JACK PINE ESTABLISHMENT: EFFECT OF STOCK TYPE, BRÄCKE SCARIFICATION, MOUNDING, AND CHEMICAL SITE PREPARATION

THREE-YEAR RESULTS

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Cover Photos:

Left: Hand planting 2+0 bare-root jack pine at the Bullock Township experimental site. (Photo by T.P. Weldon)

Middle: Jack pine one growing season after outplanting as a 2+0 bare-root seedling. Treatment #7, 20-L "pimple" mineral mounds on a mineral-soil substrate, without chemical site preparation. (Photo by J.E. Wood)

Right: Jack pine three growing seasons after outplanting as a 2+0 bare-root seedling. Treatment #15, 20-L "dimple" mineral mounds on a mineral-soil substrate, without chemical site preparation. (Photo by R.F. Sutton)

INTRODUCTION

Site preparation is almost always essential for successful outplanting of forest trees (Bärring 1965, 1967; Alm 1974; Söderström 1977; Söderström et al. 1978, 1979; Berg 1980; Martinsson 1985). Innumerable combinations of kinds and intensities of site preparation are possible. Choosing a cost-efficient method of site preparation to secure the desired results from outplanting is one of the most difficult tasks that faces the forest manager.

Patch scarification (= "screefing") has long been used by foresters to get rid of weeds and expose mineral soil before planting. Edlund (1980a,b) described patch scarification as the site preparation technique most commonly used in Sweden over the past 15 years. One of the most successful of the various machines developed to mechanize patch scarification is the Bräcke scarifier. Developed in Sweden, the Bräcke has been used in Canada since the early 1970s (Smith 1987). In the Upper Great Lakes Region of the United States, Bräcke scarification accounted for 12% of the mechanical site preparation carried out in 1981 (Sajdak 1982). Mounding, in comparison with patch scarification, has been reported as having good (Berg 1980, McMinn 1985), indifferent (Sutton 1983, Martinsson 1985) and sometimes detrimental (Sutton 1984) effects on performance. Initially promising results (Söderström 1977, Söderström et al. 1978) from mounding site preparation research in Sweden led to the development of the Bräcke mounder, an optional attachment for the Bräcke scarifier (Sutton 1984).

Response to site preparation including mounding has been found to vary with stock type (Martinsson 1985); classes and grades of stock within types may also vary greatly in their response to site conditions (Scarratt 1974, Dobbs 1976, McMinn 1982). The stock types tested in our study were those that were in operational use in Ontario at the time, and are still in use. Stock size may be more important than stock type (cf. Ball and Kolabinski 1986).

Graminaceous weeds can be exceedingly detrimental to plantation establishment (Bärring 1967, Sutton 1975). Herbicides offer a means of securing effective relief from such competition. Therefore, we evaluated chemical site preparation along with mechanical methods.

Officials of Algoma Central Railway's (ACR's) Lands and Forests Division were interested in evaluating mounding site preparation in connection with their planting program near Eton, some 200 km by rail north of Sault Ste. Marie, Ontario, on land that became grassy and largely treeless after pulpwood cutting between 1925 and 1930. In cooperation with W.L. Oliphant and S.W. Kent (Manager and Forester, respectively, of ACR's Lands and Forest Division), authors Wood and Sutton designed the field experiment for which three-year results are reported herein.

Objective

The purpose of the experiment was to assess the field performance of bare-root and paperpot jack pine[2] in relation to several site preparation and planting treatments.

Experimental Design

Plots split by stock type, with 20 bare-root and 20 paperpot trees per plot, were used in a randomized block design. Eight of 20 treatments were doubly replicated within each of the four blocks, i.e., each block of 28 plots contained two plots that received treatments 5, 6, 9, 10, 13, 14, 17, and 18, and one plot that received each of the other 12 treatments. Treatments within blocks were randomly assigned. This gave 20 x 4 = 80 or 2 x 20 x 4 = 160 trees per stock type per treatment.

The Site

Located at 47°30'N, 84°30'W, in Bullock Township in the Algoma Section (L. 10) of the Great Lakes-St. Lawrence forest region (Rowe 1972), the study area has gently rolling topography on deep glaciofluvial deposits, with mainly silt loam soils (Appendix A), at a mean elevation of about 325 m. Scattered individuals and small clumps of aspen, black spruce, and jack pine were present. Grasses, blueberries, strawberries, and bracken were abundant.

The Treatments

Superimposed on the 20 treatments (Table 1) was the comparison between 2+0 bare-root stock and Japanese FH408 paperpot stock.

Stock: Current-season (spring-lifted), bare-root 2+0 jack pine from Site Region 4200 (Skeates 1979) were supplied by the Ontario Ministry of Natural Resources (OMNR) from its Thessalon tree nursery. Overwintered (sown in the greenhouse on 7 June 1983) FH408 paperpot jack pine of Site Region 3200 provenance were produced at the Great Lakes Forestry Centre. In May 1984, the trees were planted about 2 m apart in rows separated by about 2.5 m.

The bare-root stock had foliage of good color, root systems that were well developed, and a mean shoot length of about 25 cm; however, 90% or more of the trees had flushed 2-8 cm and the roots appeared to be dry. The stock had been shipped in bags lacking packing material. The paperpot stock had good color, and many white root tips were evident at planting. A random sample of 25 trees of each stock type was used for morphological characterization (Table 2).

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2 For botanical names and authorities see Appendix B.

Table 1. Treatments applied.

Treatment no.	Bräcke scarification	Mounding	Mound shape[a]	Mound type[b]	Mound volume (L)	Herbicide[c]
1	–	–				–
2	–	–				+
3	+	–				–
4	+	–				+
5	+	+	P	M/M	10	–
6	+	+	P	M/M	10	+
7	+	+	P	M/M	20	–
8	+	+	P	M/M	20	+
9	+	+	P	M/O	10	–
10	+	+	P	M/O	10	+
11	+	+	P	M/O	20	–
12	+	+	P	M/O	20	+
13	+	+	D	M/M	10	–
14	+	+	D	M/M	10	+
15	+	+	D	M/M	20	–
16	+	+	D	M/M	20	+
17	+	+	D	M/O	10	–
18	+	+	D	M/O	10	+
19	+	+	D	M/O	20	–
20	+	+	D	M/O	20	+

[a] P = "pimple" mound, convex surface up; D = "dimple" mound, concave surface up.
[b] M/M = mineral mound placed on mineral soil on shoulder of the Bräcke patch; M/O = mineral mound placed on organic substrate.
[c] Patch treatment with herbicide applied August 1983 prior to planting May 1984.

Table 2. Morphological characteristics of planting stock.

Stock type	Total dry mass (g)	Root collar diameter (mm)	Root area index[a] (cm^2)	Shoot:root ratio	Shoot length (cm)
Bare-root	6.9 (±3.0)[b]	4.6 (±1.2)	37.5 (±12.5)	6.6 (±4.4)	25.3 (±5.0)
Paperpot	1.1 (±0.4)	2.1 (±0.4)	13.6 (±3.8)	5.6 (±2.8)	18.9 (±2.3)

[a] Morrison and Armson (1968).
[b] Figures within parentheses are standard deviations.

Bräcke scarification: This was done by a skidder-mounted Bräcke scarifier in June 1983. The four experimental blocks had been laid out beforehand, and in each block seven passes were made up one side and another seven passes down the other, each pass creating two rows of patches. The average size of Bräcke patch is 63 x 80 cm (Smith 1979); patch size, which has influenced performance in some studies (Bärring 1965, Söderström et al. 1978, Sloan and Ryker 1986), was not investigated in our study.

Mounding: Mounds were made manually in late June 1983. The positioning of the M/M mounds (mounds on a substrate of mineral soil) was sometimes made difficult because of the steepness of the shoulder; positioning of the M/O mounds (mounds on a substrate of organic matter) was also difficult in those instances in which the organic matter scuffed out of the patch had not been deposited cleanly. Unmodified mounds were generally convex from a central high point; these constituted the "pimple" mounds. "Dimple" mounds were made in August 1983 by trampling to form a central concavity in the upper surface of unmodified mounds. Containers of known volume were used to obtain the 10 L or 20 L per mound.

Herbicide treatment: Backpack sprayers were used on 30 and 31 August 1983 to apply Roundup® to a circular patch 1.4 m in diameter at 2.00 kg active ingredient/ha (5.6 L Roundup®/ha). The herbicide was mixed with water in a 1.5% solution. In the herbicide treatments trees were to be planted approximately in the center of the patch. At the time of the 30-day assessment, the lack of coincidence between the treated patches and the location of some of the outplants in treatment 2 became apparent; in this treatment, only 56% of bare-root trees and 44% of paperpot stock were planted in the treated patches. Evaluation of this treatment must be weighted accordingly.

Planting: All stock was hand-planted on 13 and 14 May (paperpots) and 14-15 May (bare-root) 1984 in moist soil. By day, the weather was partly sunny, cool in the morning and warmer in the afternoon, with light winds. There was frost by night.

Crop tree assessments: Planted stock was first assessed on 16 May 1984 when heights and stem diameter at ground level were measured. Already by that time, 10-20% of the paperpot stock and 60-70% of the bare-root stock exhibited wilting (mostly temporary) of newly flushed foliage. Thirty days after planting, and at the end of the first, second, and third growing seasons, all stock was reassessed.

Weather

Weather data recorded at the experimental site from 11 June to 22 September 1984 indicated values close to the 30-year norms for mean monthly minimum and maximum temperatures at the federal weather station at Wawa, Ontario (Anon. n.d.), 430 m elevation, 48°04'N, 84°45'W. Precipitation during the period was also close to normal.

Data Analysis

The following seedling performance parameters were examined: survival, total height, stem volume, and mean relative growth rate (RGR). Stem volume was calculated according to the volume formula for a right-circular cone (1/3 basal area x seedling height). Mean RGR (stem volume) was calculated according to the formula provided by Hunt (1982):

$$RGR\ (T_2-T_1) = (Log_eW_2-Log_eW_1)/(T_2-T_1)$$

where W_2 and W_1 represent stem volume at time 2 (T_2) and time 1 (T_1), respectively. Mean RGR is expressed per unit time (i.e., per year). Survival data were analyzed by a Chi-square test (Steel and Torrie 1980). Growth data were analyzed by analysis of variance for balanced split-plot designs (Milliken and Johnson 1984).

RESULTS AND DISCUSSION

Third-year Survival

Survival averaged 90% for bare-root stock, significantly higher than the 83% for paperpot stock (Table 3).

Table 3. Survival of jack pine after three growing seasons, by treatment and stock type, showing the significance (** = $P< 0.01$, * = $P <0.05$, NS = not significant) of differences between bare-root and paperpot stock types.

Treatment no.	Bare-root stock (%)	Paperpot stock (%)	Means (cm)
1	75	36	**
2	66	30	**
3	88	80	NS
4	94	93	NS
5	98	81	**
6	94	91	NS
7	88	94	NS
8	90	87	NS
9	94	85	**
10	92	83	*
11	91	91	NS
12	95	90	NS
13	95	93	NS
14	88	88	NS
15	98	85	**
16	94	95	NS
17	90	79	*
18	89	93	NS
19	91	94	NS
20	89	86	NS
Means	90	83	**

In 12 of 18 treatments involving mechanical site preparation, survival among bare-root stock was higher than among paperpot stock--in seven cases non-significantly, in two cases significantly ($P < 0.05$), and in three cases very significantly ($P < 0.01$). In the remaining six treatments survival of paperpot stock was greater than or equal to that of bare-root stock.

In treatments involving mechanical site preparation, survival averaged 92% for bare-root stock and 88% for paperpot stock. In treatments without mechanical site preparation survival averaged 70% for bare-root stock and 33% for paperpots. Mechanical site preparation typically increases survival rates over those on untreated sites (cf. Söderström 1977, Berg 1980, Martinsson 1985).

Without site preparation, the survival differential in favor of bare-root stock was much greater than in treatments that included mechanical site preparation. The interrelationship between stock size, performance, and intensity of site preparation has been noted by Dobbs (1976). The poorer competitive ability of small containerized outplants in comparison with larger stock is well illustrated by these results. Dobbs (ibid.) and McMinn (1985) are among those who have suggested that high costs of large stock with high performance potential might be traded off against the reduced need for site preparation.

In the non-mounded Bräcke patch treatments, bare-root survival was 20% greater than in the non-scarified treatments. In paperpots, the differential was 53% in favor of the non-mounded Bräcke patch treatments over the non-scarified treatments.

In some Swedish trials, Berg (1980) reported second-year survival of 2+1 Scots pine outplanted without site preparation as 4%, whereas survival was between 34% and 49% after patch scarification. In other Swedish trials, survival rates among 2+1 bare-root Scots pine at the end of the third growing season were 90% or more after patch scarification of various sizes, and 75% without scarification (Söderström et al. 1979). Evidently, patch scarification commonly influences survival rates in boreal outplantings. A beneficial effect on water relations may be presumed.

Mounding, when compared with Bräcke scarification alone, did not improve bare-root survival. Similarly, in a Swedish study, 1st- through 6th-year survival rates among 2+0 Scots pine were virtually identical whether planting had been in mounds or on patch-scarified ground (Martinsson 1985). Sutton (1987) reported that in six outplantings of 2+0 jack pine in boreal Ontario, the 3rd-year survival rate was 96%, whether stock was planted on the shoulder of the Bräcke patch or at the bottom of the patch, and 92% when stock was planted on mounds.

Without chemical site preparation, paperpot survival was higher in seven of the eight mounding treatments than with Bräcke scarification alone. This suggests a tendency for mounding to improve survival in the

Eton situation. With chemical site preparation, mounding did not improve survival over that obtained with Bräcke scarification alone. In Martinsson's (1985) study in Sweden, there was also very little difference in early survival of Kopparfors (K-pot) containerized Scots pine between plantings on mounds and those in scarified patches.

Mound shape and mound type would seem to be inconsequential. Mound volume had no consistent effect.

Chemical site preparation had little or no effect on bare-root or paperpot survival.

Third-year Total Height

Treatment means for total height ranged from 76 to 103 cm for bare-root stock and from 45 to 75 cm for paperpot stock (Table 4). In every treatment, total height of bare-root stock exceeded that of paperpot stock. However, third-year total height of paperpot stock was superior to that of second-year bare-root stock in 18 of 20 treatments and equal in one treatment (data on file).

Table 4. Total height (cm) after three growing seasons, by treatment, stock type, treatments combined, and stock types combined. For treatment means LSD 6.7 (P = 0.05); for stock type means LSD 2.3 (P = 0.05).

Treatment no.	Bare-root stock (cm)	Paperpot stock (cm)	Means (cm)
1	82	55	68
2	76	45	60
3	81	53	67
4	83	58	70
5	95	62	78
6	83	62	72
7	93	64	78
8	89	62	76
9	100	66	83
10	100	71	86
11	91	65	78
12	102	73	88
13	93	63	78
14	99	65	82
15	95	71	83
16	99	70	84
17	96	68	82
18	103	75	89
19	94	70	82
20	94	72	83
Means	92	64	

The mean difference in height between **third-year** paperpots and **second-year** bare-root stock in non-mounded (i.e., in the untreated and Bräcke-treated patches only) treatments was about 2 cm in favor of paperpots (data on file). In mounded treatments, however, the difference was 10 cm, the paperpots benefiting more than bare-root stock would from the more intensive site preparation.

Without chemical site preparation, the use of Bräcke patch scarification did not significantly influence total height in both stock types combined. With chemical site preparation, the Bräcke patch treatment produced significantly greater total height after three growing seasons than was obtained without the Bräcke patch treatment in both stock types combined.

Heights reported by Söderström et al. (1979) for Scots pine, three years after planting as 2+1 stock in scarified patches of three sizes, from 25 x 25 dm to 50 x 50 dm, are about half those we found for bare-root jack pine that did not receive mounding treatments. Söderström et al. (ibid.) found that on smaller patches (2 x 2 dm and 10 x 10 dm) results were intermediate between those obtained without site preparation and with the larger patches. With the Scots pine (ibid.), the significant positive response of total height to scarification did not increase with increasing patch size above 25 x 25 dm, i.e., patches more than 10 times the area of the normal Bräcke patch (cf. Smith 1979).

Mounding was generally beneficial for both stock types. Without chemical site preparation, mounding (compared with Bräcke scarification alone) significantly improved total height in every case; with chemical site preparation, mounding significantly improved total height in six out of eight cases.

Sutton (1987) found that in six outplantings of 2+0 jack pine in boreal Ontario, mean third-year total heights were 74 cm and 69 cm on the shoulder and at the bottom of the Bräcke patch, respectively, and 69 cm and 66 cm on the M/M and M/O mounds, respectively. Mean 3rd-year total heights of jack pine planted on the shoulder of the Bräcke patch exceeded, on five of the six sites, those of trees on the M/M mounds and, on all six sites, those of trees on the M/O mounds (Sutton 1987).

Sutton's (1987) data tend to point in a different direction from those of the study reported here. This may be accounted for by site differences, as mounding may ameliorate a site dominated by grasses to a greater degree than were the cutovers in the other study. Differences of this kind commonly arise from differences in stock as well.

In contrast, Martinsson (1985) found that the patch scarification treatment produced third-year total height in 1+0 Kopparfors containerized Scots pine in Sweden superior to that obtained with mounding site preparation. Lodgepole pine showed a similar, even stronger, effect.

Conditions on the Eton site would seem to be conducive to obtaining positive height responses to mounding.

Mound shape and volume had no significant effect on height growth. Although mound type had no significant effect **in the absence of** chemical site preparation, trees on M/O mounds **with** chemical site preparation were taller than those on M/M mounds in three of the four comparisons--significantly so in two of them.

There were indications, although they were non-significant, of a positive response to chemical site preparation.

Third-year Stem Volume

Computed third-year mean stem volume of bare-root stock was significantly greater than that of paperpot stock (Table 5).

Table 5. Computed stem volume (cm^3) after three growing seasons, by treatment, stock type, treatments combined, and stock types combined. For treatment means LSD 20.1 ($P = 0.05$), for stock type means LSD 5.9 ($P = 0.05$).

Treatment no.	Bare-root stock (cm^3)	Paperpot stock (cm^3)	Means (cm^3)
1	53	14	34
2	40	14	27
3	56	17	36
4	68	24	46
5	93	27	60
6	79	30	54
7	103	29	66
8	84	36	60
9	110	33	72
10	115	46	80
11	92	32	62
12	137	51	94
13	86	23	54
14	105	33	69
15	86	38	62
16	136	42	89
17	75	31	53
18	126	41	84
19	97	37	67
20	122	50	86
Means	93	32	

In non-mounded treatments, third-year volume averaged 54 cm^3 for bare-root stock and 17 cm^3 for paperpot stock; **second-year** bare-root stock averaged only 15 cm^3 (data on file). In mounded treatments, **third-year** volume averaged 103 cm^3 for bare-root stock and 36 cm^3 for paperpot stock; **second-year** bare-root stock averaged 25 cm^3 (data on file). Hence, on the basis of mean tree volume, paperpot stock can be said to be less than one year behind bare-root stock after three growing seasons in the field.

In bare-root and paperpot stock types combined, all of the 16 mounded treatments produced greater (nine significantly greater) stem volume than the best of the four non-mounded treatments.

In both stock types combined, mean third-year stem volumes were higher with than without Bräcke patch site preparation, though not significantly so.

Mean third-year stem volume for both stock types combined was higher in all mounded treatments than after Bräcke scarification alone. These differences were significant in most instances.

Sutton (1987) found that the mean third-year computed stem volume of 2+0 jack pine in six outplantings in boreal Ontario averaged 51 cm^3 for jack pine planted on the shoulder of the Bräcke patch, 37 cm^3 for those planted in the bottom of the patch, 55 cm^3 on the M/M mounds, and 51 cm^3 on the M/O mounds. However, the rankings varied with site, and each of the four treatments was best on at least one of the sites. Without mounding, Bräcke patch site preparation in the Eton study reported here gave a third-year mean stem volume very similar to that found by Sutton (1987) in the same treatment; the response attributable to mounding was much greater in the present study.

In both stock types, growth on the 20-L mound was better than on the 10-L mound. Without chemical site preparation, mound type has no significant effect. With chemical site preparation, most differences, and all significant differences, were in favor of the M/O mounds. Mound shape seemed not to affect mean third-year stem volumes.

With mechanical site preparation, all three significant differences in mean stem volumes were in favor of the chemically treated member of the pair.

Relative Growth Rate (RGR)

Mean RGR (stem volume) per annum of paperpot stock over the first three years after outplanting exceeded that of bare-root stock in 15 of the 20 comparisons (Table 6). Over all, the mean RGR of paperpot stock was significantly superior to that of bare-root stock. Over the first two growing seasons, mean RGR for paperpots ranged from 1.66 to 0.32 and for bare-root stock from 1.61 to 0.93 (data on file). Over the first three growing seasons, mean RGR for paperpots ranged from 1.65 to 0.95 and for bare-root stock from 1.58 to 1.08.

Table 6. Relative growth rate/year over the first three growing seasons, by treatment, stock type, treatments combined, and stock types combined. For treatment means LSD 0.11 ($P = 0.05$), for stock type means LSD 0.04 ($P = 0.05$).

Treatment no.	Bare-root stock	Paperpot stock	Means
1	1.14	1.08	1.11
2	1.08	0.95	1.02
3	1.10	1.22	1.16
4	1.22	1.35	1.28
5	1.38	1.38	1.38
6	1.34	1.46	1.40
7	1.35	1.44	1.40
8	1.38	1.45	1.42
9	1.42	1.48	1.45
10	1.49	1.60	1.54
11	1.42	1.46	1.44
12	1.58	1.65	1.62
13	1.44	1.35	1.40
14	1.34	1.51	1.42
15	1.39	1.50	1.44
16	1.55	1.46	1.50
17	1.35	1.44	1.40
18	1.41	1.59	1.50
19	1.31	1.51	1.41
20	1.42	1.63	1.52
Means	1.36	1.43	

In 17 of the 20 comparisons, mean RGR of paperpot stock over the first three years exceeded mean RGR of bare-root stock over the first two years (data on file). This suggests that in terms of relative growth rate, the paperpots are less than one year behind the bare-root stock.

With chemical site preparation, Bräcke patch treatment gave significantly higher mean RGR over the first three years than did no Bräcke patch for both stock types. Without chemical site preparation the differences between Bräcke patch treatment and no Bräcke patch treatment was insignificant for both stock types.

Without chemical site preparation, all mounding treatments gave significantly higher mean RGR for both stock types over the first three growing seasons than did the Bräcke patch treatment alone. With chemical site preparation, mounding was just as beneficial.

Mound shape did not influence mean computed RGR. No consistent pattern was evident in comparisons between mounds that differed only in volume.

Mound type produced responses that varied with stock type. For paperpots there were indications that M/O mounds were more beneficial than M/M mounds both with and without weed control. For bare-root stock without chemical site preparation, mound type had no consistent effect. With chemical site preparation, RGR was higher on the M/O mound than on the M/M mound in three of the four treatment pairs.

Mean RGR of both stock types over the first three growing seasons was generally improved by chemical site preparation.

CONCLUSIONS

Stock Type

Both stock types performed satisfactorily on the mounds. Comparison between size of bare-root stock after two growing seasons and size of paperpot stock after three growing seasons shows that there was less than one year's difference in growth between stock types. Without mechanical site preparation, survival was much lower in paperpot stock than in bare-root stock. There were strong indications that paperpot stock benefited relatively more than did bare-root stock from mechanical site preparation.

Mechanical Site Preparation

In our study, Bräcke scarification without mounding site preparation was not nearly as effective in promoting outplant performance as were the mounding treatments. In other studies (cf. Sutton 1984, 1987; Martinsson 1985), mounding was often less effective than patch scarification. With chemical site preparation, Bräcke scarification improved survival among both bare-root and paperpot stock. Without chemical site preparation, Bräcke scarification did not improve growth rates, but it improved survival of paperpot stock.

In our study, mounding site preparation gave strong growth responses in both stock types. Survival in both stock types was significantly higher in the mechanically site-prepared treatments than in those not so prepared. Bräcke scarification alone, however, gave survival rates that did not differ significantly from those in the Bräcke-plus-mounding treatments.

In general, the shape, volume, and type of mound had little or no effect on survival or growth performance. There were indications, however, that paperpot stock performed better on M/O mounds than on M/M mounds.

Rigorous evaluations of the results given by mounding site preparation, and especially inter-study comparisons, are difficult. This is because of the variety of biological effects achieved with mounding, even by a given operator using a given method of mounding, on sites differing in climatic zone, vegetation, slash and other debris, topography, soil material, and soil moisture conditions. Weather during the period from site preparation through the first growing season after planting, and the planting stock itself, even within a given class or grade of a given stock type, are also influential variables that can determine the results obtained.

In the Eton study reported here, there is little doubt that the response to mounding was generally strong, consistent, and positive. Nor is the benefit of mechanical site preparation to be doubted.

Chemical Site Preparation

There were consistent indications that chemical site preparation was giving positive growth responses. Chemical site preparation had little or no effect on bare-root or paperpot survival.

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Appendix A. Analyses of Eton soil sampled in July 1987[a].

Replicate	Depth (cm)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	CEC (cmol kg^{-1})	pH	Organic matter (%)	Sand (%)	Silt (%)	Clay (%)	Texture class
1	12	0.160	2.44	20	40	6	13.6	5.3	4.0	45	55	+	silt loam
	40	0.046	10.18	8	20	4	5	5.1	1.1	19	77	4	silt loam
	70	0.004	31.18	6	20	5	2.2	5.1	0.1	62	38	0	silty *(sic)* sand
2	18	0.132	1.23	28	60	9	10.9	5.1	3.2	35	65	0	silt loam
	49	0.031	6.26	18	20	4	3.7	5.2	0.8	27	73	0	silt loam
	70	0.020	21.08	21	40	6	3.6	5.2	0.5	16	81	3	silt loam
	100	0.006	11.27	4	20	4	0.8	5.1	0.0	99	1	0	sand
3	15	0.092	1.66	8	40	5	9.6	5.1	2.6	34	66	0	silt loam
	53	0.032	12.22	4	30	4	3.7	5.1	0.7	28	72	0	silt loam
	80	0.006	29.12	4	20	3	2.4	5.1	0.1	43	57	0	silt loam
4	8	0.166	1.15	16	60	7	18.6	5.0	4.9	50	50	0	silt loam
	30	0.063	2.08	10	20	4	7.1	5.0	1.6	31	69	0	silt loam
	60	0.012	21.24	7	20	4	2.5	5.2	0.4	33	67	0	silt loam

[a] Total N by micro-Kjeldahl; available P by molybdophosphoric acid after Bray and Kurtz No. 1 extraction; exchangeable K, Ca, and Mg extracted with neutral normal ammonium acetate, then K by emission, Ca and Mg by atomic absorption spectroscopy; pH 1:1 H_2O glass electrode; and organic matter by Walkley-Black chromic acid oxidation.

Appendix B. Botanical names and authorities for species mentioned in the text and abundance class for the lesser vegetation of the study area: **A** = abundant, **C** = common, **P** = present.

Trees

jack pine (*Pinus banksiana* Lamb.)

lodgepole pine (*P. contorta* Dougl.)

Scots pine (*P. silvestris* L.)

black spruce (*Picea mariana* [Mill.] B.S.P.)

trembling aspen (*Populus tremuloides* Michx.)

Lesser vegetation

pin cherry (*Prunus pensylvanica* L. fil) **P**

choke cherry (*P. virginiana* L. fil) **P**

mountain alder (*Alnus crispa* [Ait.] Pursh) **C**

juneberry (*Amelanchier bartramiana* [Tausch] Roem.) **C**

blueberries (*Vaccinium myrtilloides* Michx., *V. angustifolium* Ait.) **A**

Labrador tea (*Ledum groenlandicum* Oder) **P**

currant (*Ribes* L. spp.) **P**

bramble (*Rubus* L. spp.) **P**

fireweed (*Epilobium* L. spp.) **P**

strawberry (*Fragaria virginiana* Duchesne) **A**

bracken (*Pteridium aquilinum* [L.] Kuhn) **A**

goldenrods (*Solidago* L. spp.) **C**

pearly everlasting (*Anaphalis margaritacea* [L.] C.B. Clarke) **P**

kidney-leaved violet (*Viola renifolia* Gray) **C**

bunchberry (*Cornus canadensis* L.) **C**

closed gentian (*Gentian andrewsii* Griseb.) **P**

spreading dogbane (*Apocynum androsaemifolium* L.) **P**

rose (*Rosa* L. spp.) **P**

hair-cap moss (*Polytrichum* Dill. sp.) **C**

plume moss (*Hypnum crista-castrensis* Hedw.) **C**

common hairgrass (*Deschampsia flexuosa* [L.] Trin.) **C**

fringed brome grass (*Bromus ciliatus* L.) **C**

poverty grass (*Danthonia spicata* [L.] Beauv.) **C**

winter grass (*Oryzopsis asperifolia* Michx.) **C**

THE TREATMENTS