 # 005

THE EFFECT OF MICROSITE COMPACTION ON DIRECT SEEDING SUCCESS OF JACK PINE AND BLACK SPRUCE IN NORTHWESTERN ONTARIO

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ABSTRACT

The effects of microsite soil compaction on direct seeding were tested in conjunction with Bracke scarification. The compaction effect was achieved by manually tamping the seed spot with a wooden pallet with either a flat surface or a surface with pyramidal indentations. It was anticipated that compaction might decrease the number of seeds required to establish seedlings and extend the sowing season for jack pine and black spruce in Northwestern Ontario. Compaction increased the number of scalps stocked with jack pine by 30% after the first growing season but had no effect on black spruce. The experimental sowing rate of five seeds per scalp may have been insufficient to detect black spruce treatment responses on the dry mineral soil seed spots. No differences were found between pre-sowing and post-sowing compaction treatments for jack pine. However, compaction with a pyramidal surface improved stocking slightly over compaction with a flat surface, especially for the latest sowing date. Compaction with a pyramidal surface doubled the percent stocked scalps over conventional sowing for the latest sowing date. Compaction may allow an extension of the jack pine sowing season from late June into early July. Still, early spring sowing provided the best overall results for both species. Although no site location by compaction treatment interaction was detected, site strongly influenced emergence and survival. It was discovered that the site with moisture levels conducive to establishment for both species in the first growing season were subject to significant seedling mortality from frost heaving and drowning by the end of the second season. The study also showed that establishment of black spruce on upland sites,which may have had a significant black spruce component prior to harvesting,is problematic.

ACKNOWLEDGMENTS

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DISCLAIMER

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INTRODUCTION

Tree planting levels for the two most important conifer species in Ontario, jack pine (Pinus banksiana Lamb.) and black spruce (Picea mariana, Mill, (B.S.P.), increased sharply with the signing of the Forest Management Agreements between the Ontario Ministry of Natural Resources (OMNR) and the major pulp and paper companies. The high cost of these tree planting programs has resulted in a cap on tree planting levels and has generated interest in direct seeding as a low cost artificial regeneration method. Canada's low opportunity cost of land and relatively slow growing forests make low cost silvicultural investments a realistic strategy to maintain leadership in the supply of wood fibre (Sedjo 1986, Benson 1988).

Jack pine seed, and to a lesser extent black spruce seed, are typically aerially sown in the winter months following summer site preparation on 16,000 to 30,000 hectares annually in Northern Ontario (Anon, 1986). Aerial seeding is inexpensive and produces seedlings with more natural and healthy root systems than that obtained with planting (Smith 1986). This seeding technique is wasteful however, requiring three times the amount of seed for producing planting stock to treat an equivalent area (Anon, 1986). Aerial seeding does not necessarily provide desirable density and spacing in the regenerated areas. Aerial seeding can also be less reliable than planting because seed may fall onto unsuitable microsites where seed won't germinate or young germinants die from adverse (weather) conditions. Hence, some areas may require more than one treatment.

Experimental work by Harper et al (1965), and the recent success of shelter seeding systems (Putman and Zasada 1986, Dominy and Wood 1986), show how subtle differences in seed spot microsite qualities can have a dramatic impact on the success of seed germination and seedling survival. Jack pine's large seed, relative to that of black spruce, make it ideally adapted to upland sites because it germinates successfully on exposed mineral soil (Yeatman 1984, Riley 1980, Smith 1986). Black spruce has more difficulty germinating and surviving on mineral soil but can become established on a seed bed comprised of a soil/humus mix. The best seed bed for black spruce on lowland sites is a mixture of sphagnum moss species (Fowells 1965, Fraser 1970, Jeglum 1984, Fleming and Groot 1984). Current mechanical site preparation tools can create suitable microsites for jack pine but are less reliable for black spruce.

Direct seeding concurrent with site preparation is less expensive than the two stage aerial seeding techniques and can achieve better seedling density and spacing. Fewer seed is required because they are more accurately targeted to suitable microsites (Sidders, 1985). Unfortunately the sowing season is limited to less than two months in early spring and one month in late fall (Clark 1984).

Numerous seeding/site preparation tools have been developed (Mattice & McPhee 1979, Segaren et al 1984, Parker 1972, Smith 1980). Field experience with seeding/site preparation tools in Northwestern Ontario has been a mixture of success and failure. Sidders (1985) and Clark (1984) show that the technique can be reliable for jack pine if projects are well supervised and seed delivery rates are relatively high at approximately 37,000 seeds/ha. These rates are still half of the amount of seed required for aerial seeding. Each tool creates different types of microsites with different profiles, shapes and sizes but nearly all produce exposed mineral soil substrates. For this reason, black spruce is rarely sown with seeding/site preparation tools.

Direct seeding of jack pine in conjunction with exposed mineral soil compaction (Van Damme 1988) or weathering (Brown 1984) shows increased seedling emergence presumably from better microsite stabilization, improved heat conductance and soil capillary movement of water (Van Damme 1988, Bergman and Bergsten 1984, Heikurinen 1984). Compaction devices can be designed to fit new seeding/site preparation tools.

The purpose of this study was to determine if compaction would allow for reduced seed consumption and an extension of the spring sowing season of jack pine. Compaction may also allow for the successful direct seeding of black spruce on upland sites with mineral soil substrates. Secondly, it was of interest to see if the beneficial effects observed for jack pine would be influenced by the timing of seed drop relative to the timing of compaction and the shape of the compaction surface. This secondary investigation would influence the design of new seeding/site preparation tools.

METHODS

Site Preparation Method

A Bracke scarifier (Smith 1980) was used to site prepare all of the study locations. The Bracke scarifier/seeder is the most common seeding/site preparation tool used in Northwestern Ontario, annually treating about 5000 ha of jack pine sites. This scarifier prepares an intermittent slightly mounded mineral soil scalp microsite at pre-set spacings and delivers seed in a one-pass operation (Parker, 1972). For this study the seeders were removed from the machines prior to site preparing the study blocks. In this way machine sown seed would not interfere with the hand sown experimental spot seedings. Figure 1 shows a typical Bracke scarifier configuration and Figure 2 shows a schematic Bracke scalp with the seed spot target that is used both operationally and for this study.

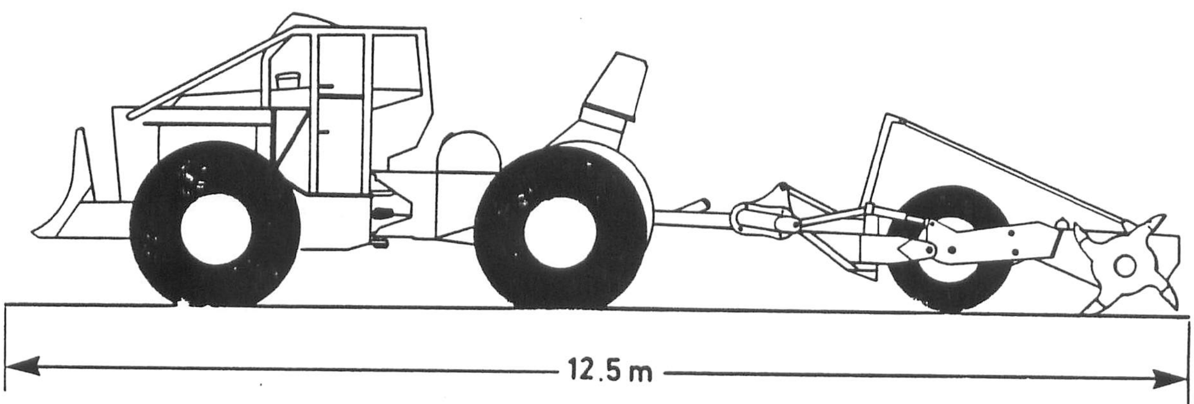

Figure 1. Standard Bracke Configuration.

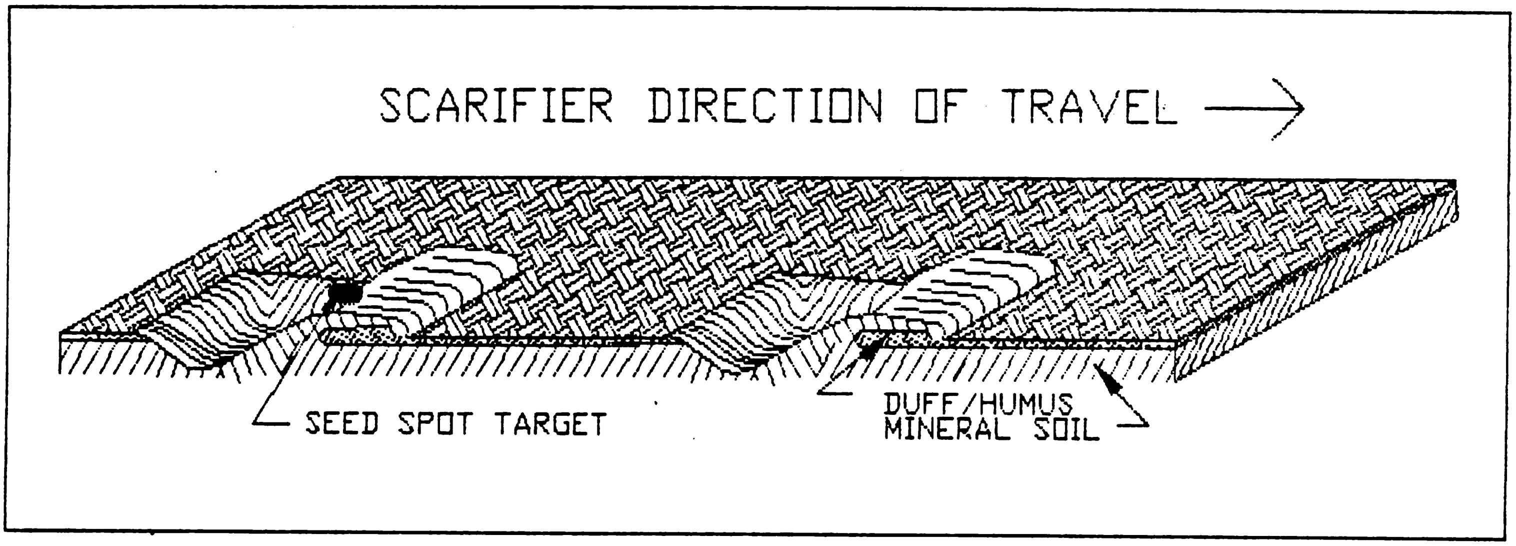

Figure 2. Bracke Scalp

Study Area Description

Three locations were selected for study in northwestern Ontario (Figure 3). The locations had to be: 1) mixed conifer cover types harvested in the winter of 1985/1986 in stands typical of upland sites; 2) large enough to accommodate the study plots; 3) relatively consistent soil textures within each location yet different textures between locations; and 4) scheduled for scarification with the Bracke scarifier in May of 1986. Blocks were generally arranged for jack pine to be sown on the more elevated and better drained deep soil portions of the site compared to those sown to black spruce.

Location 1 is approximately 150 km north of highway 17 and the town of Upsala. The study blocks are east of the Graham road on a deep medium to coarse texture sand outwash plain. The soil is a S1N type following Sims et al's (1987) Forest Ecosystem Classification (FEC) scheme. This site is most representative of areas prescribed for direct seeding of jack pine. The site was scarified with a three-row Bracke scarifier on May 9, 1986.

Location 2 is 77 km north of Thunder Bay near Abitibi-Price Camp 11. The study blocks are on a shallow silty very fine sandy loam with a perched water table over bedrock surrounded by swamp and spruce bog. The FEC soil types ranged from a SS3 on the raised rock knobs to on SS9 in the depressions of the spruce blocks. The jack pine blocks were predominantly a SS7 soil type. The site was scarified May 13, 1986 with a two-row Bracke scarifier.

Location 3 is 40 km north of Canadian Pacific Forest Products Camp 418 west of English River on a shallow to medium depth fine silty sand over bedrock. Two FEC soil types were present for both jack pine and black spruce blocks. The SS3 types were associated with the shallow to bedrock areas. Deeper soils, (SS8) dominated the area. The site was scarified with a two-row Bracke scarifier on May 20, 1986.

In general, the moisture regime was the wettest in the finer textured soils of Location 2 followed by Location 3 with Location 1 being the driest site. Location 1 was the only site that met the criteria for consistent soil types, with the others meeting all other criterion but expressing higher levels of variability of soil characteristics than was preferred. Machine passes ran parallel to one another providing distinct rows except for portions of Location 2 which required double passes due to area constraints. Appendix 1 contains detailed maps of the study blocks.

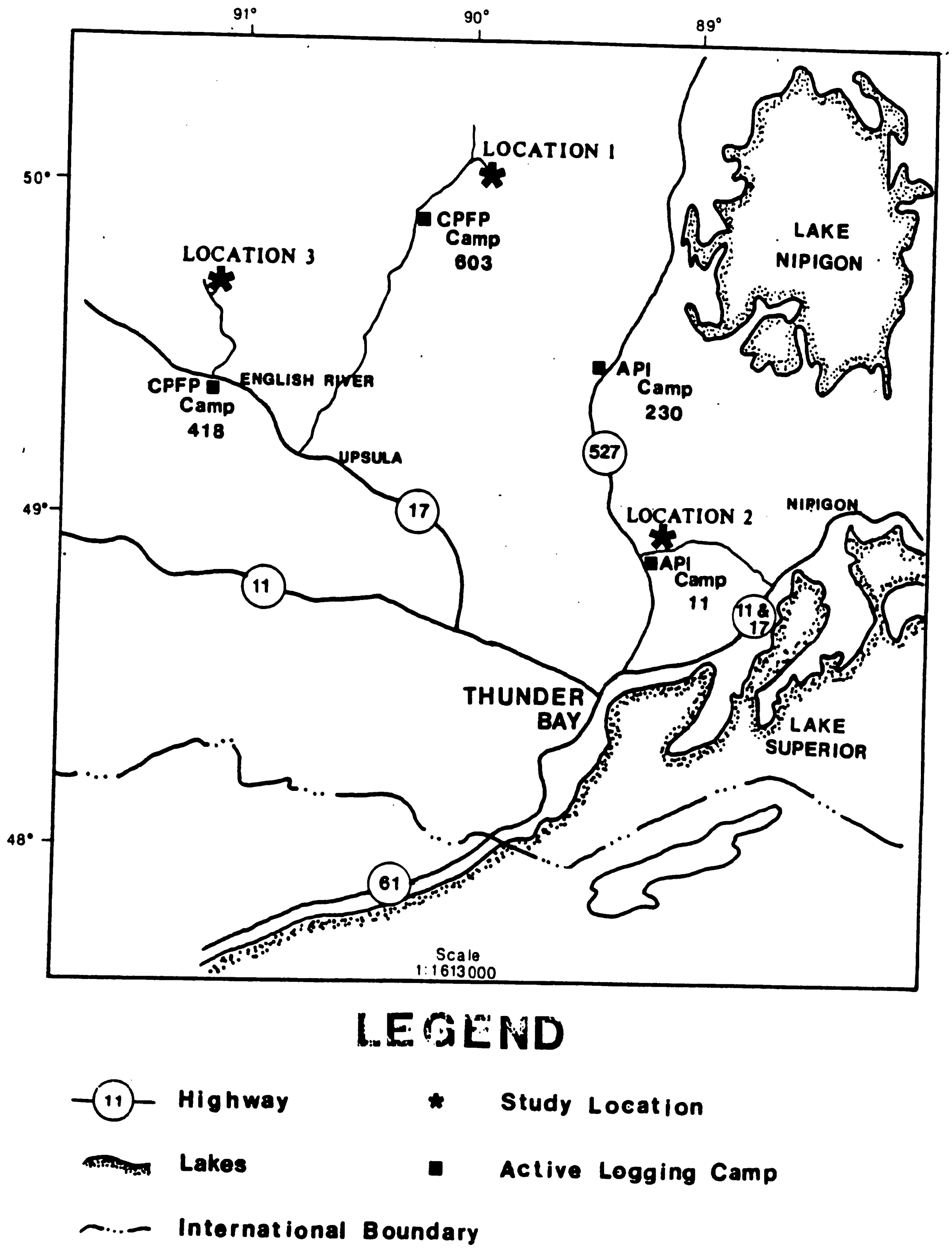

Figure 3. Map showing location of COFRDA Seeding Blocks.

Experimental Design

The experiment was a blocked 4 x 6 nested factorial with three blocks located in each of the three study locations for each species. The factors were four sowing dates (Table 1) and six sowing treatments as follows:

(1) Control - no seed sown

(2) Sow - seeds sown with no compaction treatment.

(3) SCP - seeds sown followed by compaction with a pyramidal surface.

(4) CSP - compaction with pyramidal surface followed by sowing.

(5) SCF - seeds sown followed by compaction with a flat surface.

(6) CSF - compaction with a flat surface followed by sowing.

Table 1. Sowing dates for the three locations and four sowing periods of the COFRDA Seeding Experiment in 1986.

Location 1	Location 2	Location 3
May 9	May 13-14	May 20
June 3	June 6-8	June 11
June 26-27	June 28-29	July 2-3
July 17-18	July 19-20	July 23-24

The experimental units consisted of a single row of 25 Bracke scalps. Each block contained 24 rows. Treatment combinations were assigned at random to each row within a block (Appendix 2). Block corners were staked. Treatment rows were marked with metal tags on small wooden stakes in the first and last patch of each row. Swizzle sticks, colour coded by treatment, were used to mark seed spot targets within each scalp.

On each sowing date, five seeds were hand sown in clumps onto the mid-slope seed spot target position of each scalp (Figure 2). A subset of the first five scalps was used to observe seed movement by carefully placing individual seeds in a row across all three locations. Each seed position was marked by placing a swizzle stick 3 cm upslope of the seed.

Scalps had to be a minimum of 40 cm by 40 cm in size to be sown. The next scalp in the row was sown to replace any rejected scalp.

Compaction was achieved by the sower tramping on one of two wooden pallets attached to wooden handles. One pallet had a flat surface and the other had pyramidal indentations (Figure 4).

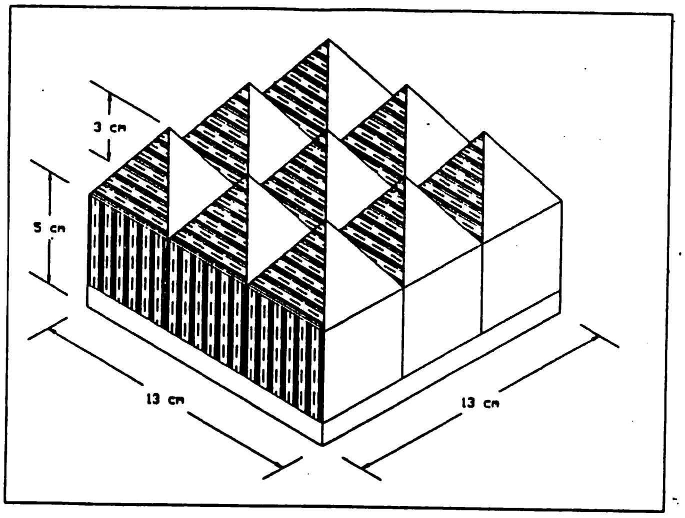

Figure 4. Pyramidal indentations of pallet used to create compaction treatment effects.

Assessment and Analysis

Percent stocked scalps were assessed in September of 1986 and September 1987. A scalp was counted as stocked if it contained one or more seedlings of the appropriate species regardless of seed origin. This data was then subjected to analysis of variance (ANOVA) based upon the experimental design constraints.

Sown scalps within all the blocks in Location 2 were assessed for scalp length, width, shape, slope, aspect, position of seed spot and soil type in 1986 for both species (Appendix 3). It was hoped that this information would give some insight into scalp attributes conducive to successful seedling establishment.

The scalp attribute information was analyzed using discriminant analysis of only the jack pine data set because results with black spruce were so poor. Three discriminant analyses were performed using the sowing treatment data set for the first sowing date,the last sowing date and all dates combined. Stocked scalp frequency by scalp attribute was also analyzed.

RESULTS

Jack Pine

Unseeded control rows were included to show the extent of natural regeneration on the study area. The average amount of natural regeneration for jack pine across the three locations was low with 12% stocked scalps in 1986 and 21% stocked scalps in 1987. All sowing treatments had the same chance for volunteer seedlings to emerge from seed originating from cones in the slash. These factors resulted in the elimination of the control rows from the analysis.

Analysis of variance indicated that location, treatment and sowing date were all highly significant factors affecting the percent stocked scalps in both the first and second year of assessment (Tables 2 and 3, respectively). Sensitivity of the test of treatment effects in 1987 was increased by pooling the nonsignificant two-way interaction mean squares and retesting (Anderson and McClean 1974). This method showed treatment effects to be significant even after the site began to fill in with volunteer seedlings in the second year. Pooling was not required to test treatment effects in the first year.

Table 2. Analysis of variance table for percent stocked scalps in 1986 for jack pine

Source	df[2]	SS[3]	MSE[4]	F-ratio	Prob. of a Larger F-ratio
Location (L)	2	11658	5829	6.35	0.03
Block (B)	6	5512	919		
Date (D)	3	24655	8218	73.09	0.00
LD[1]	6	675	112	0.28	0.94
BD	18	7111	395		
Treat (T)	4	8343	2086	13.77	0.00
LT	8	1212	152	1.01	0.46
BT	24	3612	151		
DT	12	2119	177	1.32	0.27
Residual	96	11397	119		

1. Represents interaction terms (eg. location x date = LD)
2. Degrees of freedom
3. Sum of squares
4. Mean square error

Table 3. Analysis of variance table for percent stocked scalps in 1987 for jack pine

Source	df	SS	MSE	F-ratio	Prob. of larger F-ratio
Location (L)	2	8258	4129	17.47	0.00
Block (B)	6	1417	236		
Date (D)	3	20931	6977	14.16	0.00
LD	6	2957	493	2.98	0.03
BD	18	2973	165		
Treat (T)	4	1907	477	3.45	0.06 *
LT	8	1104	138	1.11	0.39
BT	24	2986	124		
DT	12	1115	93	1.23	0.32
Residual	96	9497	99		

* Treatment tested against LT, BT, DT and residual pooled MSE=105, F=4.54, Sign.=0.01.

In 1986, Location 2 had the highest number of stocked scalps. In the second year, the stocked scalps in Location 2 decreased from 70% to 50%, whereas it increased from 50% to 66% in Location 1 (Figure 5). Overall the drop in stocked scalps for jack pine was small (2%) between the first and second growing season.

Compaction increased the percent of stocked scalps by 30% over sowing with no compaction (47% versus 62%) in the first year. This gain was reduced to 15% by the end of the second season (Figure 6). Pre-sowing versus post-sowing (SCP, SCF vs CSP, CSF) compaction made no difference to the percent stocked scalps. Compaction with the pyramidal surface was slightly more successful than compaction with the flat surface in both years.

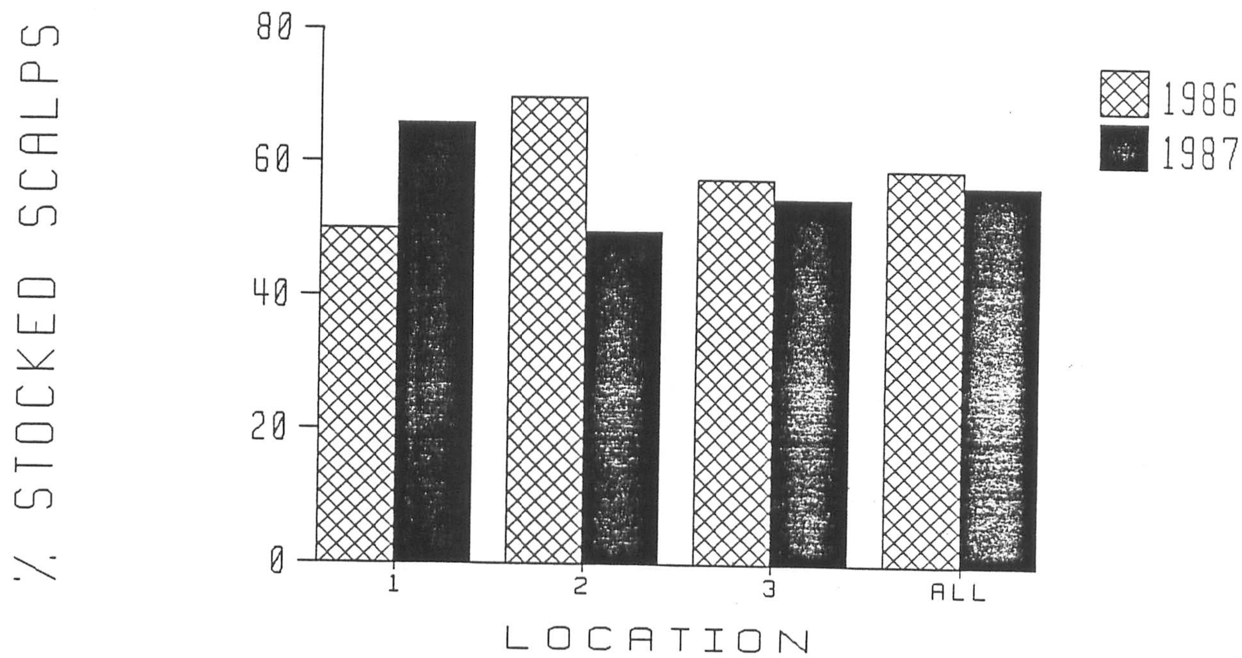

Figure 5. Histogram of the first year assessments of jack pine percent stocked scalps averaged across three locations.

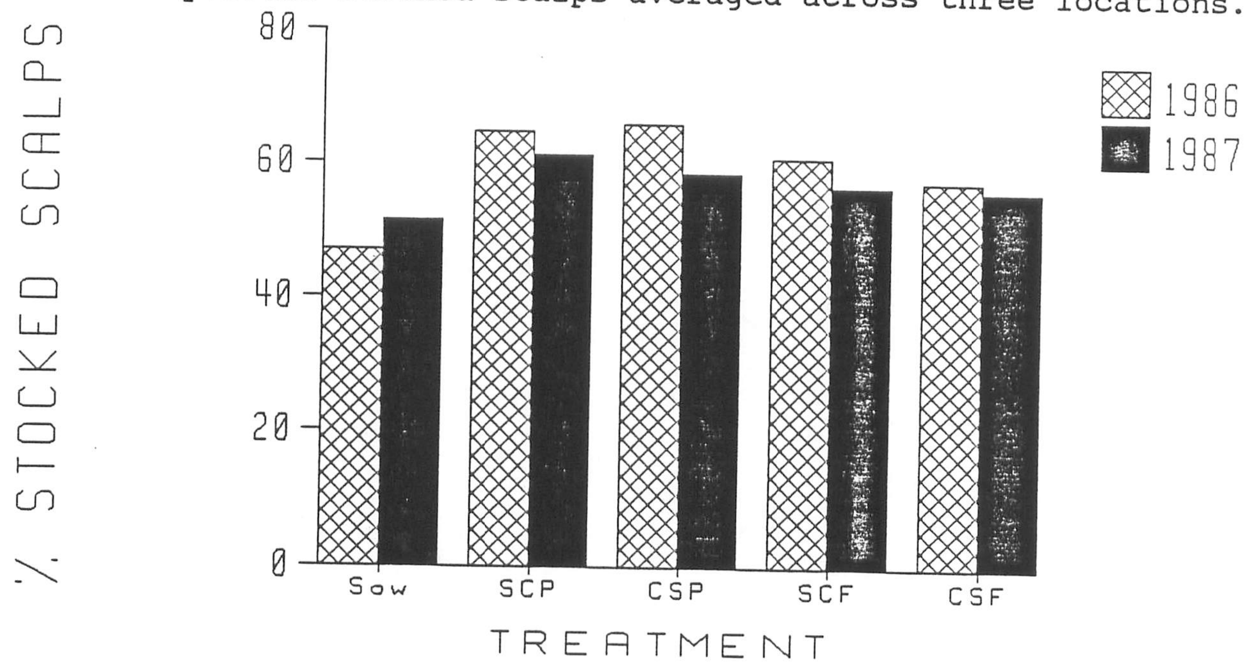

Figure 6. Histogram of two year assessments of jack pine percent stocked scalps averaged across five treatments.

Sowing date had a significant effect on the success of the combined seeding treatments with an almost linear decrease in the number of stocked scalps apparent from the mid-May to the July sowing date in both years (Figure 7). The mid-May sowing date gave the best results by the end of the first growing season and maintained this advantage in the second growing season. The June sowing date also gave acceptable results but there was a significant decrease in stocked scalps resulting from the July sowing date.

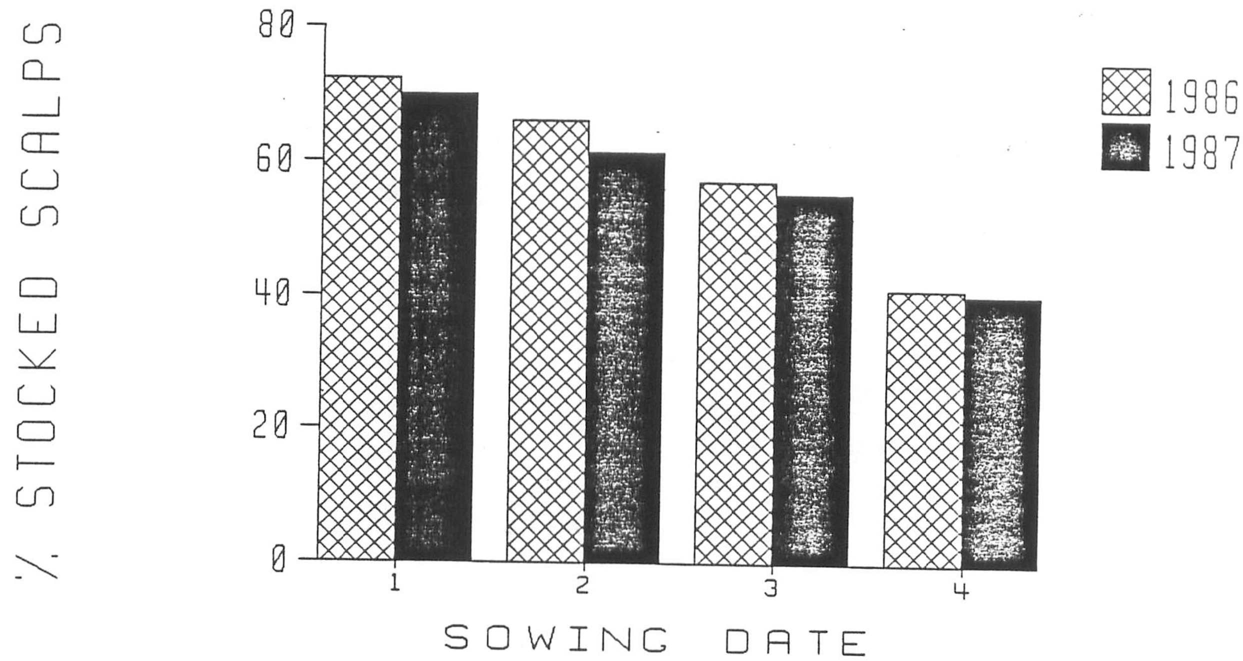

Figure 7. Histogram of two year assessments of jack pine percent stocked scalps averaged across four sowing dates. (1=mid-May, 2=early June, 3=mid-June, 4=early July)

Although no significant treatment X date interaction emerged from the data analysis, an interesting trend appeared. The improved seedling emergence associated with compaction increased with each successive sowing date despite the chance for confounding effects from the observed settling and weathering of the scalps (Figure 8). The pyramidal indentations proved superior to flat compaction treatments and had almost twice the number of stocked scalps over the uncompacted treatment resulting from the latest sowing date in July. Very little difference was evident between pre- and postsowing applications of compaction treatments. The magnitude of this difference decreased significantly after the second growing season as seed, released from cones in the slash, stocked empty scalps (Figure 9). It is possible that some seed sown the previous year also germinated as conditions became favourable.

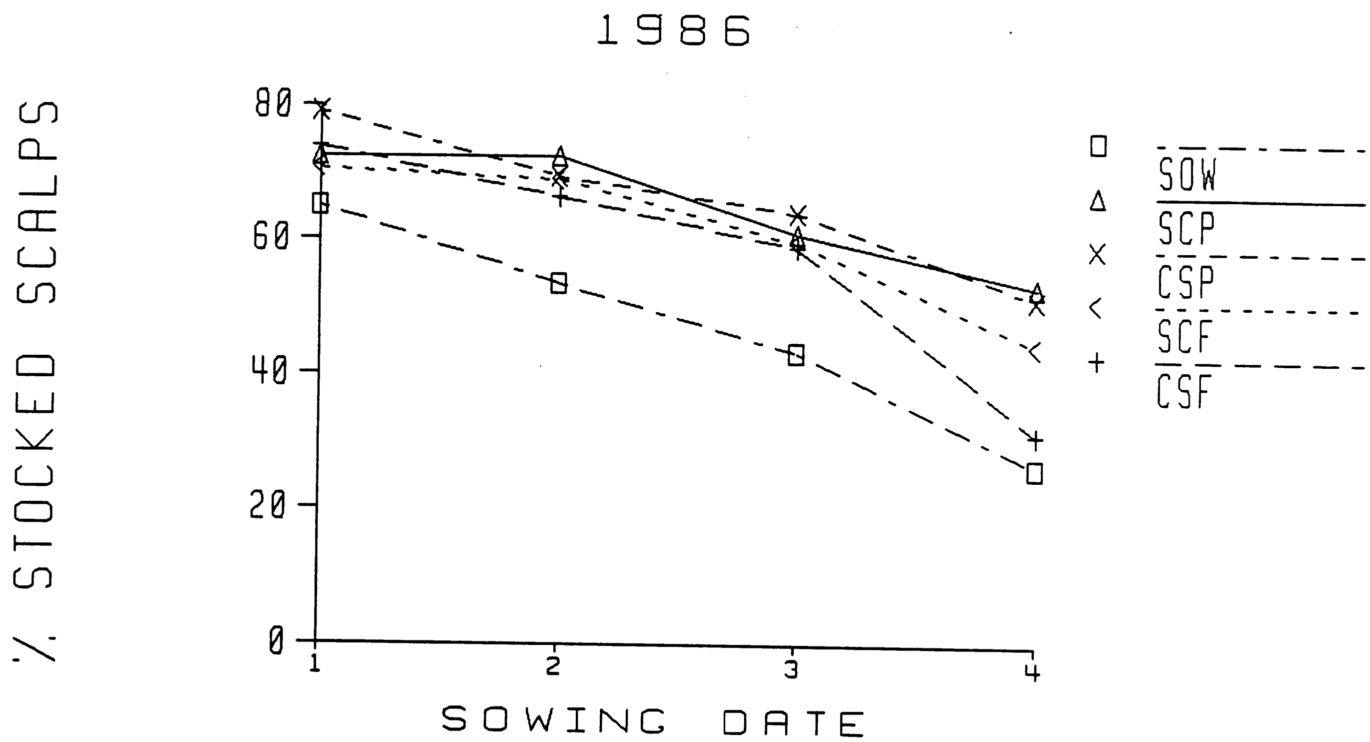

Figure 8. Graph showing the relationship between compaction treatments and sowing dates for jack pine percent stocked scalps assessed in 1986 after the first growing season.

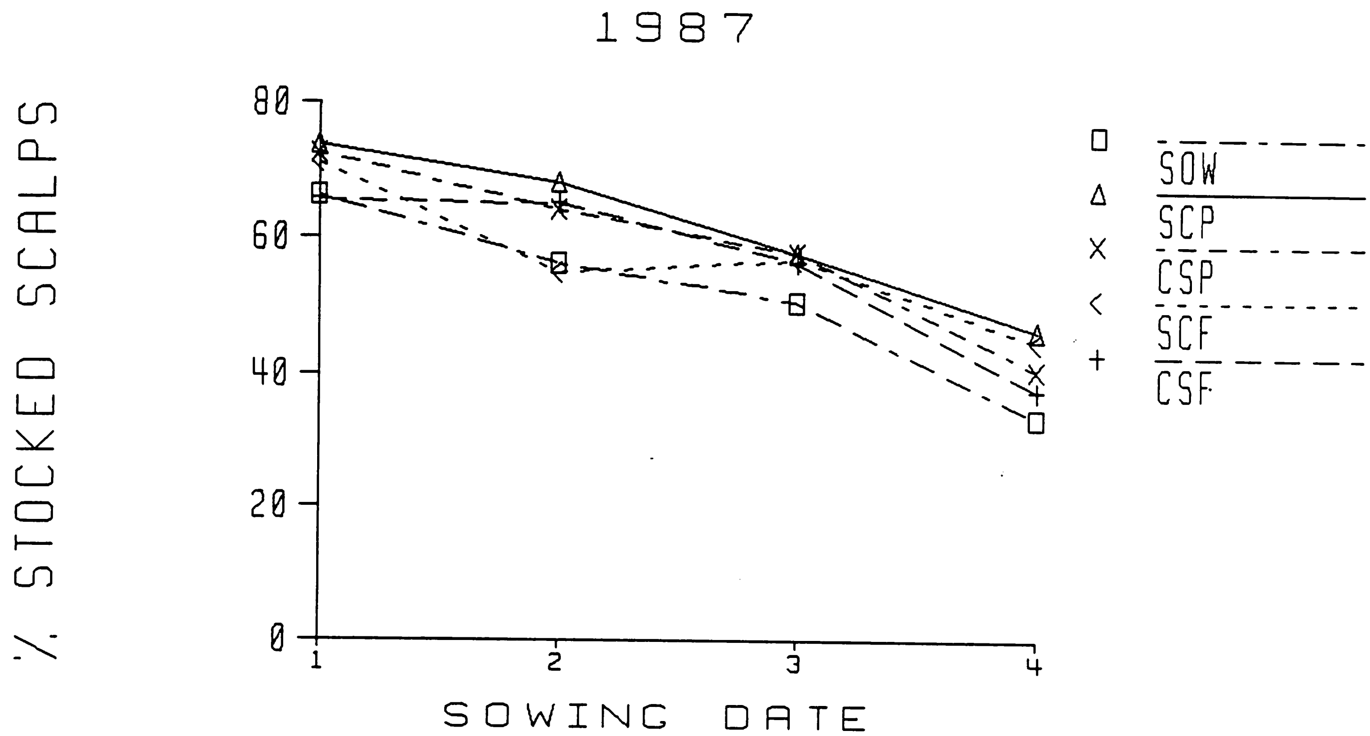

Figure 9. Graph showing the relationship between compaction treatments and sowing dates for jack pine percent stocked scalps assessed in 1987 after two seasons growth.

Scalp attributes measured in 1986 indicated that there were small differences in mean scalp length, width, type, slope, aspect, seed spot position or soil type between stocked and unstocked scalps for both species. Using discriminant analysis, these variables correctly classified unstocked and stocked scalps in 60% of the cases. The predictive value of the discriminant function was significant with seed spot soil type being the most important variable; however, only a weak trend was identified. Stocked scalps showed a 76% occurrence of mineral soil as a group. The remaining seed spot soil matrices were classed as mixed, duff, organic, or dead wood (Appendix 3).

When sowing dates were separated into first and last dates the discriminant function became nonsignificant. Analysis of stocked scalp frequency by various attributes show that scalp attributes did become more important as the season progressed, shifting emphasis from an elevated seed spot to a lower position. A long scalp with a built-up shoulder covering the inverted humus portion of the scalp appeared more conducive to jack pine seedling emergence in the latter portion of the season. These generalizations, however, are not statistically supported because of the weakness of the discriminant function in explaining the differences in patterns of stocking.

Black Spruce

Poor germination and establishment of black spruce at Location 1 and Location 3 resulted in many empty treatment rows causing these sites to be excluded from the analysis. Both locations are extremely dry and exposed, thus seeds that germinated probably desiccated despite the fact that black spruce was a significant component of the original mixed conifer cover-type.

Analysis was restricted to Location 2, a moister site which allowed for sufficient survival of the spruce seedlings to show meaningful results. Unseeded control rows were included to show the extent of natural regeneration on the study area. The average amount of natural regeneration for black spruce in Location 2 yielded 11% stocked scalps in 1986 and remained unchanged in 1987. The high number of empty rows in this treatment caused it to be dropped from the analysis to improve the resolution of sowing treatment effects.

Analysis of variance indicated that sowing date was a significant factor affecting the number of stocked scalps in 1986 but not in 1987. Compaction treatment effects were not significant in either year. (Tables 4 and 5).

Table 4. Analysis of variance table for percent stocked scalps for black spruce in 1986.

Source	df	SS	MSE	F-ratio	Prob. of larger F-ratio
Block (B)	2	442	221	-	-
Date (D)	3	10927	3642	15.4 6	0.00
BD	6	1420	237	-	-
Treat (T)	4	820	205	1.7	0.24
BT	8	950	119	-	-
DT	12	1486	124	0.6	0.79
Residual	24	4686	195	-	-

Table 5. Analysis of variance table for percent stocked scalps for Camp 11 black spruce assessed in 1987.

Source	df	SS	MSE	F-ratio	Prob. of larger F-ratio
Block (B)	2	4004	2002	-	-
Error 1	0	-	-	-	-
Date (D)	3	2762	921	2.21	0.19
BD	6	2488	415	-	-
Treat (T)	4	1075	269	1.33	0.34
BT	8	1615	202	-	-
DT	12	2889	241	0.72	0.72
Residual	24	8021	334	-	-

The number of stocked scalps decreased from the first to last sowing dates in 1986 in a more or less linear progression (68%-22% in the fall of 1987 respectively). The results from the first sowing date was quite acceptable at 68% and was significantly better than the others. By the end of the second growing season, the differences between sowing dates were nonsignificant (Fig. 10). The average number of stocked scalps decreased from 50% to 30% between the first and second growing season, indicating a considerable mortality either over winter or during the 1987 growing season.

Compaction had no effect on the number of stocked scalps for black spruce and actually showed considerably reduced percentages of stocked scalps in the second year after sowing (Figure 11). No differences between pre- and post-sowing treatments nor between flat and pyramidal surfaces were apparent.

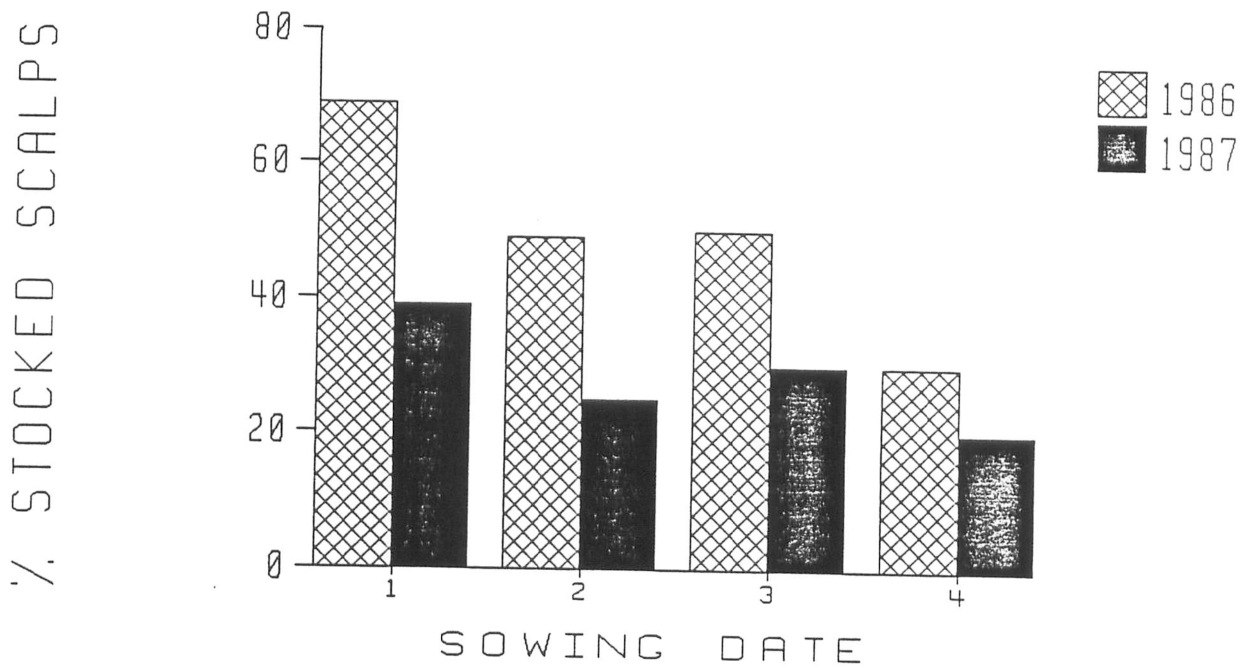

Figure 10. Histogram showing the effects of sowing dates on black spruce percent stocked scalps at Location 2, averaged for five treatments assessed over two years.

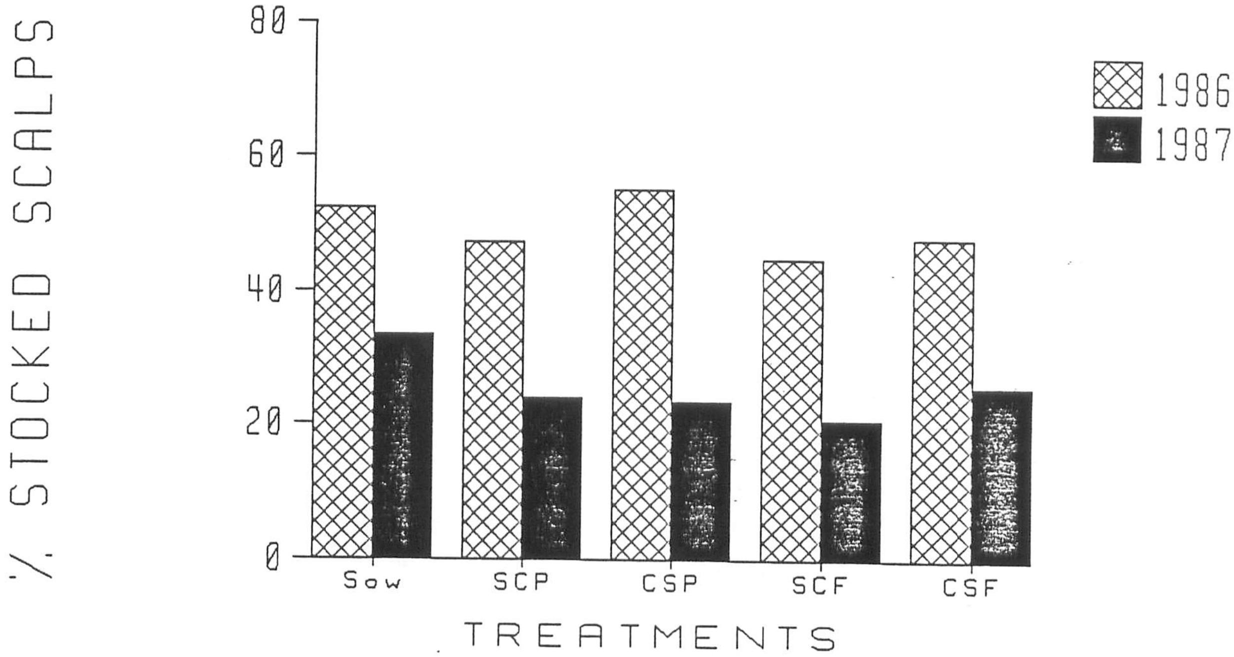

Figure 11. Histogram showing the effects of compaction treatments on black spruce percent stocked scalps at Location 2, averaged over four sowing dates and assessed over two years.

DISCUSSION

Sowing date and site quality had the strongest effects upon seedling emergence and survival. Benefits from compaction were evident for jack pine but not for black spruce. When treatment effects were averaged for both species a linear decline in percent stocked scalps followed the progression of sowing dates from mid May to mid July.

Late fall and early spring sowing result in the highest success rate for jack pine seeding because they ensure early spring germination which reduces losses to drought, frost kill and frost heaving (Clark 1984 Yeatman 1984). Sowing later in the season results in irregular germination and exposure of succulent seedlings to heat and drought causing high transpirational stress (Scott 1966, Miller and Schneider 1971, Brown 1984).

Compaction improves seed-soil contact and/or improves water relations through increased soil capillary movement of water (Bergman & Bergsten 1984). In this study, the linear decline in seedling survival with successive sowing dates suggests that any increase in soil capillary action effected by compaction was more than compensated for by the decrease in soil moisture and increase in temperature which occurred as the season progressed. However, compacted seed spots showed a slower rate of germinate decline relative to uncompacted seed spots with each successive sowing date for jack pine. Despite an apparent lack of significant sowing date x treatment interaction, compaction with a pyramidal surface doubled the number of jack pine stocked scalps compared to uncompacted scalps during the last sowing date in July. This result suggests that the jack pine sowing season could be extended with compaction treatments.

The benefits of compaction shown in this study may not outweigh the risks of late season sowing. Furthermore, the season can only be extended into early July because seedlings will not grow and develop sufficiently to withstand early fall frosts. Meaningful extension of the direct seeding season into the summer will likely require seed physiology preconditioning with germination inhibitors to hold the seeds dormant until the following spring (Groot, 1985).

Sites which are best for germination may not be best for seedling survival. A large decrease in percent stocked scalps occurred in the second year at Location 2 for both species. The fine textured soils, high organic content and the perched water table over bedrock on Location 2 provided better water relations for the seedlings resulting in better initial establishment than on the drier sites.

However, in the spring of the second year flooding (Warrington 1987) and/or frost heaving reduced survival on this site compared to the other locations.

Winston and Schneider (1977) also reported a significant decrease in percent stocking in the second year of a Bracke seeding trial with jack pine and black spruce in northern Ontario. Seed was hand sown and pressed onto the scalp surface by the sower's foot thus effecting a type of compaction in their trial. The decrease was consistent on both the dry and the moist sites. In our study, the number of black spruce stocked scalps decreased from 50% to 27% on Location 2. The number of jack pine stocked scalps also decreased on Location 2 but increased on Location 1 and remained somewhat stable on Location 3. The increase in jack pine stocking at Location 1 is not surprising because jack pine germination may continue until year five (Smith 1984) but black spruce stocking normally decreases after the first season because of drought, frost, frost heaving or lack of over winter seed viability.

Bergman and Bergsten (1984) found Pinus sylvestris L. stocking to increase disproportionately in favour of compaction sowing treatments relative to control treatments after two growing seasons in Sweden. Observations from our study show an even increase only at Location 1 regardless of treatment for jack pine. Perhaps this reflects the uniform drainage and aspect of the outwash plains at Location 1 whereas the variable topography of the remaining two locations could have contributed to this erratic response.

Compaction improved the establishment of jack pine in the first season after sowing and maintained it at a slightly higher level in the second year when compared with sowing without compaction. The poorly stocked uncompacted scalps tended to fill in with seed from cones in the slash, diminishing any gain in stocked scalps from compaction by the second year. However, any gain in stocked scalps in the first season is important for capturing the site from unwanted competing vegetation.

A thin seed cover of soil is thought to be beneficial for jack pine germination as long as it does not prevent the hypocotyl from emerging (Arnott 1974, Brown 1984). Compaction using a pyramidal surface did increase stocking for jack pine especially on the last sowing date. The indentations create a concave seed spot with shading and protection from predators, and the edges erode covering the seed with a thin layer of soil (Bergman and Bergsten 1984).

The increased stocking in the compacted scalps could be the result of a more stable seed spot which reduces washing of the seeds. In many cases, from two to five centimeters in depth of soil had washed away from the swizzle stick markers before the end of the first season. Black spruce's small seed size makes it particularly vulnerable to water movement and burying which may help explain the poor results shown by this species in this study.

Hand placed seed shelter cone systems (Dominy & Wood 1986) are now used on large reforestation projects. These systems not only modify temperature and relative humidity above the seed/soil interface, they also hold the soil and seed in place preventing washing or burying. Black spruce seeded into shelter cones gave excellent results on sites in the vicinity of our studies (Campbell 1988). Perhaps the success of these systems is related to seed spot stabilization.

No compaction treatment by location interaction was detected by the analysis of variance. This suggests that compaction treatment effects are stable across a range of site types.

The gains in jack pine stocking achieved with compaction may result in fewer seeds being used. This would warrant the development of compacting devices for seeding/site preparation equipment. The devices could be a costly development and be vulnerable to breakdown from the rigors of broken terrain and frequent obstacles typical of most boreal cutovers. The results of this study would favour a pyramidal compaction surface over a flat compaction surface.

Although timing of seed drop relative to compaction did not appear to be important, pre-sowing compacting would likely be more desirable than post-sowing compacting because seed could stick with the soil to the compacting wheel surface. Seed could also be damaged by the compacting wheel.

Mechanized compaction could be applied at pressures which far exceed those possible with the manual treatments tested in this study. Perhaps the compaction effect could be enhanced with higher pressures.

Observation of soil movement within the scalp and the favourable effect of compacting in stabilizing the seed spot suggest that any modification to site preparation techniques that improve seed spot stability are beneficial. Trencher disc angle, Bracke gearings, and barrel drag weights can be adjusted to produce shallow, sloping seed spots that should be more stable. Sites prepared and allowed to settle for a year prior to aerial seeding would also give better results than aerial seeding directly after site preparation due to microsite stabilization (Brown, 1984).

Unfortunately the discriminant analysis did not reliably quantify the relationship of various scalp attributes such as scalp slope to seedling emergence. The failure of the discriminant analysis to distinguish stocked and unstocked scalps based upon the scalp dimensions and profiles suggests the following problems. First, the scalp features were described by gross measures not necessarily relevant to the small seed spot environment. Second, the site preparation and seed placement were fairly consistent. Finally, the data was collected a postiori and lacked a sufficient design to detect seed spot microsite differences related to scalp attrobites. However, the discriminant analysis did show a weak positive relationship between occurrences of mineral soil seed spots and stocked scalps for jack pine. This relationship was found to be very important for successful aerial seeding of jack pine by Riley (1980). Site preparation must be intense enough to create mineral soil seed spots for jack pine.

The mineral soil seed spots on the midslope of the scalps used in this study were not the most receptive seed bed type for black spruce. Winston (1975) found slow growing sphagnum moss, moist or rotten wood, mineral soil with a light cover of moss and moist mineral soil to be suitable seedbeds for black spruce. Jeglum's (1984) work in stripcuts show needle beds, live moss, and dark peat to be more important than mineral soil. Fleming and Groot (1984) found the mineral/duff interface to be most suitable for black spruce seeding. It would be difficult to calibrate seed drop to hit these variable and irregular seedbeds and mechanical methods cannot create these seedbed types in a reliable manner. The receptive seedbeds described above are useful for broadcast aerial seeding or natural seeding from residual seed trees or stands.

Compaction failed to improve the ability of exposed mineral soil to encourage black spruce establishment from seed. Black spruce will continue to be a problem for direct seeding on upland sites in Northwestern Ontario. For this reason very high seeding rates are recommended. It is possible that compaction may have shown modest levels of improvement if the initial sowing rates had been higher than the five seeds per scalp used in this study. Fleming and Groot (1984) indicate that 5-8 seedlings per hundred sown is the best one can expect for direct seeding on upland sites on receptive seed beds.

CONCLUSIONS

Site type and sowing date had a greater influence on the establishment of jack pine and black spruce than the compaction treatments tested in this study. Microsite compaction significantly improved the establishment of direct seeded jack pine but had no effect on black spruce. Black spruce may require higher seeding rates than those used in this study to test for compaction effects. The mineral soil seed spots created by the site preparation in this study are not suitable for black spruce. The timing of the compaction relative to seed drop had no impact on the success of direct seeding but the pyramidal compaction surface improved jack pine seedling establishment slightly over compaction with a flat surface. Compaction treatments can be used to extend the jack pine sowing season into July; however, best results are achieved with early spring sowing for both species. The potential for improved jack pine stocking and distribution from scarifier/seeders with compacting devices warrant the development and testing of these machines.

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APPENDIX 1

TREATMENTS ASSIGNED TO SPECIFIC ROW NUMBERS

(1) Control - no seed sown

(2) Sow - seeds sown with no compaction treatment.

(3) SCP - seeds sown followed by compaction with a pyramidal surface.

(4) CSP - compaction with pyramidal surface followed by sowing.

(5) SCF - seeds sown followed by compaction with a flat surface.

(6) CSF - compaction with a flat surface followed by sowing.

Note that the number extensions refer to sowing dates.

LOCATION 1

ROWS	BLOCK 1	BLOCK 2	BLOCK 3
1	CONTROL4	CONTROL2	SCP1
2	CONTROL1	-	-
3	SOW3	CSP1	CSF2
4	-	CONTROL3	SCF4
5	SCP2	CSP3	SCF1
6	CSP1	SOW1	-
7	-	CONTROL1	CSF 3
8	CSP2	SOW4	CSF4
9	-	CSF1	CSF4
10	SCF3	CSF1	CSP3
11	SCP1	CONTROL4	CSP3
12	SCF4	SCF3	CONTROL1
13	CSF3	CSF4	CONTROL4
14	CSF4	-	SOW2
15	SCF1	CSP4	SCF2
16	SOW4	SCF2	SCP3
17	SCP3	SOW3	SCF3
18	SCP4	CSP2	SOW3
19	CSF1	SCF1	CSP2
20	CONTROL2	SCP3	SOW4
21	SOW2	SCF4	SCP4
22	CONTROL3	SCP1	CSF1
23	SOW1	SCP2	CSP4
24	CSP3	SCF2	CONTROL3
25	CSF2	CSF3	CONTROL2
26	CSP4	SOW2	SCP2
27	SCF2	-	SOW1

LOCATION 2

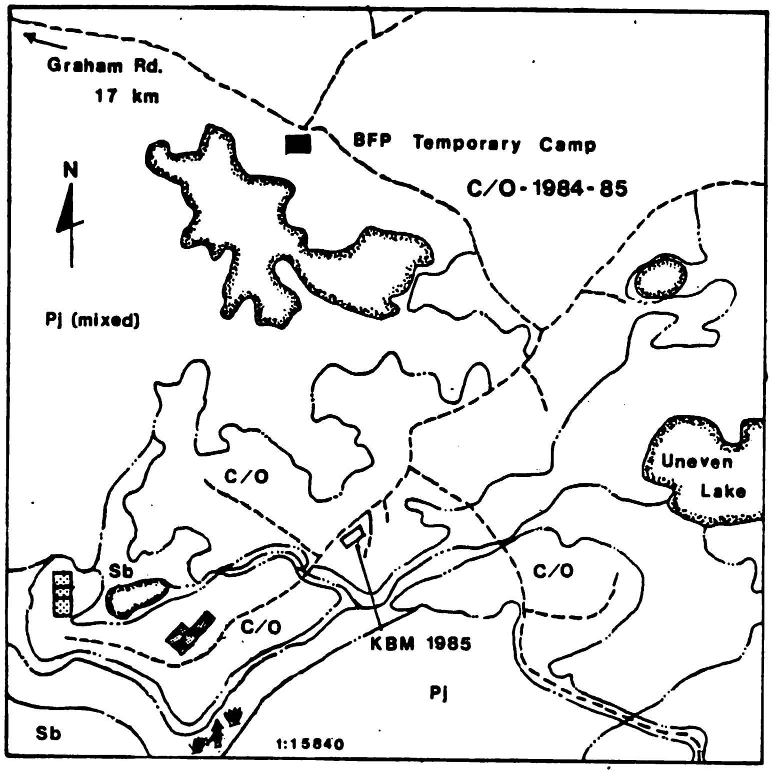
ROWS	BLOCK 1	BLOCK 2	BLOCK 3
1	CONTROL3	SOW1	CSP2
2	CSP4	SCP4	SCFI
3	CONTROL1	CSP2	CONTROL1
4	SCP4	SOW3	CSF1
5	CSP1	CSF2	SOW1
6	SCF1	CONTROL1	CONTROL4
7	SOW3	SCF1	SCP3
8	SCP3	CONTROL4	SOW2
9	SCP2	SOW2	CSF2
10	SOW1	CONTROL3	CSP4
11	CSF4	SOW4	SCP2
12	SOW2	SCF3	CSF3
13	CONTROL2	SCF2	SCP1
14	CSF3	SCF4	SCP1
15	SCF3	CSF3	SCP3
16	SCP1	SCP1	CONTROL2
17	SCP3	SCF4	SCP4
18	CSF2	SCP2	SCF2
19	SOW4	SCP3	CONTROL3
20	SCF1	CONTROL2	CSF4
21	SCF4	CSF1	SCF3
22	CSP2	CSP1	SOW4
23	SCF2	CSP4	SCF4
24	CONTROL4	CSP3	SOW3

LOCATION 3

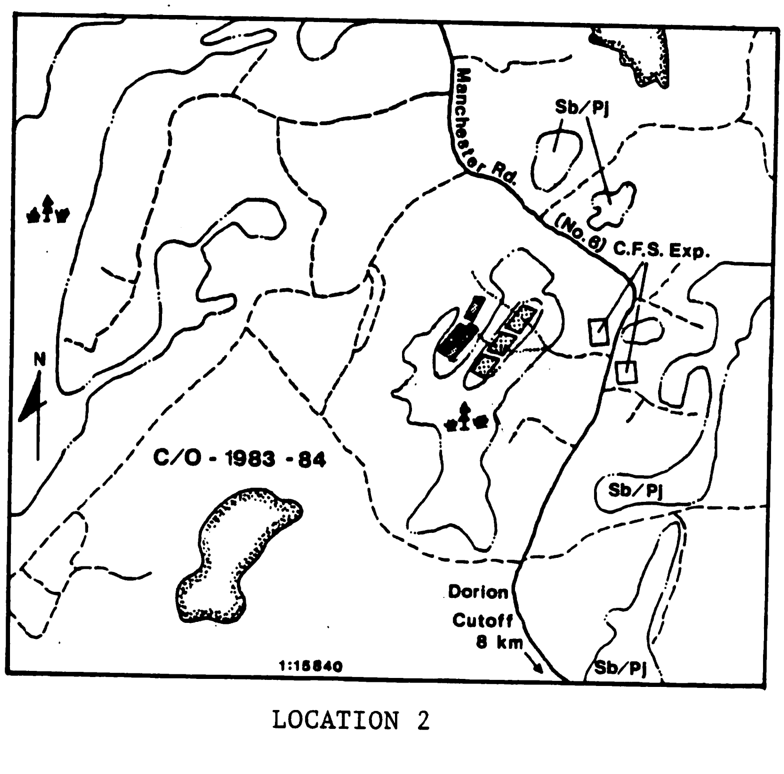
ROWS	BLOCK 1	BLOCK 2	BLOCK 3
1	SOW1	CSP4	CSP2
2	SOW3	CONTROL4	CSF3
3	SCF3	SCP4	SOW3
4	SCP3	SCF3	SOW1
5	CSP2	SOW1	CONTROL1
6	CSF4	CSF3	CONTROL4
7	CONTROL3	CSF4	SCP1
8	SCF2	CSP3	CSP4
9	SCP4	SCF1	CSP1
10	SCP2	CONTROL3	SCP4
11	CSF3	SCP3	CSF4
12	SCF4	SOW2	SOW4
13	CSP1	CONTROL1	CSF1
14	CSP3	SCP1	CSF2
15	SCP1	SOW4	SOW2
16	SOW4	SOW3	SCF2
17	SOW2	CONTROL2	CONTROL3
18	CONTROL1	SCF2	CONTROL2
19	SCF1	CSF1	SCP3
20	CSF2	CSF1	CSP3
21	CONTROL4	CSP4	SCF3
22	CSF1	CSP2	SCF4
23	CONTROL2	SCF4	SCF1
24	SCP4	SCP2	SCP2

APPENDIX 2

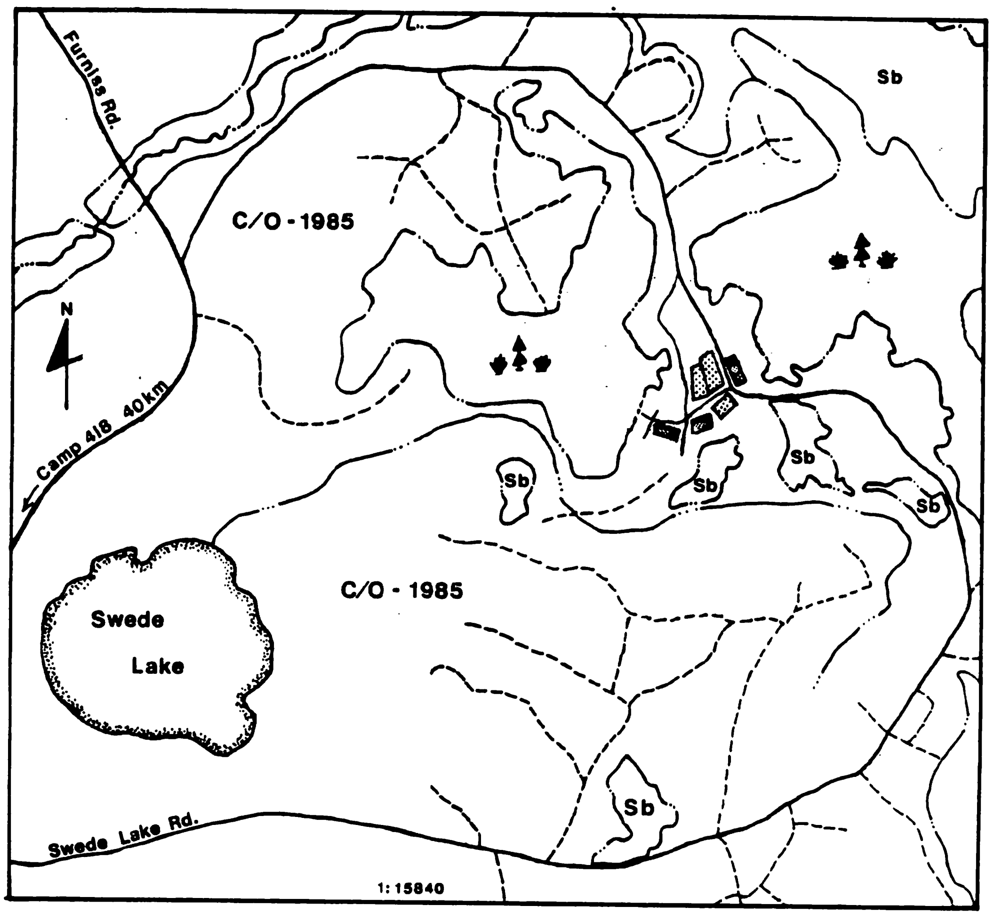
MAPS DETAILING STUDY BLOCK LOCATIONS



LOCATION 1



LOCATION 2


Furniss Rd.
C/O - 1985
Sb
N
Camp 418 40km
Sb
Sb
Sb
Sb
C/O - 1985
Swede
Lake
Sb
Swede Lake Rd.
1: 15840

LOCATION 3

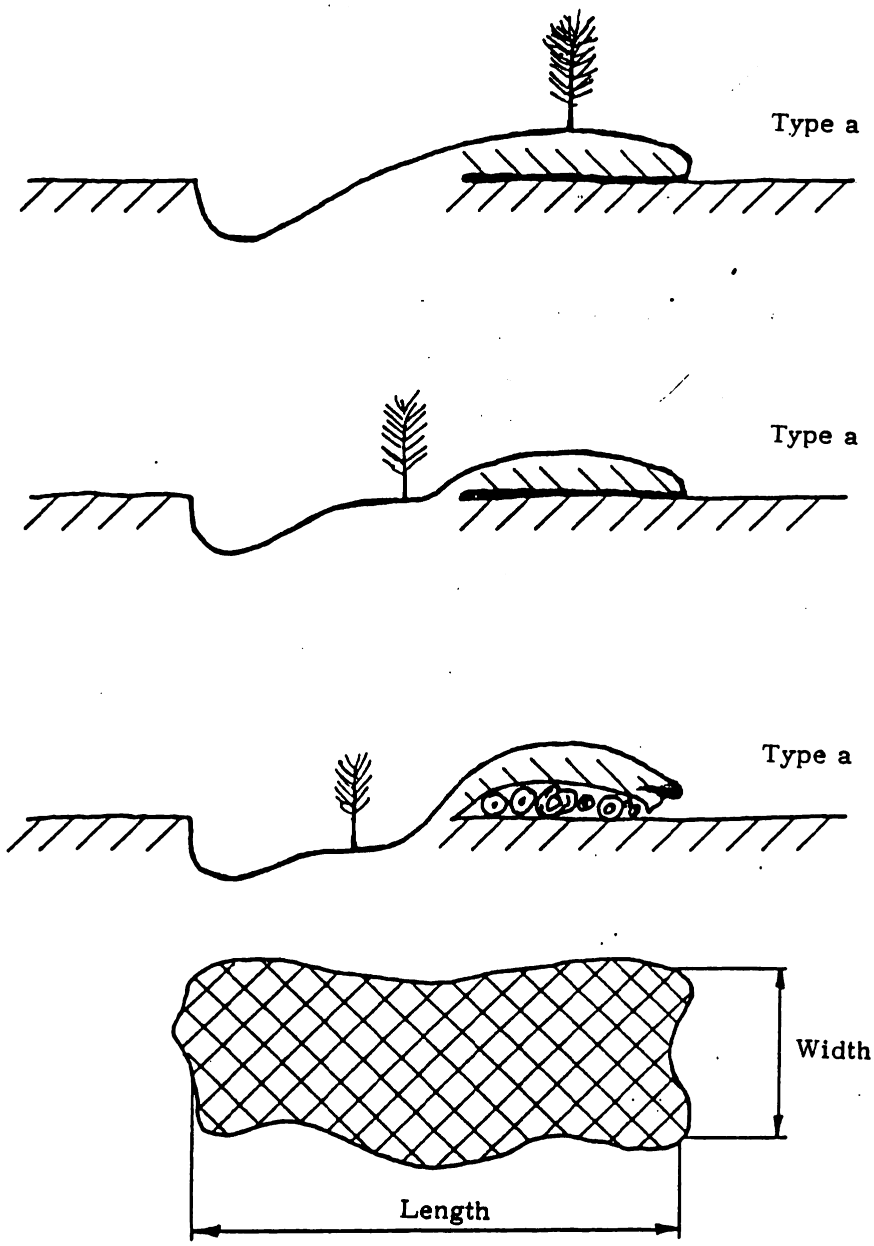
APPENDIX 3

This appendix contains tally sheets header codes for scalp attribute data. Note that only four soil matrix categories were used. Scalp profile codes A-C are described on the following pages.[1]

* * * * * * * * * * * *

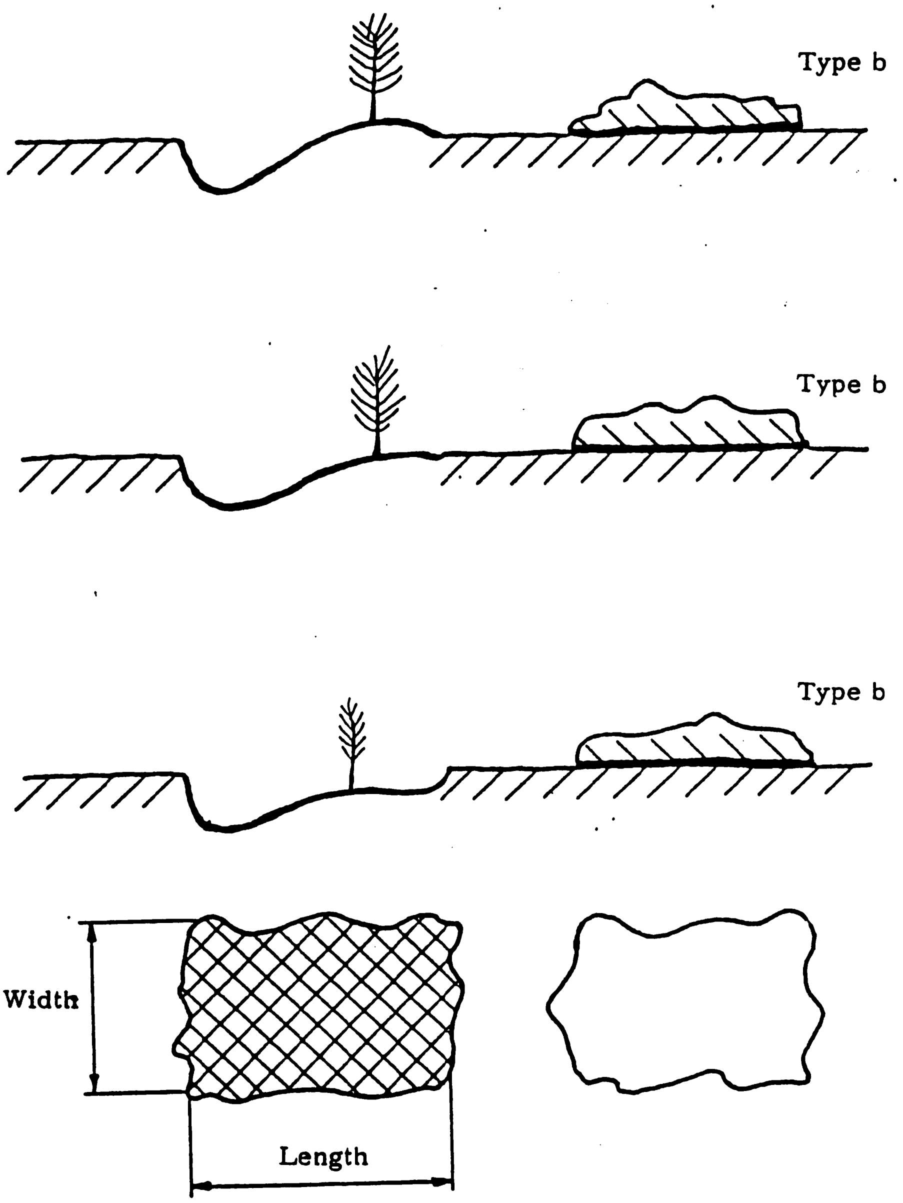
1 Charlesworth, E. 1983. Adaptation of a scarifier to different site types and scarification obstacles. UNpub. Manuscript, KBM Forestry Consultants Inc. Thunder Bay, Ont.

LENGTH AND WIDTH OF EXPOSED MINERAL SOIL - Profile types a



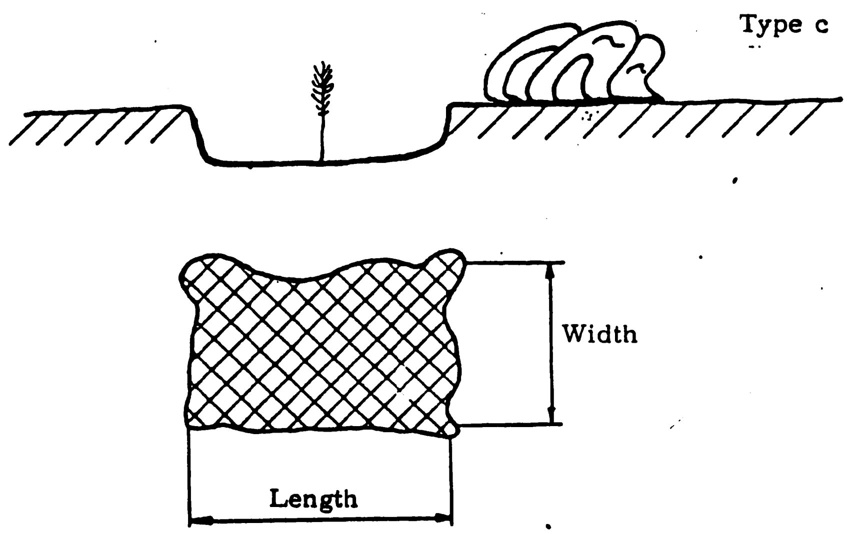
Requirement: the inverted layer has to be held together and covered by mineral soil

LENGTH and WIDTH of exposed mineral soil - Profile types b



Requirement: Inverted layer is separate and/or not covered by mineral soil

LENGTH and WIDTH of exposed mineral soil - Profile types c



Requirement: No drainage and the planting spot is always below ground level

CODE INDEX

COL. 1-2	BLOCK
1SB1	1
1SB2	2
1SB3	3
1PJ1	4
1PJ2	5
1PJ3	6
2SB1	7
2SB2	8
2SB3	9
2PJ1	10
2PJ2	11
2PJ3	12
3SB1	13
3SB2	14
3SB2	15
3PJ1	16
3PJ2	17
3PJ3	18

COL. 5	TREATMENT
CONTROL	1
SEED	2
SCP	3
CSP	4
SCF	5
CSF	6

COL.14	PROFILE
A	1
B	2
C	3

COL. 15	PROFILE LEVEL
+	1
=	2
-	3

COL. 16	SLOPE
0 - 10	1
f0 - 20	2
20 +	3

COL. 17	SPOT LEVEL
_ - 10 cm g.l.	1
-10 cm 3cm g.l.	2
3cm g.l.	3

COL. 18	ASPECT
N	1
E	2
S	3
W	4

COL. 19	MATRIX
Mineral	1
Duff	2
Mixed	3
Wood	4

Column's 25-40 array for # unhealthy/cause - field = 3

Poor health	1
Dead	2

Drought	1
Drowning	2
Frost Heaving	3
Erosion	4
Smothering	5
Animal	6
Others	7