Jack pine establishment in Ontario: 5-year comparison of stock types $\pm$ bracke scarification, mounding, and chemical site preparation

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Field experimentation was begun in 1984 to assess performance of jack pine (*Pinus banksiana* Lamb.) (2+0 bareroot and FH408 Japanese paperpot) in relation to mechanical site preparation, including Bracke scarification with and without supplementary mounding, and site preparation using Roundup® herbicide. Twenty treatments encompassed 4480 trees in 40-tree plots split equally between bareroot and paperpot stock. The study site, about 200 km north of Sault Ste. Marie, Ontario, had deep silt loam soil. After 3 growing seasons, survival was significantly higher among bareroot than among paperpot stock, but survival no longer differed significantly ($P < 0.05$) between stock types 2 years later. In years 4 and 5, the rate of increase in mean total height of bareroot stock was 11% less than that of paperpot stock, though bareroot stock was 40 and 4.7 cm greater in mean total 5th-year height and 5th-year height increment, respectively. Paperpot stock needed mechanical site preparation more than did bareroot stock. By the end of year 5, positive responses of survival and growth to mounding had become clear in both stock types; however, although mound size had little or no effect on survival or total height, mean stem volume was significantly ($P < 0.01$) greater on 20-L vs. 10-L mounds. Fifth-year mean stem volume was also significantly ($P < 0.01$) greater on mineral-on-organic (M/O) than on mineral-on-mineral (M/M) mounds. Chemical site preparation had no effect on relative growth rates beyond year 3. Indices that combined survival with total height or stem volume after 5 years show the significant ($P < 0.01$) superiority of: 20-L vs. 10-L mounds, M/O vs. M/M mounds, and chemical vs. no-chemical site preparation.

Nous avons entrepris en 1984, à environ 200 km au nord de Sault Ste. Marie, en Ontario, des expériences sur le terrain pour évaluer le rendement du pin gris (*Pinus banksiana* Lamb.) (semis à racines nues 2+0 et en godet-papier japonais FH408) en fonction de la préparation mécanique du terrain, dont le scarifiage au moyen d'un cultivateur Bracke avec ou sans aménagement de buttes et l'application de l'herbicide Roundup® avant plantation. Nous avons appliqué 20 traitements différents à 4 480 arbres répartis dans des parcelles de 40 arbres; la moitié de ces parcelles renfermaient de semis à racines nues et l'autre, des semis en godet-papier. Le sol en cet endroit est un loam limoneux profond. Après 3 saisons de croissance, le taux de survie des semis à racines nues était supérieur à celui des semis en godet, mais les taux de survie des deux types de semis ne différaient plus de façon significative ($P < 0,05$) 2 ans plus tard. Au cours des quatrième et cinquième années, le taux d'allongement moyen des semis à racines nues était de 11% inférieur à celui des semis en godet-papier, mais la hauteur totale et l'allongement moyens des semis à racines nues étaient respectivement de 40 et de 4,7 cm supérieurs dans la cinquième année. Les semis en godet-papier avaient davantage besoin que le terrain soit préparé mécaniquement. Vers la fin de la cinquième année, nous avons observé un effet positif évident des buttes sur la survie et la croissance des deux types de semis; la taille des buttes avait peu ou pas d'effet sur la survie et la hauteur des plants, mais le volume moyen des tiges sur les buttes de 20 L était significativement supérieur ($P < 0,01$) à celui des tiges des plants des buttes de 10 L. Le volume moyen des tiges des semis sur buttes constituées de sol minéral sur sol organique était significativement supérieur ($P < 0,01$) à celui des tiges des plants des buttes constituées de sol minéral sur minéral sur sol minéral. L'utilisation d'herbicide n'a plus eu d'effet sur les taux de croissance relatifs au-delà de la troisième année. Des indices combinant le taux de survie et la hauteur totale ou le volume de la tige après 5 ans ont montré de façon statistiquement significative ($P < 0,01$) que l'utilisation d'herbicide accroît le rendement et que les buttes de 20 L sont plus efficaces que les buttes de 10 L, tout comme les buttes M/O par rapport aux buttes M/M.

Introduction

Plantations of conifers in boreal regions are seldom successful without site preparation (Bärring 1965, 1967; Alm 1974; Söderström 1977; Söderström *et al.* 1978, 1979; Berg 1980; Martinsson 1985). Innumerable combinations of kinds, timings, and intensities of site preparation treatment are possible. Choosing a cost-efficient method of site preparation to secure the desired results from outplanting is one of the most difficult tasks facing the forest manager (Wood *et al.* 1988).

The opportunity to test mounding site preparation (Sutton 1993) for establishing jack pine¹ arose when the Lands and Forests Division of the Algoma Central Railway (ACR)

initiated a planting program for land that, following pulpwood cutting (between 1925 and 1930) and fire, had become grassy and sparsely treed (Fig. 1). The site lies about 200 km north of Sault Ste. Marie, Ontario. In co-operation with W.L. Oliphant (then, Manager of ACR's Lands and Forests Division) and ACR's Forester S.W. Kent, field experimentation was designed and implemented. Three-year results were reported by Wood *et al.* (1988). The 5-year results presented here are examined similarly as well as by the method of contrasts between weighted means. Indications that contradict those suggested by the 3-year data are emphasized.

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¹Botanical names for species mentioned in the text are given in Appendix A.

Figure 1. General view of the experimental site before planting.

Objective

The objective of the experimentation was to assess the field performance of bareroot and paperpot jack pine in relation to several site preparation and planting treatments, especially mounding.

Experimental Design

The experimental design allowed comparisons of performance between two stock types outplanted after 20 kinds of site treatments (Table 1, Fig. 2). Plots split by stock type, with 20 bareroot and 20 paperpot trees per plot, were used in a randomized block design. Eight of the 20 treatments

were doubly replicated within each of the four blocks: each block of 28 plots contained two plots each of treatments 5, 6, 9, 10, 13, 14, 17, and 18, and one plot each of the other 12 treatments. Within blocks, treatments were randomly assigned. This gave either $20 \times 4 = 80$ or $2 \times 20 \times 4 = 160$ trees per stock type per treatment, for a total of 2240 trees per stock type.

Site

Located at a mean elevation of about 325 m near Eton (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 had gently rolling topography on deep glaciofluvial deposits, with mainly silt loam soils. Scattered individual stems and small clumps of aspen, black spruce, and jack pine were present; grasses, blueberries, strawberry, and bracken were abundant.

Treatments

Stock Type

Superimposed on the 20 treatments was the comparison between spring-lifted 2+0 bareroot stock and overwintered FH408 Japanese paperpot stock. The stock, planted in May 1984, was described in detail by Wood *et al.* (1988). The stock types tested in our study were in current operational use in Ontario.

Bracke Scarification

A skidder-mounted Bracke scarifier prepared the site in June 1983. In each of four experimental blocks, seven passes were made up one side and another seven passes down the other, each pass creating two rows of patches. 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, in which Bracke patches were of average size, about 63×80 cm (Smith 1979).

Table 1. Description of treatments used in the present study

Treatment no.	Bracke scarification	Mounding	Mound			Herbicide ³
			shape ¹	position ²	volume (L)	
1	—	—	n/a	n/a	n/a	—
2	—	—	n/a	n/a	n/a	+
3	+	—	n/a	n/a	n/a	—
4	+	—	n/a	n/a	n/a	+
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	+

¹P = "pimple" mound, convex surface; D = "dimple" mound, concave surface.

²M/M = mineral mound placed on mineral soil on shoulder of the Bracke patch; M/O = mineral mound placed on organic substrate.

³Herbicide patch-treatment applied August 1983 prior to planting May 1984.

Figure 2. The treatments. ↗ denotes chemical spray.

Mounding

Mounds were made by hand in late June 1983. The positioning of the mounds was sometimes difficult; with mounds of mineral soil on a substrate of mineral soil (M/M mounds), the shoulder was typically very steep, and with mounds of mineral soil on organic matter (M/O mounds), the organic divot from the patch had not always been deposited cleanly. "Dimple" mounds were formed in August 1983 by trampling to form a central concavity in the upper surface of the mounds. Other mounds were generally convex with a central high point; these constituted the "pimple" mounds.

Containers of known volume were used to obtain the required 10 or 20 L of mineral matter per mound.

Chemical Site Preparation

Backpack sprayers were used 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 to make a 1.5% solution. Each tree in the herbicide treatments was to be planted centrally in a patch that had been treated, but the 30-day assessment revealed that, at least in the chemical site preparation treatment, only 56% of bareroot trees and 44% of paperpot had been planted in treated patches. Evaluation of this treatment must be weighted accordingly.

Planting

All stock was hand-planted into moist soil, paperpots on 13 and 14 May, bareroot on 14 and 15 May 1984. Plants were spaced about 2 m apart in rows about 2.5 m apart. The weather was partly sunny, cool in the morning and warmer in the afternoon, with light winds; there was frost by night. Weather data recorded at the experimental site from 11 June through 22 September 1984 indicated values close to the 30-year norms for mean monthly minimum and mean monthly maximum temperatures at the federal weather station at Wawa, Ontario (Anon., undated), 430 m elevation, 48°04'N, 84°45'W. Precipitation during this period was also close to normal.

Data Collection

Height and ground-level stem diameter of the newly planted stock were measured on 16 May 1984. By that time, 10–20% of the paperpot stock and 60–70% of the bareroot stock already exhibited wilting (mostly temporary) of newly flushed foliage. Reassessments were carried out 30 days after planting and at the end of each of the 1st, 2nd, 3rd, and 5th growing seasons.

Data Analysis

The seedling performance parameters examined were survival, total height, height increment, stem diameter at ground level, stem volume, mean relative growth rates (RGR) for height and stem volume, Index I (mean tree height multiplied by percentage survival, 5-year data), and Index II (mean stem volume multiplied by percentage survival, 5-year data).

Relationships between the two indices were examined by regression analysis. Stem volume was calculated using the volume formula for a right-circular cone ($1/3$ basal area $\times$ height). Relative growth rates were calculated using the formula given by Hunt (1982):

$$RGR(T_2 - T_1) = (\text{Log}_e W_2 - \text{Log}_e W_1) / (T_2 - T_1)$$

where W_2 and W_1 represent the parameter of interest (e.g., total height, stem volume, etc.) at time 2 (T_2) and time 1 (T_1), respectively. Mean RGR is expressed in units of time^{-1} .

Five defined contrasts were also examined using weighted sums of means (Winer 1971): no site preparation vs. Bracke treatment only; no site preparation vs. chemical site preparation only; mounding site preparation vs. Bracke treatment

only; 10-L vs. 20-L mounds; and M/M vs. M/O mounds. Orthogonality is immaterial in such comparisons (Winer 1971; Milliken and Johnson 1984).

Survival data were analyzed by chi-square test (Steel and Torrie 1980). Growth data were analyzed using the P7D package (BMDP 1990) package for analysis of variance for balanced split-plot designs (Milliken and Johnson 1984). All expressions of significance are based on $P < 0.05$ unless otherwise stated. Redundant analyses are not reported here, but all data are on file [TYPE 1423].

Results

After 5 growing seasons, the effects of treatments became clearer than were apparent to Wood *et al.* (1988) after 3 growing seasons. Comparisons of performance after 3 and 5 growing seasons were summarized for survival (Table 2), height (Table 3), stem volume (Table 4), and indices that combine survival and growth (Table 5). Regressions of Index II on Index I gave significant ($P < 0.001$) R^2 values of 0.798 and 0.871 for bareroot and paperpot stock, respectively. ANOVA for both indices gave virtually identical results for bareroot ($R^2=0.86$) and paperpot ($R^2=0.88$) stock; the effects of block, treatment, and stock type were all significant ($P < 0.001$), and neither the block $\times$ treatment nor the treatment $\times$ stock type interaction was significant. Significant relationships determined by analyses of the defined contrasts are listed (Table 6).

Differences in performance between the two stock types narrowed during the 4th and 5th growing seasons. In particular, the survival differential, significant in favor of bareroot stock after 3 growing seasons, became insignificant. Growth differentials decreased.

Mounding site preparation also became significantly superior to non-mounding scarification during the 4th and 5th growing seasons. Mound size, which seemed to have little effect on survival or growth by the end of the 3rd growing

season, had become significant after 5 growing seasons (Table 6). Mound type, which also "had little effect on survival or growth" up to the end of the 3rd growing season (Wood *et al.* 1988) showed significant (mostly $P < 0.01$) effects in favor of M/O mounds (Table 6) when evaluated after 5 growing seasons using defined contrasts. For both stock types, both mound sizes, and both herbicide treatments, Index II values for stock planted on M/O mounds exceeded those for stock planted on M/M mounds; bareroot and paperpot stock planted on M/O mounds averaged 115 and 129%, respectively, of index values for trees planted on M/M mounds (Table 5). Notwithstanding the imperfect locating of planting spots with respect to the chemically treated patches, chemical site preparation was found, after 3 growing seasons, to be giving growth responses "consistently in favor of chemical site preparation" (Wood *et al.* 1988); these indications were sustained after 5 growing seasons. Chemical site preparation had more effect with M/O than with M/M mounds and with paperpot than with bareroot stock.

Discussion

Stock Type

Stock types as disparate as bareroot and paperpot stock can be expected to perform differently after outplanting in a given environment. Martinsson (1985) found that the response to site preparation, including mounding, varied with stock type; classes and grades of stock within types may also respond very differently to site conditions (cf. Scarratt 1974; Dobbs 1976; McMinn 1982). Stock size also influences performance, and may be more important than stock type (cf. Ball and Kolabinski 1986). Of prime interest in the present study, therefore, are the temporal changes in the differential between the two stock types. Furthermore, since there can be great variation among lots of any given stock type (Sutton 1979; McCreary and Duryea 1985), extrapolation

Table 2. Survival of jack pine after three and five growing seasons, by treatment and stock type, showing the significance (** = $P < 0.01$, * = $P < 0.05$, NS = not significant) of differences between bareroot and paperpot stock types

Treatment no.	Bareroot stock			Paperpot stock			Difference between bareroot and paperpot survival at end of	
	3rd yr (%)	5th yr (%)	Ratio 5th-:3rd-yr survival	3rd yr (%)	5th yr (%)	Ratio 5th-:3rd-yr survival	3rd yr	5th yr
1	75	60	0.80	36	31	0.86	**	**
2	66	44	0.67	30	29	0.97	**	*
3	88	62	0.70	80	58	0.72	NS	NS
4	94	64	0.68	93	76	0.82	NS	NS
5	98	84	0.86	81	76	0.94	**	NS
6	94	74	0.79	91	74	0.81	NS	NS
7	88	71	0.81	94	86	0.91	NS	**
8	89	78	0.88	87	71	0.82	NS	NS
9	94	81	0.86	85	80	0.94	**	NS
10	92	81	0.88	83	78	0.94	*	NS
11	91	78	0.86	91	87	0.96	NS	*
12	95	83	0.87	90	86	0.96	NS	NS
13	95	74	0.78	93	70	0.75	NS	NS
14	88	76	0.86	88	72	0.82	NS	NS
15	98	85	0.87	85	79	0.93	**	NS
16	94	82	0.87	95	85	0.89	NS	NS
17	90	79	0.88	79	68	0.86	*	NS
18	89	79	0.89	93	88	0.95	NS	NS
19	91	76	0.84	94	88	0.94	NS	NS
20	89	72	0.81	86	78	0.91	NS	NS
Mean	90	74	0.82	83	73	0.88	**	NS

Table 3. Total height of jack pine after three and five growing seasons, by treatment and stock type. For each stock type, differences between treatment means of 6.7 (3rd-year) and 13.4 cm (5th-year) are significant ($P < 0.05$).

Treatment no.	Bareroot stock			Paperpot stock		
	3rd yr (cm)	5th yr (cm)	Ratio 5th:3rd-yr height	3rd yr (cm)	5th yr (cm)	Ratio 5th:3rd-yr height
1	82	176	2.15	55	126	2.29
2	76	169	2.22	45	113	2.51
3	81	156	1.93	53	114	2.15
4	83	166	2.00	58	126	2.17
5	95	182	1.92	62	143	2.31
6	83	174	2.10	62	143	2.31
7	93	193	2.08	64	150	2.34
8	89	182	2.04	62	143	2.31
9	100	196	1.96	66	151	2.29
10	100	201	2.01	71	163	2.30
11	91	192	2.11	65	149	2.29
12	102	202	1.98	73	167	2.29
13	93	196	2.11	63	145	2.30
14	99	187	1.89	65	144	2.22
15	95	181	1.91	71	150	2.11
16	99	199	2.01	70	159	2.27
17	96	196	2.04	68	144	2.12
18	103	211	2.05	75	165	2.20
19	94	186	1.98	70	160	2.29
20	94	206	2.19	72	161	2.24
Mean	92	188	2.03	64	146	2.27

Table 4. Computed stem volume of jack pine after three and five growing seasons, by treatment and stock type. For each stock type, differences between treatment means of 20.1 (3rd-year) and 171.0 cm³ (5th-year) are significant ($P < 0.05$).

Treatment no.	Bareroot stock			Paperpot stock		
	3rd yr (cm ³)	5th yr (cm ³)	Ratio 5th:3rd-yr volume	3rd yr (cm ³)	5th yr (cm ³)	Ratio 5th:3rd-yr volume
1	53	495	9.34	14	181	12.93
2	40	458	11.45	14	211	15.07
3	56	410	7.32	17	190	11.18
4	68	569	8.37	24	221	9.21
5	93	738	7.94	27	346	12.81
6	80	700	8.75	30	378	12.60
7	103	881	8.55	29	426	14.69
8	84	652	7.76	36	422	11.72
9	110	860	7.82	33	460	13.94
10	115	1021	8.88	47	562	11.96
11	92	859	9.34	32	425	13.28
12	137	1002	7.31	51	588	11.53
13	86	806	9.37	23	289	12.57
14	105	759	7.23	33	404	12.24
15	86	652	7.58	38	386	10.16
16	136	1139	8.38	42	488	11.62
17	75	653	8.71	31	339	10.94
18	126	920	7.30	41	454	11.07
19	97	756	7.79	37	439	11.86
20	122	1142	9.36	50	572	11.44
Mean	93	774	8.30	32 ¹	389 ¹	12.01

¹Significantly ($P < 0.0001$) different from the equivalent bareroot stock mean.

of the results of any study that uses but one stock lot per type must be done with caution.

(a) *Survival.* Mortality was higher among bareroot than paperpot stock during the 4th and 5th growing seasons, eliminating the significant ($P < 0.01$) overall 3rd-year differences between stock types reported by Wood *et al.* (1988) (Table 2). Survival rates in five of the seven treatments that showed significant (mostly $P < 0.01$) differences in favor of bareroot stock after 3 growing seasons were

no longer significant after 5 growing seasons. Bareroot survival rates in the two treatments without mechanical site preparation also lost ground compared with paperpot survival but remained significantly ($P < 0.01$ in treatment 1) higher than paperpot survival rates. Thus, site preparation involving cultivation was more necessary for the relatively small containerized stock than for the bareroot stock. Moreover, in treatments 7 and 11 (20-L M/M and M/O mounds, respectively, without chemical site preparation), paperpot survival during the 4th and 5th growing

Table 5. Index I and Index II (see text) for jack pine, by treatment and stock type. For each stock type, differences between treatment means of 23.8 (Index I) and 177.5 (Index II) are significant ($P < 0.05$)

Treatment	Bareroot stock		Paperpot stock	
	Index I	Index II	Index I	Index II
1	106	297	39	56
2	74	200	32	61
3	98	256	65	109
4	106	363	97	172
5	154	622	109	263
6	128	516	107	281
7	137	627	129	368
8	141	505	101	298
9	158	693	122	370
10	162	823	126	432
11	149	665	130	369
12	168	833	143	503
13	142	584	103	206
14	142	579	105	293
15	154	554	118	303
16	164	940	135	414
17	154	514	97	229
18	164	713	144	397
19	142	576	140	384
20	149	828	125	443

Table 6. Variables found to be significant (* = $P < 0.05$, ** = $P < 0.01$) using defined contrasts

Contrast ¹	Variables
no site preparation vs. Bracke only	Total height ** and height increment 1988** RGR (volume** and height**, years 4-5).
no site preparation vs. chemical site prep	Total height 1984* and 1985**, and height increment 1985*.
mounding vs. Bracke	Ground-level stem diameter 1984*, 1985**, 1986**, and 1988**; total height 1985**, 1986**, and 1988**; height increment 1985*, 1986**, and 1988**; stem volume 1986** and 1988**; and RGR (volume** years 0-3, 0-5, and 4-5) and RGR (height** years 0-3, 0-5, and 4-5).
10-L mounds vs. 20-L mounds	Ground-level stem diameter 1986** and 1988**; stem volume 1986** and 1988**; and RGR (volume** years 0-3 and 0-5).
M/M mounds vs. M/O mounds	Ground-level stem diameter 1984*, 1985**, 1986**, and 1988**; total height 1985*, 1986**, and 1988**; height increment 1985**, 1986**, and 1988**; stem volume 1986** and 1988**; and RGR (volume** years 0-3 and 0-5), and RGR (height** years 0-3 and 0-5).

¹In each contrast, the **boldfaced** member identifies the treatment associated with significantly superior performances with respect to the specified variables.

seasons became significantly higher than bareroot survival (Table 2).

(b) *Growth*. Differentials in height and volume between the two stock types decreased markedly during the 4th and 5th growing seasons. After 5 growing seasons, paperpot stock was closer in total height and volume to 5th- than to 3rd-year values attained by bareroot stock (Tables 3 and 4). These developments were reflected well by the appropriate RGRs; for instance, the overall RGR (volume) of paperpot stock exceeded that of bareroot stock by 5% after 3 growing seasons, 9% after 5, and 22% during the 4th and 5th growing seasons (data on file). On both mound types, the RGRs (volume) of paperpot stock were significantly greater than

those of bareroot stock. Paperpot growth performance was catching up with that of bareroot stock.

Scarification

(a) *Survival*. In both stock types, the superiority of scarification without mounding compared with no scarification decreased in the 4th and 5th growing seasons. The differentials decreased from 20% to 11% for bareroot and from 53% to 37% for paperpot stock. Elsewhere, Söderström (1977), Söderström *et al.* (1979), Berg (1980), and Martinsson (1985) found that mechanical site preparation typically increased survival rates compared with survival on untreated sites.

Compared with mounding, Bracke scarification without mounding gave lower 5th-year survival of paperpot stock in five of the eight mounding treatments, though there had been no difference 2 years earlier. Among bareroot stock as well, the differential in survival increased in favor of the mounded treatments by the end of the 5th growing season in relation to that in the scarified-only treatment.

(b) *Growth*. Fifth-year total heights of both bareroot and paperpot stock without chemical site preparation were significantly greater in the untreated control than in the Bracke-only treatment. This was unexpected, for the presence or absence of Bracke patch had not significantly influenced 3rd-year total height for both stock types combined. With chemical site preparation, paperpot stock in the Bracke patch treatment were significantly taller after 5 growing seasons than were those with no Bracke patches; but bareroot stock showed no such response.

Bracke patch site preparation without mounding gave a 5th-year mean stem volume not significantly different from that reported by Sutton (1991) for jack pine treated similarly in another boreal Ontario study.

Compared with Bracke scarification by itself, mounding gave significantly ($P < 0.01$) higher RGR (volume) for years 4 through 5 as well as for years 0 through 5 (Table 6).

In other studies on cutover sites, 3-year results with jack pine (Sutton 1984), 5-year results with jack pine and black spruce (Sutton 1991), and 6-year results with Scots pine, lodgepole pine, and Norway spruce (Martinsson 1985), have shown that mounding is commonly less or no more effective than patch scarification.

Mounding

(a) *Survival*. Mounding, though it had not improved 3rd-year survival of bareroot stock, clearly became superior to patch scarification without mounding by the end of the 5th growing season. Among paperpot stock on mounds without chemical site preparation, 5th-year survival in all eight treatments was higher than with Bracke scarification alone.

In another study in boreal Ontario, survival rates in 11 outplantings averaged 92% after 5 growing seasons for 2+0 jack pine planted after Bracke patch scarification, with or without mounding (Sutton 1991); after 3 growing seasons, mortality had been 4% higher among mound-planted stock than for patch scarification without mounding, but whereas mortality continued to increase in the non-mounded treatments, there was no further mortality in the mounded treatments. In a Swedish study, Martinsson (1985) found 1st-year through 6th-year survival rates to be virtually identical among 2+0 Scots pine whether planting had been on mounds or in scarified patches.

(b) *Growth*. Mounding increased total height in both stock types. Mean 5th-year total heights for paperpot stock were lower in all four, and for bareroot stock lower in three of the four, non-mounding treatments than in any of the 16 mounding treatments. In another boreal Ontario study with 11 outplantings of 2+0 bareroot jack pine, Sutton (1991) reported 5-year data showing, at least with respect to bareroot stock, that mounding site preparation conferred no benefit compared with regular Bracke scarification. In Sweden, Martinsson (1985) obtained superior 3rd-year total height in 1+0 Kopparfors containerized Scots pine planted in scarified patches compared with those planted in mounds. For lodgepole pine, a similar effect was even stronger. In contrast, the Eton site in the present study seems to be conducive to obtaining height responses to mounding, perhaps because of its greater grassiness compared with typical cutovers.

In the study on 11 sites in boreal Ontario, Sutton (1991) found that 3rd-year mean computed stem volume of 2+0 jack pine averaged 49 cm³ in jack pine outplanted on the shoulder of the Bracke patch, 35 cm³ in those planted in the bottom of the patch, 55 cm³ on the M/M mounds, and 54 cm³ on the M/O mounds. Fifth-year values of 438, 337, 493, and 465 cm³, respectively, represented increases of 895, 955, 895, and 859%, respectively, between the 3rd and 5th years. However, rankings varied with site, and the Bracke patch shoulder and each kind of mound gave the best results on at least two of the sites. The response attributable to mounding was much greater on the grassy site of the Eton study reported here than on Sutton's (1991) 11 cutover sites.

In the present study, although mound size was found by analysis of variance to have a non-significant effect on 3rd-year (Wood *et al.* 1988) and 5th-year total heights and stem volumes, the method of defined contrasts showed that the mean stem volumes of trees of each stock type planted on 20-L mounds were significantly ($P < 0.01$) greater than those of trees on the 10-L mounds both at the end of 3 years and after 5 growing seasons (Table 6). Differentials in Index II values in favor of 20-L mounds averaged 110 and 127% for bareroot and paperpot stock, respectively (data on file).

Similarly, M/O mounds gave significantly ($P < 0.01$) greater 3rd-year and 5th-year stem volumes than did M/M mounds (Table 6). Paperpot stock responded more strongly than did bareroot stock. With chemical site preparation, trees on M/O mounds were significantly taller after 5 growing seasons than were trees on M/M mounds in all four comparisons (data on file). Without chemical site preparation, mound type had no significant effect on mean stem volume; with chemical site preparation, most differences, and all significant differences, were in favor of the M/O mounds (data on file). All eight comparisons of Index II values between mound types were in favor of stock planted on M/O mounds, with average differentials of 115 and 129% for bareroot and paperpot stock, respectively (data on file).

Earlier indications by Wood *et al.* (1988) of higher RGR among stock on M/O mounds than on M/M mounds, though confirmed by significant ($P < 0.01$) differences in RGR (years 0 through 5) when examined by defined contrasts, were not maintained in years 4 through 5. By analysis of variance, neither mound type nor chemical site preparation influenced RGR (volume) of bareroot stock significantly, whether for years 0 through 5 or for years 4 through 5 (data on file). For paperpot stock, RGR for years 4 and 5 showed

a similar lack of influence by mound type and chemical site preparation, but the significantly ($P < 0.01$) higher RGR (years 0 through 5) of stock on the M/O mounds in the chemical site preparation treatment than in the other treatments follows the initial positive response to chemical site preparation noted by Wood *et al.* (1988). Evaluation using defined contrasts also showed that, through the first 5 years after outplanting, paperpot stock on M/O mounds with chemical site preparation achieved RGRs significantly higher than for any other treatment combination.

Chemical Site Preparation

(a) *Survival*. Chemical site preparation had no effect on 5th-year survival of either bareroot or paperpot stock, perhaps reflecting the compromised effectiveness of the chemical treatment already noted.

(b) *Growth*. Seven of the eight Index II comparisons favored chemical site preparation, with differentials of 118 and 123% for bareroot and paperpot stock, respectively (data on file). For trees on M/O mounds, there are indications of a positive response of total height to chemical site preparation.

Summary and Conclusions

Stock Type

Acceptable survival depended on mechanical site preparation, especially for paperpot stock. Over all, mortality during the 4th and 5th growing seasons was 54% greater among bareroot than among paperpot stock; by the end of the 5th growing season, the two stock types no longer differed significantly in survival.

On mounds, both stock types performed satisfactorily.

Given sufficient site preparation, performance of paperpot stock after 5 growing seasons was as good or better than that of bareroot stock after 4 growing seasons, although the relative long-term stability of the two stock types must still be determined.

Mechanical Site Preparation

Mechanical site preparation by Bracke scarification without mounding gave significantly lower 5-year total height, stem volume, and relative growth rates than did Bracke scarification with mounding. The grassiness of our Eton site may have been a factor in determining the response to mounding.

The superiority of M/O mounding compared with M/M mounding became obvious during the 4th and 5th years, especially in paperpot stock. Most differences between mound types were significant.

Mound size made no difference to survival rates of bareroot stock, but paperpot stock survival averaged 10% more on 20-L than on 10-L mounds. Stem volume was significantly ($P < 0.01$) greater on 20-L than on 10-L mounds.

On these grassy sites, mounding gave responses in jack pine that were generally strong, consistent, and positive.

Chemical Site Preparation

Early indications that chemical site preparation was giving positive growth responses (cf. Wood *et al.* 1988) were maintained through the 5th growing season, particularly on M/O mounds.

Acknowledgments

The authors thank Messrs. W.L. Oliphant, S.W. Kent, and G. Raines, all of the Algoma Central Railway's Lands and

Forest Division, who provided field support to establish the study and monitor performance. In addition, we acknowledge the contributions made by two programs sponsored by the Government of Canada: Unemployment Insurance Job Creation — Forestry Sector; and Environment 2000.

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Appendix A

Botanical names and authorities² for: (a) tree species mentioned in the text, and (b) the lesser flora at Eton (A = abundant, C = common, and P = present).

- (a) black spruce (*Picea mariana* [Mill.] B.S.P.)
jack pine (*Pinus banksiana* Lamb.)
lodgepole pine (*P. contorta* Dougl.)
Norway spruce (*Picea abies* [L.] Karst.)
Scots pine (*P. sylvestris* L.)
trembling aspen (*Populus tremuloides* Michx.)
- (b) pincherry (*Prunus pensylvanica* L. fil) P
chokecherry (*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* Oeder) P
currant (*Ribes* L. spp.) P
bramble (*Rubus* L. spp.) P
fireweed (*Epilobium* L. sp.) P
strawberry (*Fragaria virginiana* Duchesne) A
bracken (*Pteridium aquilinum* [L.] Kuhn) A
goldenrods (*Solidago* L. spp.) C

²Trees after Hosie (1969), shrubs according to Soper and Heimbürger (1982), and other plants according to Fernald (1950).

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

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