center West and eight plots each on Areas South and North (Figs. 2-5). Plots were 20 × 20 m, each having five uniformly spaced transects, and these were in turn subdivided into 4-m² sample quadrats. The resulting 200 quadrats per major site were then used for determining slash depth and cover before and after burn, mapping to scale duff cover before and after burn, and measuring duff depth before and after burn at 200 randomly spaced steel observation pins. Mapped duff cover information was subsequently converted to numerical values by a dot-grid method. Changes in vegetative cover resulting from the burn were, in each case, estimate for the entire plot area (Chrosciewicz 1978a). The same 24 plots were later used for experimental seeding tests (Chrosciewicz 1987).

Tree regeneration that followed the various postburn operational treatments was surveyed in late August and early September 1979. This was done by means of parallel transects, 80 or 160 m long, 20 m apart, and all traversing the middle portions of the different treatment sections. Transects consisted of single rows of 4-m² sample quadrats, and the total number of such quadrats per treatment section was roughly related to the net areal extent of each treatment. Consequently, the intensity of sampling ranged by treatment sections between 1.9% and 2.3%. The total number of 4-m² quadrats, however, was arbitrarily assigned to all other sampling situations. This latter group consisted of the one untreated burn on Area South and two extra untreated clear-cut controls, which were randomly selected and surveyed to have comparable regeneration values away from all postcut treatments.

Overall tree regeneration included jack pine, black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce, tamarack (*Larix laricina* (Du Roi) K. Koch), aspen, balsam poplar (*Populus balsamifera* L.), and paper birch (*Betula papyrifera* Marsh.). Trees living in 1979 were counted and recorded by species on all 4-m² quadrats. Height measurements of dominant trees, one per species present on every stocked quadrat, supplemented the count tally. The incidence of J-roots due to occasional cases of improper planting was recorded, as was the damage caused to some trees by terminal weevil (*Pissodes terminalis* Hopping), northern pitch-twig moth (*Petrova albicapitana* Busck), and snowshoe hare (*Lepus americanus* Erxleben).

Heights of dominant jack pine were measured again in October 1985 to obtain a rough assessment of their growth performance. The tree heights so measured totaled 111 on the planted area sections and 44 on the seeded area sections. The total number of 4-m² quadrats involved in this particular survey was about one-tenth that of the 1979 survey. The transects composed of these quadrats were randomly located in about the middle of each treatment section.

The 1979 regeneration was assessed by species and groups of species in terms of stocking (Table 1), density (Table 2), and height (Table 3). Mean jack pine

Table 1. Regeneration stocking in 1979 after eight growing seasons[a]

Area	Soil moisture regime	Operational postburn treatment	Extent of treatment (ha)	4-m² quadrats sampled (n)	4-m² quadrats stocked (%) Jack pine	Other conifers[b]	Trembling aspen	Other hardwoods[c]	Any tree species
Center East	2	Fall 1971 planting[d]	7.09	360	24	16	84	2	90
South	2	Fall 1971 planting[d]	3.74	200	48	20	66	12	84
North	3	Fall 1971 planting[d]	4.95	240	32	22	65	20	83
Center East	2	Spring 1972 planting[d]	6.11	320	67	17	52	2	89
South	2	Spring 1972 planting[d]	7.33	360	43	14	89	3	95
North	3	Spring 1972 planting[d]	5.44	280	70	31	36	15	87
Center West	2	Fall 1971 seeding[e]	15.79	800	23	2	60	5	71
North	2	Fall 1971 seeding[e]	4.28	200	25	24	70	8	84
Center West	2	Spring 1972 seeding[e]	17.46	880	22	20	66	2	79
North	2	Spring 1972 seeding[e]	2.06	120	27	52	69	20	89
South	3	Fall 1971 seeding[f]	6.62	320	12	27	66	9	78
South	2	Burning only	—[g]	160	14	25	54	4	72
Control	2	—	—	200	6	27	6	10	42
Control	3	—	—	200	18	14	32	0	52

[a] Ingress trees are included with those planted and broadcast seeded.
[b] Black spruce (93–100%), tamarack (0–7%), and white spruce (0–4%).
[c] Balsam poplar (0–100%) and paper birch (0–94%).
[d] Planting jack pine conventional 2 + 2 nursery stock, spacing 1.8 × 1.8 m.
[e] Broadcast seeding 0.56 kg/ha of jack pine seeds; viability 65%.
[f] Broadcast seeding 0.42 kg/ha of jack pine seeds and 0.14 kg/ha of white spruce seeds; viability 65%.
[g] Not available.

Table 2. Regeneration density in 1979 after eight growing seasons[a]

Area	Soil moisture regime	Operational postburn treatment	Living trees (n/ha)				
			Jack pine	Other conifers[b]	Trembling aspen	Other hardwoods[c]	Any tree species
Center East	2	Fall 1971 planting[d]	667	521	12 576	63	13 827
South	2	Fall 1971 planting[d]	2 200	750	5 475	450	8 875
North	3	Fall 1971 planting[d]	1 781	1 031	5 438	1 156	9 406
Center East	2	Spring 1972 planting[d]	2 062	617	6 102	63	8 844
South	2	Spring 1972 planting[d]	1 208	424	13 778	91	15 501
North	3	Spring 1972 planting[d]	6 884	1 393	3 018	688	11 983
Center West	2	Fall 1971 seeding[e]	803	50	5 412	187	6 452
North	2	Fall 1971 seeding[e]	912	950	6 050	288	8 200
Center West	2	Spring 1972 seeding[e]	878	813	8 006	54	9 751
North	2	Spring 1972 seeding[e]	854	2 896	11 479	542	15 771
South	3	Fall 1971 seeding[f]	672	1 047	6 617	281	8 617
South	2	Burning only	688	1 094	5 125	93	7 000
Control	2	—[g]	200	1 200	288	412	2 100
Control	3	—	662	550	1 550	0	2 762

[a] Ingress trees are included with those planted and broadcast seeded.
[b] Black spruce (93–100%), tamarack (0–7%), and white spruce (0–4%).
[c] Balsam poplar (0–100%) and paper birch (0–94%).
[d] Planting jack pine conventional 2 + 2 nursery stock, spacing 1.8 × 1.8 m.
[e] Broadcast seeding 0.56 kg/ha of jack pine seeds; viability 65%.
[f] Broadcast seeding 0.42 kg/ha of jack pine seeds and 0.14 kg/ha of white spruce seeds; viability 65%.
[g] Not available.

Table 3. Regeneration height in 1979 after eight growing seasons[a]

Area	Soil moisture regime	Operational postburn treatment	Mean heights of dominant trees (m)			
			Jack pine	Other conifers[b]	Trembling aspen	Other hardwoods[c]
Center East	2	Fall 1971 planting[d]	1.88	0.19	1.68	0.32
South	2	Fall 1971 planting[d]	2.48	0.29	1.31	0.61
North	3	Fall 1971 planting[d]	1.76	0.20	0.81	0.46
Center East	2	Spring 1972 planting[d]	2.04	0.16	1.45	0.66
South	2	Spring 1972 planting[d]	2.10	0.20	2.79	0.58
North	3	Spring 1972 planting[d]	1.57	0.26	1.76	0.79
Center West	2	Fall 1971 seeding[e]	1.07	0.17	1.46	0.42
North	2	Fall 1971 seeding[e]	1.13	0.16	1.74	0.94
Center West	2	Spring 1972 seeding[e]	0.80	0.24	1.61	0.48
North	2	Spring 1972 seeding[e]	1.06	0.27	1.84	0.70
South	3	Fall 1971 seeding[f]	1.07	0.20	2.30	1.05
South	2	Burning only	1.27	0.24	2.79	0.48
Control	2	—[g]	1.06	0.71	1.47	0.87
Control	3	—	1.20	0.97	1.09	0

[a] Ingress trees are included with those planted and broadcast seeded.
[b] Black spruce (93–100%), tamarack (0–7%), and white spruce (0–4%).
[c] Balsam poplar (0–100%) and paper birch (0–94%).
[d] Planting jack pine conventional 2 + 2 nursery stock, spacing 1.8 × 1.8 m.
[e] Broadcast seeding 0.56 kg/ha of jack pine seeds; viability 65%.
[f] Broadcast seeding 0.42 kg/ha of jack pine seeds and 0.14 kg/ha of white spruce seeds; viability 65%.
[g] Not available.

stocking and density values were then statistically compared between treatments (Table 4) and, on area sections with the same treatments, similar comparisons were made between dominant heights of jack pine and aspen (Table 5). One-way analyses of variance and *t* tests were used in these comparisons (Snedecor and Cochran 1980). Damage to pine from various causes was expressed as a percentage of affected trees. Finally, differences between mean jack pine dominant heights in 1979 and 1985 were used to calculate, by combined treatments, mean annual growth over the intervening time of 6 years.

RESULTS AND DISCUSSION

Fuel Consumption

In this series of operational burns (Chrosciewicz 1978a), as in previous and subsequent experiments (Chrosciewicz 1959, 1967, 1968, 1970, 1974, 1976, 1978b–d, 1980, 1983a–b, 1987, 1988), fire consumed much of the unwanted logging slash, aerial parts of vegetation, surface moss and litter, and underlying duff in quantities that on average were directly related to the fuel moisture ratings under which the materials were burned. Mean duff depths ranged by area and site from 6.4 to 7.9 cm before burn and from 2.0 to 3.8 cm after burn. Generally, the reduction of duff depth was substantial, and this in turn resulted in a considerable reduction of duff cover with the consequent exposure of mineral soil that averaged 10–24% (Chrosciewicz 1978a).

Organic materials that remained after the fires included surface-charred stumps, discarded logs, odd pieces of branch wood, partially burned duff, and occasional patches of scorched but unburned vegetation where scarification due to logging interfered to a degree with spread of fire. Generally, however, slash fire hazard was eliminated, and all four areas became relatively free from major physical impediments to subsequent planting and seeding.

Slash, vegetation, and forest floor conditions were totally unaffected by fire on clear-cut controls. Controls were devoid of exposed mineral soil, and depths of undisturbed duff there averaged 6.8–7.2 cm.

Establishment and Composition of Forest Regeneration

Toward the end of the eighth growing season, jack pine regeneration was much better after planting than after seeding, and it was predominantly better after planting in the spring than after planting in the fall (Tables 1 and 2). Spring planting of pine resulted in 43–70% stocking with 1208–6884 trees/ha, while fall planting of pine resulted in 24–48% stocking with 667–2200 trees/ha. There was very little difference between spring seeding of pine, which produced 22–27% stocking with 854–878 trees/ha, and fall seeding of pine, which produced 23–25% stocking with 803–912 trees/ha. Fall seeding of jack pine and white spruce was the least successful of all postburn treatments, resulting in only 672 pine trees/ha at 12% stocking, with just 8 white spruce trees/ha at stocking approaching 0%[3]. Even burning alone produced somewhat better, if not comparable, results with 688 pine trees/ha at 14% stocking. As for controls, they had 200–662 pine trees/ha at 6–18% stocking, both increasing with the soil moisture regime (Tables 1 and 2).

In statistical terms (Table 4), the treatment mean jack pine stocking and density values were not significantly different ($P > 0.05$) between the fall and the spring applications of planting and seeding. The overall differences, however, among the combined planting treatments, the combined seeding treatments, and the controls were all significant ($P < 0.05$) in terms of mean pine stocking and not significant ($P > 0.05$) in two out of three cases in terms of mean pine density. The only significant ($P < 0.05$) exception in this latter comparison was the mean density difference between the combined seeding treatments and the controls (Table 4).

The numbers of jack pine per hectare within the fall-planted section of Area South and more so within the fall-planted and spring-planted sections of Area North were disproportionately large and thus caused misleading impressions (Table 2). Normally, in plantations with 1.8-m approximate spacing, a stocked 4-m^2 quadrat should have contained one, sometimes two, and rarely three or four planted trees. This

[3]As a minor component of regeneration, white spruce is included with the other conifers in Tables 1–3.

Table 4. Comparisons of 1979 jack pine stocking and density[a]

Operational postburn treatment	Area sections (n)	Mean jack pine stocking[b] (%)	Mean jack pine density[b] (n/ha)
Fall 1971 planting	3	35 (± 12)	1 549 (± 792)
		NS	NS
Spring 1972 planting	3	60 (± 15)	3 385 (± 3 060)
Fall 1971 seeding	2	24 (± 1)	858 (± 77)
		NS	NS
Spring 1972 seeding	2	24 (± 4)	866 (± 17)
Combined planting	6	47 (± 18)	2 467 (± 2 238)
		*	NS
Combined seeding	4	24 (± 2) (Combined planting vs. Controls: *)	862 (± 46) (Combined planting vs. Controls: NS)
		*	*
Controls	2	12 (± 8)	431 (± 327)

[a] Because of treatment differences, the seeded and burned-only sections of Area South are not included.
[b] Differences between means (with ± standard deviations) significant at P < 0.05 (*); the not significant (NS) designations indicate P > 0.05.

Table 5. Comparisons of 1979 jack pine and trembling aspen dominant heights[a]

Tree species	Planted area sections: Trees measured (n)	Planted area sections: Mean height[b] (m)	Seeded area sections: Trees measured (n)	Seeded area sections: Mean height[b] (m)	Controls: Trees measured (n)	Controls: Mean height[b] (m)
Jack pine	827	1.95 (± 0.72)	459	0.96 (± 0.59)	47	1.16 (± 0.62)
		**		***		NS
Trembling aspen	1 174	1.80 (± 1.17)	1 281	1.58 (± 1.15)	78	1.15 (± 1.70)

[a] Because of treatment differences, the seeded and burned-only sections of Area South are not included.
[b] Differences between means (with ± standard deviations) significant at P < 0.01 (**) or P < 0.001 (***); the not significant (NS) designation indicates P > 0.05.

was not always the case, however, because in addition to planted trees, clusters of numerous natural pine seedlings often occurred on affected sections. In terms of stocked 4-m² quadrats, about 3% of them within the fall-planted section of Area South, 15% of them within the fall-planted section of Area North, and 23% of them within the spring-planted section on Area North contained clusters of naturally seeded-in pine regeneration. The number of seedlings per cluster could have been anywhere from 5 to 39, and this to varying degrees affected the total tree counts per hectare.

Field investigations disclosed that the clusters of natural pine regeneration occurred in places where localized scarification of the forest floor in combination with slash displacement by skidding of timber prevented the fire from burning some odd fragments of cone-bearing branches that still remained. While seeds in cones of the pine slash were destroyed with burning slash on the outside, the heat so generated helped release seeds from unburned cones[4] within scarified patches. Clustering of seedlings was a good indication of seed dispersal from cones near the ground.

Whether within the burned area sections or on clear-cut controls, trembling aspen and several other tree species were growing along with the pine (Tables 1 and 2). As a group, the other conifers, consisting mostly of black spruce with some white spruce and tamarack, were occasionally more numerous and had better stocking values than jack pine. This occurred even more with trembling aspen, which in the majority of cases dominated the pine both numerically and by its stocking values. Balsam poplar and paper birch, belonging to the other hardwoods category, were in most cases considerably less numerous and had rather sporadic occurrences (Tables 1 and 2). Black spruce, white spruce, tamarack, and paper birch probably seeded-in from uncut stands nearby, while both trembling aspen and balsam poplar originated in situ from root suckering of parent trees just after burning.

In terms of combined tree species present, the planted area sections were stocked 83–95% with 8844–15 501 trees/ha, while the seeded area sections were stocked 71–89% with 6452–15 771 trees/ha. Burning alone resulted in 72% of such stocking with 7000 trees/ha, and stocking by any tree species on clear-cut controls was 42–52% with just 2100–2762 trees/ha (Tables 1 and 2).

Generally, the young stands produced by the various burning, planting, and seeding combinations had mixed species compositions in which aspen, jack pine, and black spruce predominated. Untreated clear-cut controls had also mixed compositions, but both their total numbers of trees per hectare and their overall stocking percents by 4-m² quadrats were substantially less than those on treated area sections.

Growth of Forest Regeneration

Eight growing seasons after postburn treatments, mean heights of dominant jack pine ranged from 1.57 to 2.48 m on planted area sections and from 0.80 to 1.13 m on seeded area sections. Otherwise, the remaining mean dominant jack pine heights were 1.27 m on untreated burn and 1.06–1.20 m on untreated clear-cut controls (Table 3). As for aspen dominants, their mean heights ranged from 0.81 to 2.79 m on burned area sections and from 1.09 to 1.47 on controls (Table 3). Other conifers, notably black spruce with some white spruce and tamarack, as well as other hardwoods, notably balsam poplar and paper birch, had mean dominant heights that placed them in intermediate stand positions (Table 3).

Differences between mean dominant heights of jack pine and trembling aspen varied considerably with treatments (Table 5). On planted area sections the pine was taller than aspen, whereas on seeded area sections the aspen was taller than pine, and the differences between their mean dominant heights were highly significant ($P < 0.01$) and very highly significant ($P < 0.001$), respectively. On controls, the mean dominant heights of both species were not significantly different ($P > 0.05$) (Table 5).

The mean dominant jack pine heights were 1.95 and 0.96 m on planted and seeded area sections, respectively, in 1979 (Table 5) and 3.79 and 2.75 m on planted and seeded area sections, respectively, in 1985. In each case, the dominant pine had comparable mean annual height growth, 0.31 m in plantations and 0.30 m on seeded area sections.

Damage to Pine

On the average, about 14% of planted jack pine exhibited J-roots resulting from improper planting.

[4]A temperature of about 50°C is required to melt the bonding material that seals the scales in jack pine cones (Cameron 1953).

It was feared that eventually these trees would become uprooted by wind, although so far no such losses have been observed.

In the first eight growing seasons after postburn treatments, insect damage to jack pine was more common in plantations than on seeded area sections. On the average, about 8% of planted pine and 1% of seeded pine had leader damage by terminal weevils, and a further 2% of planted pine had leader damage by northern pitch-twig moths. About 7% of pine on the untreated burn and about 5% of pine on clear-cut controls exhibited damage by terminal weevils. There was no evidence of injury, however, by northern pitch-twig moths on seeded area sections or on the untreated burn, although about 1% of the pine on controls had their leaders damaged by these insects.

Snowshoe hares were numerically at the peak of their population cycle during the winter months of 1978–79, and much of the browsing, or top-clipping, on pine occurred at that time. Damage was noted on all sections of Area South because there, more than on any other area, the hares found an adequate protective shelter and ample winter forage in the luxuriant, bushy, predominantly aspen vegetation on and around the area. About 2–22% of fall-and spring-planted pine, about 45% of fall-seeded pine, and 43% of natural pine within the untreated burn of the same area had clipped tops by hares. Fall-and spring-planted pine on Areas Center East and North as well as fall- and spring-seeded pine on Area Center West and fall-seeded pine on Area North were totally free from hare damage, and damage to pine on the spring-seeded section of Area North was just 2%. As for clear-cut controls, about 2–6% of the pine there were damaged by hares. Most of the damaged trees survived, but in one instance, within the spring-planted section of Area South, about 5% of the pine died as a direct result of hare damage.

Recovery of Minor Vegetation

The fires destroyed practically all aerial parts of vegetation, but many roots and rhizomes in and below the residual, partially burned duff remained unharmed. Resprouting of some plants and germination of others began within a few days after each burn, and by the following summer some of the original plants as well as a few newcomers were establishing themselves in considerable numbers.

The newcomer group of species included cranesbill (*Geranium bicknellii* Britt.), pale corydalis (*Corydalis sempervirens* (L.) Pers.), and dragonhead (*Moldavica parviflora* (Nutt.) Britt.). They, in combination with some of the original herbs, grasses, sedges, and shrubs, formed the first-year ground cover of about 50–95%. By the second year after burning, however, the previously dominating cranesbill, pale corydalis, and dragonhead had almost completely disappeared and were replaced by other plant species, which by then had a combined ground cover of 50–90%. This successive cover consisted predominantly of twinflower (*Linnaea borealis* L. var. *americana* (Forbes) Rehd.), bunchberry, wild-lily-of-the-valley (*Maianthemum canadense* Desf. var. *interius* Fern.), sour-top blueberry, fireweed, goldenrod (*Solidago nemoralis* Ait. var. *decemflora* (DC.) Fern.), grass, sedge (*Carex* spp.), rose (*Rosa acicularis* Lindl.), and willow. Common bearberry reestablished itself primarily on fresh sites, and sweet coltsfoot, strawberry, wood horsetail (*Equisetum sylvaticum* L.), lungwort (*Mertensia paniculata* (Ait.) G. Don), raspberry, and green alder flourished on moderately moist sites. Schreber's moss was consumed by fire, and haircap moss (*Polytrichum juniperinum* Hedw.) had begun to colonize the sites in its place. The postburn successional trends described here were similar to those reported previously from other areas in central Saskatchewan (Chrosciewicz 1983a). As for the vegetation within the clear-cut controls, no major changes in its original composition were observed.

CONCLUSIONS

The foregoing evaluation of postburn operational treatments showed that, on average, significantly better jack pine stocking can be obtained from planting than from seeding and from either planting or seeding when compared with controls. Seasonal differentiations between fall and spring planting and seeding resulted in stocking differences that, on average, were not significant. Treatment differences in terms of mean jack pine density between fall and spring of both planting and seeding and between most treatment combinations were also not significant. Excessive variations among replicate treatments in terms of both jack pine stocking and jack pine density were responsible for making these results much less conclusive than expected. Nevertheless, Ball and Kolabinski (1986) have reported variable survival rates from the same burns

(Figs. 2, 4, and 5) for their experimentally fall-planted, bare-root pine, so those authors tend to support spring planting. Similarly, the results of experimental seeding on the same burns (Figs. 2–5) have clearly indicated spring is the best seeding season (Chrosciewicz 1987). There are, therefore, good reasons to recommend that all these facts should be considered when timing of future postburn planting or seeding treatments is contemplated.

It is likely that operational burning with subsequent planting or seeding will find their primary applications on those nonreproducing areas that are for some reason totally devoid of natural sources of conifer seeds. Unstocked or poorly stocked older cutovers and burns and areas requiring radical sanitation, as in cases of mistletoe (*Arceuthobium americanum* Nutt.) infestation, would also qualify. Guidelines for operational burns are already available (Chrosciewicz 1978a), but more information is required on how to reduce further the costs of planting and seeding to make the combined treatments more attractive.

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