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Mounding Site Preparation for Jack Pine and Black Spruce in Boreal Ontario: Five-year Results

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Forestry Canada, Ontario Region
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ABSTRACT

Eleven plantations of each of jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.) were established with bareroot stock during a 3-year period beginning in 1980 on sites appropriate for those species between latitudes 48°27' and 50°22' N and longitudes 85°10' and 92°03' W. Site preparation provided five kinds of microsite for planting: (a) untreated, (b) Bracke patch shoulder, (c) Bracke patch bottom, (d) mound of mineral soil on the Bracke patch shoulder, and (e) mound of mineral soil on the minimound of material scuffed out of the Bracke patch. On each site, four 30-tree plots per microsite were planted. Five trees per plot were excavated 30 days after outplanting for purposes reported elsewhere. Root growth capacity was determined on subsamples of planting stock; performance in a low-stress (nursery) test planting was determined in other subsamples. Performance data were collected for 5 years. Several evaluations were conducted: height after five growing seasons; relative growth rate (height, years 1 through 5); stem diameter after five growing seasons; stem volume after five growing seasons; relative growth rate (volume, years 1 through 5); and two performance indices that combined survival and growth. The evaluations showed that, though both species performed well on mounded microsites, performance was equally good after outplanting on the shoulder of the standard Bracke patch.

RÉSUMÉ

11 plantations de pins gris (*Pinus banksiana* Lamb.) et d'épinettes noires (*Picea mariana* [Mill.] B.S.P.) ont été établies au moyen de plants à racines nues durant une période de 3 ans commençant en 1980, sur des sites favorables à ces essences, entre les latitude 48°27' et 50°22'N et les longitudes 85°10' et 92°03'O. 5 types de microsites ont été obtenus après préparation du terrain: (a) non traité, (b) épaule de la parcelle Bracke, (c) extrémité de la parcelle Bracke, (d) monticule de sol minéral sur l'épaule de la parcelle Bracke, et (e) monticule de sol minéral sur le minimonticule des matériaux enlevés sur la parcelle Bracke. Sur chaque

terrain, 4 parcelles de 30 arbres ont été plantées par microsite. 5 arbres par parcelle ont été enlevés 30 jours après leur plantation sur le terrain afin de déterminer la croissance des racines. La capacité de croissance racinaire a été calculée à l'aide de sous-échantillons du matériel planté; la performance dans une plantation-test (pépinière) à stress peu élevé a été déterminée à l'aide d'autres sous-échantillons. Des données sur la performance ont été recueillies pendant 5 ans. Les évaluations (hauteur après 5 saisons de croissance; taux de croissance relatifs [hauteur et volume, années 1 à 5]; diamètre et volume de la tige après 5 saisons de croissance; et 2 indices de performance combinant la survie et la croissance) révèlent que, bien que les deux essences aient bien évolué sur les monticules, la performance était également bonne après la plantation sur l'épaule de la parcelle standard Bräcke.

COVER: *(top)* Thunder Bay black spruce planted in 1982 on a mineral-on-mineral mound microsite, one growing season after planting.

(bottom) One of the better black spruce at White River, planted in 1982 on a mineral-on-organic microsite, five growing seasons after planting; fifth-year height increment was 52 cm.

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MOUNDING SITE PREPARATION FOR JACK PINE AND BLACK SPRUCE IN BOREAL ONTARIO: FIVE-YEAR RESULTS

INTRODUCTION

Successful establishment of forest stands in Ontario usually requires some kind of site preparation. "Mounding" site preparation has been advocated as having potential for improving the performance (survival and growth) of outplanted trees, especially in cold climates (Söderström 1977; Söderström et al. 1978; Edlund 1980a,b; McMinn 1980; Parolin et al. 1981; Sutton 1983). I have completed a major review of mounding site preparation which is being prepared for publication; please contact me for details.

To evaluate the effectiveness of mounding site preparation for establishing jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.) in boreal Ontario, a study sponsored by the Ontario Ministry of Natural Resources (OMNR) was begun in 1979. The study was conducted collaboratively with the Great Lakes Forestry Centre of the Canadian Forestry Service (now Forestry Canada, Ontario Region), with partial funding from the Canada Department of Regional Economic Expansion. The author designed the study, served as scientific authority, and oversaw the field work, which was ably conducted by KBM Forestry Consultants, Inc., Thunder Bay, Ontario.

This paper reports and assesses the results from the first 5 years of that study. While site preparation should always be tailored to the particular character of the site and aimed at producing a specific result (see Sutton 1989), this paper addresses the general case from the standpoint of regional forest management.

MATERIALS AND METHODS

Experimental Approach

Four considerations governed the experimentation: (1) the strong effect exerted on outplant performance by the nature and condition of the stock at the time of planting (Sutton 1979); (2) the variability among provenances and stock lots; (3) the variability of outplant performance among sites in any given planting year; and (4) the variability of outplant performance resulting from year-to-year differences in weather. Thus, in order to assess the overall value of mounding site preparation, it was necessary not only to characterize the planting stock at the time of planting, but also to plant more than one stock lot per species in more than one year and at many locations.

The experimentation has provided a population of 11 plantings of each species as the basis for evaluating the site preparation treatments.

Characterization of Planting Stock

Pedigree and Chronology

The jack pine (2+0) and black spruce (1½+1½) production-run bareroot planting stock was supplied by the Thunder Bay Forest Station Nursery (48°22' N, 89°20' W) of OMNR. Details of pedigree and stock-handling chronology are given in Appendix A. Morphological characterization of planting stock (cf. Appendices D, E, H, and K) was supplemented by root growth capacity (RGC) determinations and nursery test plantings.

RGC Tests

Each year of planting, for each species, the planting stock lots for two of the four sites planted were subsampled immediately after being picked up at the nursery, 1 to 3 days before planting. These statistically random subsamples (n = 60 in 1980 and 1982, 30 in 1981) were delivered without delay to the subcontractor, Prof. R.J. Day (School of Forestry, Lakehead University, Thunder Bay, Ontario), for RGC determination.

Standard Lakehead University RGC tests were conducted on potted stock in a controlled-environment chamber that had cool white fluorescent and tungsten lamps emitting 35,000-50,000 lx; 16-hour days, preceded and followed by 1 hour of half illumination, and 6-hour nights; 25°C day and 17.5°C night temperatures, with 2-hour transitions at dawn and dusk; and relative humidities of 50 to 60% by day and 80 to 100% by night.

At the beginning of each test, the following data were determined for each tree: height, ground-level stem diameter, root system volume (Racey et al. 1984), root area index (Morrison and Armson 1968), number of unsuberized roots < 1 cm long, number of unsuberized roots ≥ 1 cm long, and condition class (1 = good, tree developing normally; 2 = good or moderately good, but leading shoot defective; 3 = unthrifty; 4 = tree dead or virtually so).

After 30 days in the growth chamber, each tree was reassessed for the following: number of unsuberized roots < 1 cm long, number of unsuberized roots ≥ 1 cm long, aggregate length of roots ≥ 1 cm long, and condition class. RGC values (Sutton 1990) were reported as the difference between initial and 30-day totals. In the 1981 and 1982 RGC tests, the totals of roots < 1 cm long were reported; in 1980, root counts greater than 25 were reported simply as > 25.

Nursery Test Plantings

To confirm the viability of the planting stock used in the field outplantings, statistically random subsamples (n=60) were abstracted, immediately on receipt of each lot of stock, and planted without delay in the southwest section of block 6 in the Thunder Bay Forest Station Nursery. Though not irrigated, the nursery test plantings provided data on performance under relatively homogeneous, low-stress conditions. The data collected from each tree were height, stem diameter at ground level, and condition class (cf. RGC-tests, above) 30 days after planting and at the end of one growing season.

Outplanting Sites

Of 12 jack pine outplantings ("sites") established from 1980 through 1982, 11 survived the first 5 years after establishment; all 11 black spruce outplantings that were established during the same period survived the first 5 years (Appendix B). All planting was in spring on recent clearcuts (Fig. 1). The sites, located in Sections B4, B7, B8, B9 and B11 of Rowe's (1972) Boreal Forest Region in Ontario, lie between latitudes 48°27' and 50°22' N and longitudes 85°10' and 92°03' W. Note that a site name merely denotes the broad geographical area in which the site is located, not the specific location; some "Thunder Bay" sites, for instance, are more than 100 km apart. Hereafter, sites are identified by the abbreviation "P82" (for example), which refers to sites planted in 1982.

Microsites

Five kinds of microsite for planting were created by site preparation during the year prior to planting: (a) untreated (i.e., no site preparation); (b) Bracke patch shoulder; (c) Bracke patch bottom; (d) mound of mineral soil on mineral soil of Bracke patch shoulder; and (e) mound of mineral soil on the minimound of mainly organic material scuffed out during the making of the associated Bracke patch (Fig. 2). A Bracke Scarifier was involved in creating microsites *b* through *e*; the 20-L mound component of microsites *d* and *e* were added manually in order to simulate Bracke Mounder site preparation.

Note that the "untreated" control (microsite *a*) in this study is not precisely equivalent to a wholly untreated site. While it is true that planting in microsite *a* was into ground that had not been prepared, the results from this would probably be influenced to some extent by the site disturbance

Figure 1. Two of the study sites, newly planted: (top) jack pine planted in 1982 ("P82") at Thunder Bay, and (bottom) P82 black spruce at White River. See also Figure 4.

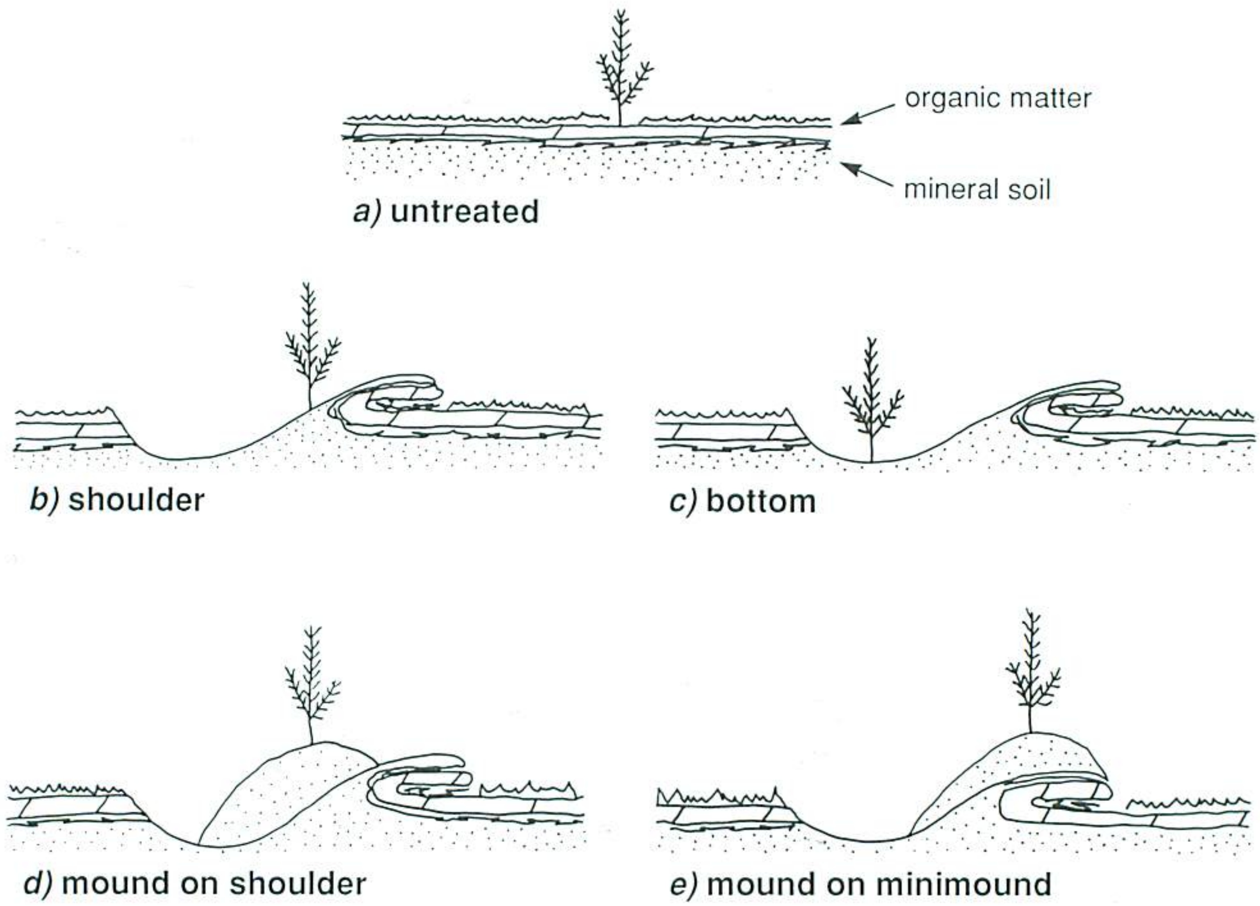

Figure 2. Diagrammatic representation of the five treatments (after Edlund 1980a,b), showing planting positions: (a) untreated; (b) shoulder of Bracke patch; (c) bottom of Bracke patch; (d) 20-L mound of soil on shoulder of Bracke patch; and (e) 20-L mound on material scuffed out of Bracke patch.

that occurred while creating the other microsites. Performance of outplants on microsite *a* is likely to exceed that on wholly untreated sites, but the degree of difference is hard to determine. Because such an effect would diminish the differences between the control and other treatments, any benefits attributable to the other microsites compared with the control are likely to be conservative estimates.

Weather

Newly outplanted stock is vulnerable to soil-moisture deficits at the time of planting and for some weeks thereafter; therefore, it is highly desirable to gain some indication of the weather faced by the young trees in the various plantings. Weather data were not collected at the individual planting sites, but regional weather patterns can be inferred from data reported by suitably chosen weather stations.

The weather records (Anon. 1980-1982, 1982) suggest that prolonged periods of below-normal precipitation occurred throughout much or all of the study area in 1980 and 1981 (Appendix C). In 1980, newly outplanted trees were probably stressed by substantially sub-normal precipitation during April through June; any effect would be exacerbated by the higher-than-normal temperatures in May. In 1981, there were substantial deficits in precipitation every month from April through September, excepting only June. Though below normal in April 1982, precipitation thereafter was mostly higher than normal, so that moisture stress was probably less of a constraint on establishment for the 1982 plantings than for those from 1981 and 1980.

Field Experimental Design

On each site, four 30-tree plots (replicates)[1] per microsite were planted by the operational slit method. Immediately after planting, all trees were measured for total height and ground-level stem diameter. With statistical randomness, 30 days after planting, five trees per plot were chosen and excavated for field root growth determinations (cf. Sutton 1987). The performance of the remaining 25 trees per plot was monitored from the first through the fifth year.

Data Analysis

Survival three and five growing seasons after outplanting, and height and stem volume data through the first, second, third, and fifth growing seasons, are reported. Survival/mortality relationships with treatment were examined by BMDP4F chi-square tests (Anon. 1990). Growth data were subjected to one-way analyses of variance using Minitab (Anon. 1989) *aovoneway* software.

Several criteria are useful in evaluating the field performance of outplanted stock. Each is important in its own right; none is alone sufficient. Those used here are survival rate after five growing seasons; survival ratio, fifth:third year; height after five growing seasons; relative growth rate (RGR) – height, years one through five; stem diameter at ground level after five growing seasons; computed stem volume after five growing seasons; (RGR) – volume, years one through five; performance index I (survival % x RGR – height, years one through five); and performance index II (survival % x RGR – volume, years one through five).

[1]In error, only three such plots were established on microsite *b* of the *P81* black spruce site at White River; five plots were established on microsite *c*.

Fifth-year data are the latest available. Survival rates influence stand dynamics, including canopy closure, crown and branch dimensions, stand density, and competition; height and height increment also influence stand dynamics and susceptibility to weed competition (including smothering), browsing and snow press; stem volume both integrates height and sturdiness and reflects aerial biomass production better than either height or diameter separately; and performance indices combining survival and relative growth rates attempt to quantify performance in a single value.

Relative growth rates for height and stem volume over the 5 years since planting were calculated by means of Hunt's (1982) procedure. The increase in height and volume of an outplant during the period of establishment may be considered to depend partly on the size of the tree (the "capital") and partly on the rate of change (the "interest"). For a thorough discussion of relative growth rate, see Evans (1972).

Relationships between root growth capacity and outplant performance, determined by correlation analysis, have been reported previously (Sutton 1987); only summaries are presented here.

The results obtained with site preparation of any kind, including mounding, can vary greatly with site, weather and planting stock characteristics. The precariousness of generalizations based on a population of 11 plantings per species during a 3-year period must be recognized.

RESULTS AND DISCUSSION

Planting Stock

Viability

The viability of the planting stock was confirmed by the virtual 100% survival rates in the nursery test plantings of both species. The root growth capacity data (see RGC, below) support this conclusion.

Variability

There was considerable variation in both initial size (as is typical of shipping-run stock) and growth during the first growing season, both within and between lots (Appendix D).

RGC

Root growth capacity data (Appendix E) are those reported by the subcontractor, Professor R.J. Day. Problems associated with meaningful quantification of RGC test data have been discussed elsewhere (Sutton 1987, 1990); the evidence suggests that, in its present form, "RGC testing is silviculturally useful chiefly as a means of detecting planting stock that, while visually unimpaired, is moribund" (Sutton 1990). The RGC data in the present study correlate poorly with field performance, with the exception of the significant (P=0.01) relationship between the average mean length of roots ≥ 1 cm and survival 3 and 5 years after planting (Sutton 1987). Other correlations between four components of RGC and performance variables are sporadic and inconsistent. (The four RGC components are designated as: RGC-a = the mean number of new roots < 1 cm long per tree; RGC-b = the mean number of of new roots ≥ 1 cm per tree; RGC-c = the mean aggregate length of roots ≥ 1 cm long per tree; and RGC-d = the average mean length of roots ≥ 1 cm, derived from RGC-b and RGC-c.)

Even in the low-stress nursery environment, none of the four components of jack pine RGC correlated with any performance variable; in the case of black spruce, RGC-a and RGC-b are significantly (P=0.05) correlated with first-year height increment, but RGC-c and RGC-d are not, and no RGC component correlates with diameter increment.

Thus, while differences in RGC among stock lots are evident, the main conclusion that can be drawn from the RGC data is that the planting stock was viable. This accords with the evidence from the nursery test planting.

Outplant Field Performance

Field performance is determined by the interplay of the performance potential of the planting stock at the time of planting and the environments subsequently experienced by the stock. Without clonal planting stock and rigid production regimes, inter-year comparisons of outplant performance will always be biased by differences among planting stock lots; however, three potent sources of variation that influence outplant performance are site, microsite and weather in the year of planting.

The stock used in the present study was shown to be viable by the nursery and RGC tests; thus, the influence of microsites on field performance at any given site can be attributed to interactions between viable stock and the microsite characteristics, which in turn were determined by the interactions of the microsites with site and weather. Ecophysiological considerations were beyond the scope of this study; survival and growth are the main criteria used in evaluating the results.

Worth noting is the fact that, though microsite *b* is generally the planting spot prescribed after operational Bracke scarification, the more easily planted microsite *c* is commonly used, notwithstanding guidelines to the contrary[2].

Jack Pine Survival

Jack pine survival rates over the first 5 years after outplanting exceeded 85% in 45 of the 55 site x microsite combinations (Appendix F). In the P80 plantings, for instance, only the untreated microsite at White River (73%) and the patch-bottom microsite at Foleyet (84%) gave survival rates of less than 85%; in the *P82* plantings, only the untreated microsites at Savant Lake and White River achieved less than 85% survival. By operational standards, these rates are high.

[2]Laird Van Damme, R.P.F., General Manager, KBM Forestry Consultants, Inc., 360 Mooney Street, Thunder Bay, Ontario. P7B 5R4

The depression of survival rates observed on mineral-on-organic mounds in the P81 plantings is attributed mainly to water stress exacerbated by poor root/soil contact in mounds that were less consolidated than those on a mineral substrate. Deep planting might have been advantageous here (cf. Sutton 1967).

Strictly, the data do not support conclusions about any effect of year of planting, if this information is examined independently of site effects; the sites planted differed among years as did the planting stock. The 11 plantings serve as 11 replications of the site preparation treatments.

The poor showing of microsite *e* in all three 1981 plantings, in contrast with consistently superior results with this microsite in the P80 and P82 plantings, may reflect an effect of year of planting, yet the similarity of jack pine survival rates among unmounded microsites, averaged over sites within years of planting, suggests that survival rates were not greatly influenced by year of planting (Table 1). This latter indication is supported by the fact that survival rates on untreated microsites (73 to 99%) varied more widely among the four plantings in 1980 than among the other seven plantings in 1981 and 1982.

In each year of planting, survival rates differed significantly (P=0.05) among sites, but no single

Table 1. Jack pine fifth-year survival (%), by year of planting and microsite; n = 400 (*P80* and *P82*) or = 300 (*P81*).

Planting year	Microsite[a]				
	a	*b*	*c*	*d*	*e*
P80	88a	94ab	92ab	96b	94b
P81	85b	93c	92bc	87bc	67a
P82	83a	94bc	89ab	98d	98cd

[a] Within each year of planting (row), values not followed by the same letter differ significantly (P=0.05) by chi-square test; within microsites (columns), only microsite *e* gave differences that differ significantly (P=0.05) by chi-square test.

microsite emerged as superior. In the *P80* plantings, only microsite *d* did *not* give significantly different survival rates among the four plantings; microsites *a* and *e* in the *P81* plantings, and *P82* microsites *b* and *d*, all showed significant within-year differences.

The overall superiority of microsites *d* and *b* (Table 2) is clear but not overwhelming. Though survival was highest on microsite *d* in the *P80* plantings, this did not differ significantly from either microsites *e* or *b*, which were tied for second place. In the *P81* plantings, survival rates were highest in microsites *b* and *c*, though microsite *d* was not significantly inferior. In the *P82* plantings, survival rates were highest on microsites *d* and *e*, but, again, those on microsite *b* were not significantly lower.

Table 2. Jack pine fifth-year survival (%) by microsite, all 11 plantings; overall n = 1100.

Microsite[a]				
a	*b*	*c*	*d*	*e*
85a	94cd	91bc	95d	88ab

[a] Values not followed by the same letter differ significantly (P=0.05) by chi-square test.

For jack pine, even the patch-bottom (microsite *c*) gave good survival; fifth-year survival was not less than 84% in any of the 11 plantings. On typical jack pine sites, planting jack pine in the bottom of the Bracke patch did not imperil survival; in the *P81* planting at White River, survival on microsite *c* was *greater* than that on any of the other microsites and significantly higher than that on microsite *e*. In dry years and dry situations, planting on microsite *c* might be advantageous to survival.

Mortality among outplants in forest tree plantations is generally concentrated in the first year or two after planting, often becoming negligible thereafter. If the mortality between the end of the third and fifth growing seasons is assumed to reflect the general well-being of the plantations, the mounded microsites are clearly superior and the untreated and patch-bottom microsites clearly inferior (Appendix G). Similar results have been observed in British Columbia[3]. Very few trees planted on mounds died after the third growing season. Obviously, survival rate can be influenced by microsite beyond the third year after planting. In particular, the continuing decline of survival rates in the untreated microsite contrasts with the more stable situation in the mounded microsites *d* and *e*.

Survival rates on the two microsites most favorable to jack pine survival after five growing seasons, patch-shoulder (*b*) and mineral-on-mineral mound (*d*), differ so little from one another that neither microsite can be recommended as more advantageous to survival than the other. The shoulder microsite gave better survival than the mound in the three *P81* plantings, poorer in three of four *P82* plantings, and equal survival with the mineral-on-mineral mound in the *P80* plantings.

Compared with mounding, the patch-shoulder microsite is cheaper to produce, less environmentally disruptive, and less conducive to instability among young outplants (Fig. 3) and possibly also in subsequent pole-stage stands. Therefore, from a survival standpoint, mounding site preparation for bareroot jack pine on sites typical of the species in Ontario is not warranted.

Jack Pine Growth

Fifth-year data, the latest available, can be presumed to be the best available reflection of post-planting performance (Fig. 4), though annual height increment is a useful indicator of stand dynamics. Stem volume usefully combines stem height and stem diameter. Mean height increment in the first, second, third and fifth growing seasons after outplanting; mean total height initially, and after three and five growing seasons; mean ground-level stem diameter after one, two, three and five growing seasons; and mean stem volume (computed using a conic formula) after three and five growing seasons, are given in Appendix H, by planting year, site and microsite.

Microsite treatment had very little significant effect on performance. Among the five microsite treatments, the range in mean total height after five growing seasons was only 13 cm (Table 3a), and no two treatments differed significantly (P=0.05) from each another (Table 3b). Similar lack of significance is shown in relative growth rate (height, years one through five) (Tables 4a,b), ground-level stem diameter after five growing seasons (Tables 5a,b), computed stem volume after five growing seasons (Tables 6a,b), and relative growth rate (volume, years one through five) (Tables 7a,b). Only in comparisons of performance based on survival in combination with relative growth rates were any significant relationships found; in both performance indices, the untreated microsite (*a*) was significantly (P=0.05) inferior to both the patch-shoulder microsite (*b*) and the mineral-on-mineral mound microsite (*d*) (Tables 8a,b and 9a,b).

This does not prove that there are no differences among the microsite treatments. Of the two mounding treatments, the mineral-on-mineral microsite (*d*) seems generally to have been superior to the mineral-on-organic microsite (*e*); both of these microsites, as well as patch-shoulder microsite (*b*), seem generally superior to the untreated microsite (*a*). And, although the performance (excepting stem diameter) of jack pine on the patch-shoulder microsite was virtually identical with performance on the mineral-on-mineral mound microsite, the 5-year period of observation may have been too short to detect the full effect of the treatments on growth and stability. However, the suggestive, albeit non-significant, difference in stem diameter (29 versus 32 mm) between the patch-shoulder and the mound microsites might be discounted, for there is some possibility that even modest erosion or settling of mounds could have increased the exposure of root swell of stems compared with the other microsites.

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[3] Lorne Bedford, Site Preparation Specialist, British Columbia Ministry of Forests, Silviculture Branch, 31 Bastion Square, Victoria, B.C. V8W 3E7.

Table 3a. Jack pine: mean total height (cm) after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
134	147	137	143	140	0.934

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among total heights are real is 100% - P = 6.6%.

Table 4a. Jack pine: mean relative growth rate (height, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
0.408	0.425	0.407	0.422	0.412	0.919

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among growth rates are real is 100% - P = 8.1%.

Table 3b. Jack pine: probabilities[a] that differences in total height after five growing seasons between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.419			
c	0.865	0.543		
d	0.551	0.843	0.683	
e	0.715	0.664	0.855	0.817

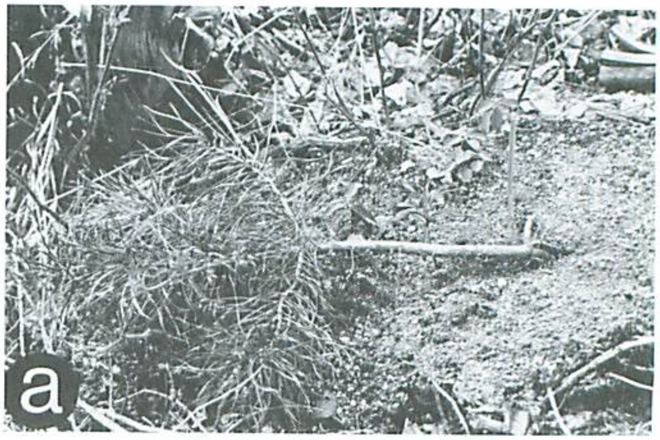
[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in total height between microsites *a* and *b* is 100% - 41.9% = 58.1%.

Table 4b. Jack pine: probabilities[a] that differences in relative growth rate (height, years 1 through 5) between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.488			
c	0.971	0.491		
d	0.552	0.906	0.552	
e	0.874	0.584	0.853	0.658

[a] By Minitab one-way analysis of variance, e.g., the chance that there is a real difference in growth rate between microsites *b* and *d* is 100% - 90.6% = 9.4%.

Figure 3. Roots of jack pine exposed on mound microsites throught various combinations of mound erosion, fróst heaving and twizzling (movement of the root collar/stem base caused by wind action on the aerial parts of an insufficiently anchored outplant leading to the development of a base-upward conical depression in the soil around and below the root collar [Sutton and Tinus 1983]):



a - P80, White River, microsite e; the swizzle stick is vertical;

b - P81, White River, microsite e;

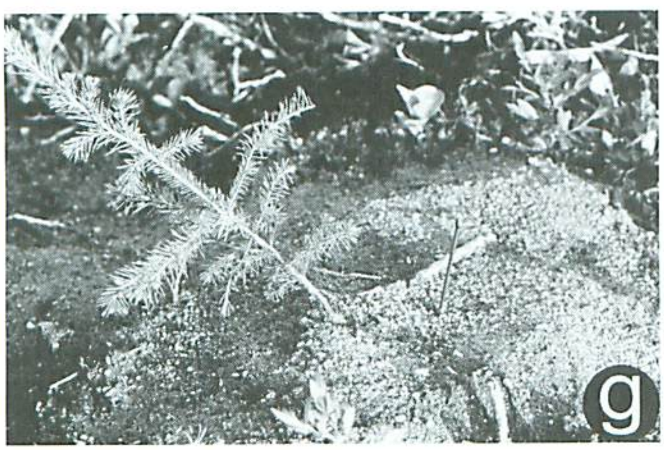
c - P80, Cochrane, microsite d;

d - P82, Savant Lake, microsite e.

Figure 3 (concl.). Roots of black spruce exposed on mound microsites through various combinations of mound erosion, frost heaving, and twizzling:

e - P82, Ignace, microsite d;

f - P82, Ignace, microsite e;



g - P82, Savant lake, microsite e, toppled black spruce, mounding eroding downslope

h - P82, Thunder Bay, microsite e.

Table 5a. Jack pine: mean ground-level stem diameter (mm) after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
26	29	26	32	32	0.118

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among diameters are real is 88.2%.

Table 5b. Jack pine: probabilities[a] that differences in stem diameter (ground-level) after five growing seasons between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.250			
c	0.944	0.244		
d	0.062	0.419	0.064	
e	0.064	0.481	0.067	0.875

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in diameter between microsites *b* and *d* is 58.1%

Table 6a. Jack pine: mean computed stem volume (cm^3) after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
335	437	337	493	465	0.353

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among volumes are real is 64.7%.

Table 6b. Jack pine: probabilities[a] that differences in computed stem volume (cm^3) after five growing seasons between the members of the indicated pairs of microsites are due to chance

	Microsite			
	a	*b*	*c*	*d*
b	0.296			
c	0.979	0.283		
d	0.134	0.597	0.123	
e	0.199	0.786	0.186	0.793

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in volume between microsites *b* and *d* due to chance is 40.3%.

Table 7a. Jack pine: mean relative growth rate (volume, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
1.146	1.186	1.126	1.176	1.209	0.765

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among growth rates are real is 23.5%.

Table 8a. Jack pine: performance index I (% survival x relative growth rate of height, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
3468	3972	3690	3995	3638	0.170

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among indices are real is 83.0%.

Table 7b. Jack pine: probabilities[a] that differences in relative growth rate (volume, years 1 through 5) between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.533			
c	0.782	0.396		
d	0.661	0.889	0.506	
e	0.337	0.734	0.247	0.648

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in growth rate between microsites *b* and *d* is 11.1%.

Table 8b. Jack pine: probabilities[a] that differences in performance index I between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.018*			
c	0.305	0.202		
d	0.026*	0.915	0.212	
e	0.547	0.247	0.860	0.244

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in performance index I between microsites *b* and *d* is 8.5%. Asterisks indicate that the probability is significant at P=0.05.

Table 9a. Jack pine: performance index II (% survival x relative growth rate of volume, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
9718	11109	10202	11168	10752	0.292

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among indices are real is 70.8%.

Table 9b. Jack pine: probabilities[a] that differences in performance index II between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.019* .			
c	0.399	0.158		
d	0.048*	0.936	0.212	
e	0.252	0.701	0.559	0.684

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in performance index II between microsites *b* and *d* is 6.4%. Asterisks indicate that the probability is significant at P=0.05.

Black Spruce Survival

Survival rates for black spruce at the end of the fifth growing season averaged 88.4% over the 55 site x microsite combinations (Appendix I), almost as high as those for jack pine.

Unsurprisingly, the greatest mortality occurred on microsite *c* on sites with high water tables; survival rates among black spruce planted in the patch bottom were lower than those on other microsites on five of the seven *P80* and *P81* sites. In the *P80* White River planting, for example, survival on microsite *c* was only 33%, reflecting prolonged high water-table levels in the spring and early summer; here, the wetness of the site depressed survival even among black spruce planted on the patch shoulder. A permanent water table close to the surface in the *P81* White River planting depressed survival to 56%.

More surprising is the rather poor showing of the mineral-on-organic mound microsite (*e*) in the *P80* and *P81* black spruce plantings, in which survival rates, averaged over sites within years, were second-lowest next to those in the patch bottom, though rates were still 83 and 84%, respectively (Table 10). Survival rates were generally, and on several sites substantially, higher on the mineral-on-mineral mound microsite (*d*) than on the mineral-on-organic mounds microsite (*e*). Mortality on microsite *e* is attributed to the greater tendency, compared with microsite *d*, toward dryness; typically, *e* mounds settled less well than did *d* mounds, and *e* mounds can be presumed to have incurred greater disruption of capillarity between the mound and the underlying soil moisture, effects that compounded the greater difficulty of stabilizing outplants in *e* mounds compared with *d* mounds. Deep planting (cf. Sutton 1967) would probably be particularly beneficial for trees planted on *e* mounds.

On four of the seven *P81* and *P82* sites, survival rates were lower on the untreated microsite than on the others, yet survival ranged from 81 to 100% and averaged 89% over the 11 sites. Again, the probability must be noted that the results shown by the "untreated" control (microsite *a*) would differ to some extent from results that would have been obtained had the whole site been left untreated.

Results varied considerably among years of planting. In the *P82* plantings, for instance, no microsite had less than 84% survival, whereas in the *P80* plantings 8 of the 20 site x microsite combinations had survival rates of 82% or less.

Figure 4. Two of the study sites, five growing seasons after planting: (top) P82 jack pine at Thunder Bay, and (bottom) P82 black spruce at White River. See also Figure 1.

Table 10. Black spruce fifth-year survival (%), by year of planting and microsite; n = 400 (P80 and P82) or = 300 (P81).

Planting year	Microsite[a]				
	a	*b*	*c*	*d*	*e*
P80	88b	86b	69a	90b	84b
P81	91bc	94cd	72a	97d	83b
P82	89a	95abc	92ab	98c	97bc

[a] Within each year of planting (row), values not followed by the same letter differ significantly (P=0.05) by chi-square test; within microsites (columns), all but microsite *a* gave differences that differ significantly (P=0.05) by chi-square test.

The data do not allow apportionment of cause among year of planting, site, and planting stock; however, the similarity of survival on the untreated microsite (*a*) among the three years of planting suggest that the effect of year of planting was relatively minor.

As with jack pine, black spruce survival rates declined less from the third year to the fifth in mounded microsites than in the other years (Appendix J). Survival rates from year three to the end of year five on both mounded microsites (*d* and *e*) were 99% or greater in 10 of 11 plantings. The decline in survival rate was greatest on the patch bottom microsite (*c*). Obviously, survival rates were influenced by microsite beyond the third year after planting.

The two microsites with the highest black spruce survival over all (patch-shoulder microsite *b* and mineral-on-mineral mound microsite *d*) are those of prime interest in the present study (Table 11). Though non-significant, the difference between them widened from 1% at the end of three growing seasons to 4% at the end of five. This difference, even if real, seems too small to warrant choosing mounding site preparation rather than the cheaper, simpler, gentler patch scarification and planting on the shoulder.

Table 11. Black spruce fifth-year survival (%), by microsite; all 11 plantings overall, n = 1100.

Microsite[a]				
a	*b*	*c*	*d*	*e*
89b	91b	78a	95c	89b

[a] Values not followed by the same letter differ significantly (P=0.05) by chi-square test.

Black Spruce Growth

As with jack pine, the greatest weight is placed on fifth-year data in the evaluation of black spruce performance. Mean height increment in the first, second, third and fifth growing seasons after outplanting; mean total height initially and after three and five growing seasons; mean ground-level stem diameter after one, two, three and five growing seasons; and mean stem volume (computed by means of a conic formula) after three and five growing seasons, are given in Appendix K, by planting year, site and microsite.

After five growing seasons in the field, mean total height of black spruce did not differ significantly (P=0.05) among microsites; only 9 cm separated the greatest total height from the least (Table 12a). Heights of black spruce were about half those of jack pine. In further contrast with jack pine, for which the untreated microsite (*a*) gave the lowest total height, black spruce total height after five growing seasons was greater on the untreated microsite than on microsites *c* and *e*. The poor showing of black spruce on patch-bottom microsite (*c*) was expected because of the wetness of some of the sites. As with jack pine, however, no two microsite treatments differed significantly (P=0.05) from each other in their effect on total height (Table 12b), on relative growth rate (height, years one through five) (Tables 13a,b), on ground-level stem diameter after five growing seasons (Tables 14a,b), computed stem volume after five growing seasons (Tables 15a,b), and relative growth rate (volume, years one through five) (Tables 16a,b). Performance indices I (Tables 17a,b) and II (Tables 18a,b) showed similar tendencies to those seen in jack pine, but in black spruce no microsite differed significantly from another. The closest approach to significance in any of these growth parameters was the probability (P=0.059) of a difference between the patch-bottom and mineral-on-mineral mound microsites in performance index II.

The variability of biological data obtained from experimentation of this kind is commonly great enough to obscure the effects of silvicultural treatment. Certainly, the statistical non-significance of differences in performance among microsites in the first 5 years after outplanting does not mean that real and important differences do not exist. However, the results produced by microsite treatments *b* and *d* are so close that the likelihood of significant differences developing between them is remote. Concern about future stability of black spruce planted on mounds is less than that for jack pine because spruces are better able than pines to adapt their root systems to soil conditions by adventitious rooting (Sutton 1969).

Table 12a. Black spruce: mean total height (cm) after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
77	82	73	78	74	0.733

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among total heights are real is 26.7%.

Table 12b. Black spruce: probabilities[a] that differences in total height after five growing seasons between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.556			
c	0.520	0.312		
d	0.685	0.527	0.481	
e	0.733	0.617	0.727	0.484

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in total height between microsites *b* and *d* is 47.3%.

Table 13a. Black spruce: mean relative growth rate (height, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
0.249	0.256	0.234	0.250	0.244	0.802

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among growth rates are real is 19.8%.

Table 13b. Black spruce: probabilities[a] that differences in relative growth rate (height, years 1 through 5) between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.665			
c	0.476	0.298		
d	0.667	0.526	0.441	
e	0.802	0.709	0.720	0.740

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in growth rate between microsites *b* and *d* is 47.4%.

Table 14a. Black spruce: mean stem diameter (mm) at ground-level after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
16	17	15	18	17	0.511

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among diameters are real is 48.9%.

Table 15a. Black spruce: mean computed stem volume (cm^3) after five growing seasons, by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
71	86	63	93	80	0.650

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among stem volumes are real is 35.0%.

Table 14b. Black spruce: probabilities[a] that differences in stem diameter (ground-level) after five growing seasons between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.698			
c	0.622	0.376		
d	0.437	0.312	0.133	
e	0.511	0.421	0.242	0.789

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in diameter between microsites *b* and *d* is 68.8%.

Table 15b. Black spruce: probabilities[a] that differences in computed stem volume after five growing seasons between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.509			
c	0.557	0.329		
d	0.512	0.406	0.185	
e	0.650	0.571	0.366	0.544

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in stem volume between microsite *b* and *d* is 59.4%.

Table 16a. Black spruce: mean relative growth rate (stem volume, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
0.781	0.783	0.724	0.809	0.793	0.801

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among growth rates are real is 19.9%.

Table 17a. Black spruce: performance index I (% survival x relative growth rate of height, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
2226	2362	1904	2376	2158	0.223

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among indices are real is 77.7%.

Table 16b. Black spruce: probabilities[a] that differences in relative growth rate (volume, years 1 through 5) between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.979			
c	0.676	0.480		
d	0.685	0.520	0.265	
e	0.801	0.679	0.467	0.802

[a] By Minitab one-way analysis of variance; e.g. the chance that there is a real difference in growth rate between microsites *b* and *d* is 48.0%.

Table 17b. Black spruce: probabilities[a] that differences in performance index I between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.461			
c	0.165	0.120		
d	0.158	0.128	0.095	
e	0.223	0.190	0.178	0.277

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in performance index I between microsites *b* and *d* is 87.2%.

Table 18a. Black spruce: performance index II (% survival x relative growth rate of volume, years 1 through 5), by microsite.

Microsite					
a	*b*	*c*	*d*	*e*	P[a]
6967	7231	5926	7720	7066	0.262

[a] P = probability by Minitab one-way analysis of variance; the chance that differences among indices are real is 73.8%.

Table 18b. Black spruce: probabilities[a] that differences in performance index II between the members of the indicated pairs of microsites are due to chance.

	Microsite			
	a	*b*	*c*	*d*
b	0.708			
c	0.275	0.190		
d	0.167	0.125	0.059	
e	0.267	0.209	0.124	0.380

[a] By Minitab one-way analysis of variance; e.g., the chance that there is a real difference in performance index II between microsites *b* and *d* is 87.5%.

CONCLUSIONS

After outplanting on mounded microsites, jack pine and black spruce performed well during the first half-decade; performance was equally good after outplanting on the shoulder of the standard, unmodified Bracke patch (Fig. 5). The results obtained in the experimentation reported here reveal no benefit to bareroot stock from mounding site preparation compared with regular Bracke patch scarification. The extra expense incurred in mounding on sites normally prepared by Bracke patch scarification is unwarranted on the basis of these results. Furthermore, the continued stability of trees, especially pines, planted on mounds cannot be unreservedly assumed. Mounding may nevertheless be useful on sites that are wet or heavily grassed, especially if herbicide cannot be used.

Field performance during the first half-decade may be an insufficient criterion by which to evaluate the silvicultural and management value of the investigated methods of site preparation; monitoring should be extended to cover at least the first decade after outplanting.

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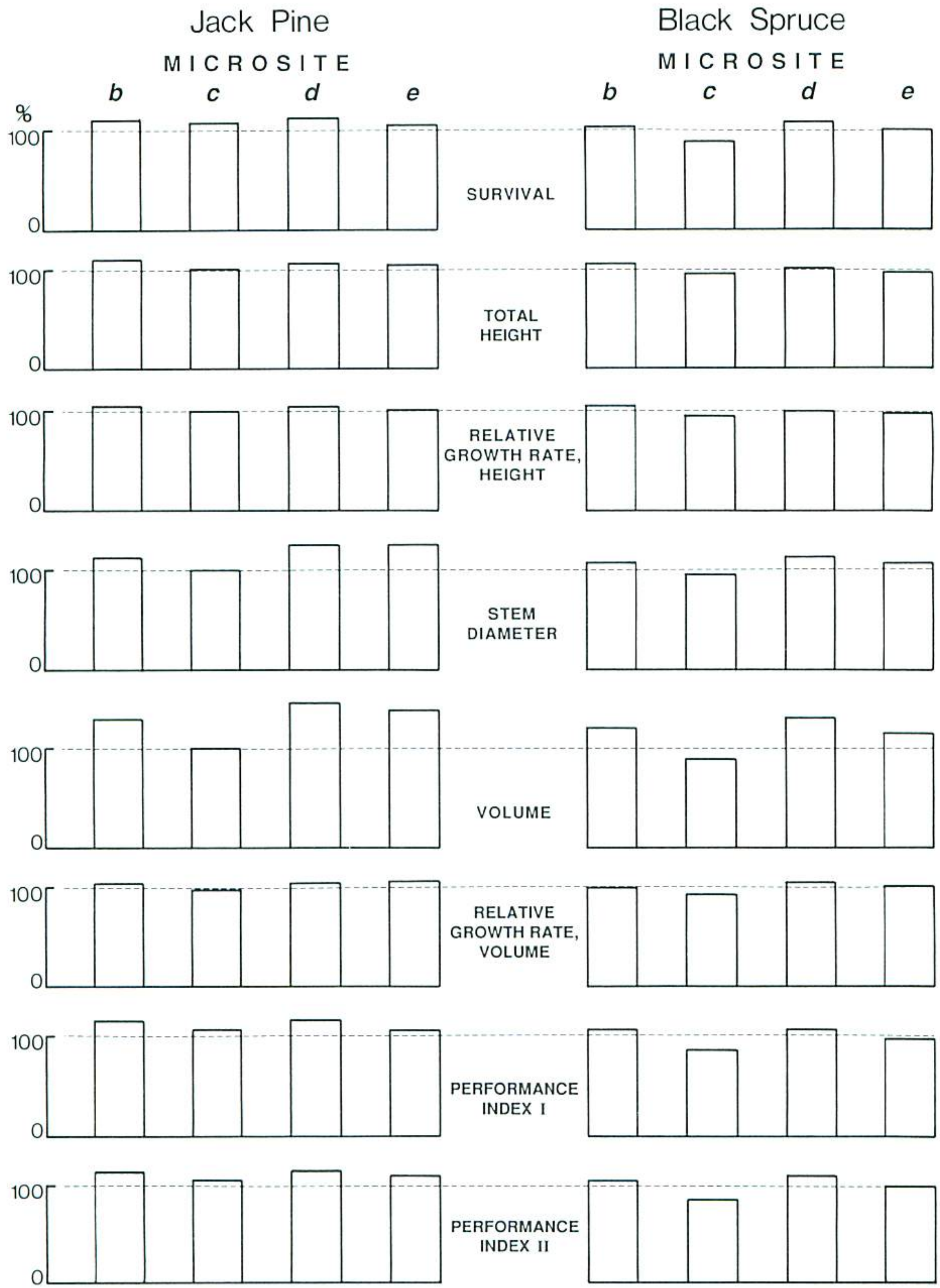

Figure 5. Performance on microsites b through e, as a percentage of performance on untreated microsite a, for jack pine and black spruce, by eight criteria; relative growth rates are for years 1 through 5, and all other data relate to the end of the fifth growing season.

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APPENDICES

Appendix A. Planting stock pedigree and chronology.

Planting year/site[a]	Seed lot[b]	Site region	Lift date	Storage[c]	Pickup date	RGC[d] lot no.	Plant date	Top height[e] (cm)	Stem diameter[e] (mm)
				2 + 0 JACK PINE					
P80									
Cochrane	M77-147	3215	1 May	N-R	23 May	-	30 May	16.1a	3.9b
Foleyet	M77-147	3215	1 May	N-R	23 May	-	27 May	16.6bc	3.5a
Savant Lake	M77-147	3215	1 May	N	16 May	1	16 May	16.4ab	4.3c
White River	M77-147	3215	1 May	N-B	20 May	2	22 May	17.0c	3.6a
P81									
Chapleau	77-990	3215B[f]	27 Apr	N	21 May	-	27 May	14.1a	3.4a
Ignace	77-990	3215B	27 Apr	N	15 May	1	18 May	14.0a	3.6b
Thunder Bay	77-990	3215B	27 Apr	N	12 May	2	14 May	13.7a	3.4a
White River	77-990	3215B	27 Apr	N	21 May	-	24 May	13.9a	3.3a
P82									
Ignace	78-748	25-3414	8 May	N	10 May	-	15 May	20.2c	3.8d
Savant Lake	78-748	25-3414	8 May	N	10 May	-	13 May	20.5c	3.7c
Thunder Bay	78-748	25-3414	8 May	N	8 May	1	9 May	19.6b	3.6b
White River	78-748	25-3414	12 May	N	18 May	2	18 May	18.4a	3.4a

(cont'd)

Appendix A. Planting stock pedigree and chronology (concl.).

Planting year/site[a]	Seed lot[b]	Site region	Lift date	Storage[c]	Pickup date	RGC[d] lot no.	Plant date	Top height[e] (cm)	Stem diameter[e] (mm)
				1½ + 1½ **BLACK SPRUCE**					
P80									
Cochrane	73-182	3200B	5 May	N	20 May	-	29 May	18.9ab	3.4a
Foleyet	73-182	3200B	5 May	N	20 May	-	26 May	18.4a	3.5a
Savant Lake	M76-122	3400	14 May	-	14 May	1	17 May	20.0c	4.4b
White River	73-182	3200B	5 May	N	20 May	2	23 May	19.4bc	3.5a
P81									
Ignace	M77-149	3200B	27 Apr	N	15 May	-	18 May	20.7a	4.5a
Thunder Bay	M77-149	3200B	27 Apr	N	12 May	1	13 May	22.1b	5.1c
White River	M77-149	3200B	27 Apr	N	21 May	2	23 May	22.8b	4.8b
P82									
Ignace	M77-155	4400	6 May	N	10 May	-	16 May	23.3b	4.1b
Savant Lake	M77-155	4400	6 May	N	10 May	1	13 May	23.3b	3.8a
Thunder Bay	M77-151	4400	6 May	N	8 May	2	8 May	23.4b	3.9a
White River	M78-138	4400	28 Apr	N	18 May	-	19 May	21.3a	3.9a

[a] Note that site names merely denote the broad geographical location of the sites; *P80*, *P81*, and *P82* = planted in 1980, 1981, and 1982, respectively.

[b] Jack pine: M77-147 = Wawa District, Acton Twp, 1976 collection; 77-990 = Wawa District, Acton Twp, 1977 collection, tested 93% germination; 78-748 = 1978 seed collection, Spruce River Seed Collection Area, Thunder Bay District, sand tests germinated 93%. Black spruce: M76-122 = mixed Thunder Bay and Geraldton Districts, 1976 collection; 73-182 = Kapuskasing, Cochrane and Hearst Districts, 1973 collection; M77-149 = mixed 1973 and 1974 collections, Nipigon, Kapuskasing, Chapleau, Hearst, Cochrane, Kirkland Lake, Timmins and White River Districts, sand tests germinated 97%; M77-151 = 1971 collection; M78-138 = mixed 1971 and 1976 seed collected in Geraldton, Sioux Lookout and Thunder Bay districts.

[c] N-R = stored at nursery at 1-2°C with low relative humidity until 8 May then shipped by refrigerated van to White River and there transferred to another refrigerated van at 3°C; N = stored at nursery at 1-2°C with low relative humidity; NB = cool-stored at nursery until 9 May then shipped by refrigerated van to the Beardmore mine shaft at 3°C with high relative humidity, and returned to the nursery on the day of pickup.

[d] RGC = Root Growth Capacity; determinations made on subsamples of two lots of planting stock per species per year of planting.

[e] Within columns, within species, and within planting years, values differ significantly (P=0.05) according to Tukey's Multiple Comparison Test unless followed by the same letter.

[f] The B designation indicates that seed was of medium size.

Appendix B. Field outplanting sites: location and selected site factors.

Year of planting	Site[a]	Latitude (N)	Longitude (W)	Mean elevation (m)	Soil texture in upper 25 cm	Moisture regime[b]	LFH thickness (cm)	Competition potential[c] Initial (at planting)	Ultimate
					JACK PINE				
1980	Cochrane	49°55'	81°42'	275	fine sand	fresh	<6	low	moderate
(*P80*)	Foleyet	48°25'	82°26'	310	medium sand	very fresh	2-6	low	moderate
	Savant Lake	50°22'	90°45'	425	fine sand/medium sand	fresh	0-12	low/moderate	moderate/high
	White River	48°38'	85°22'	390	loamy sand/loam	fresh	5-15	low	moderate
1981	Chapleau[d]	47°40'	83°24'	465	gravelly sandy loam	–	–	–	–
(*P81*)	Ignace	49°49'	92°02'	425	silt loam	fresh	4-8	moderate	moderate
	Thunder Bay	49°34'	89°54'	440	loamy sand (local gravel)	fresh	8-11	low	moderate
	White River	48°28'	85°10'	396	silt loam/clay	fresh	7	high	high
1982	Ignace	49°51'	92°03'	425	medium sand over gravel	fresh	7-10	low	moderate
(*P82*)	Savant Lake	50°15'	90°58'	425	medium sand	fresh	5-8	low	low/moderate
	Thunder Bay	48°48'	89°12'	425	medium sand/coarse sand	fresh	9-12	low	moderate
	White River	48°44'	85°16'	425	medium sand	very fresh	6-8	low	moderate
					BLACK SPRUCE				
1980	Cochrane	49°11'	79°56'	305	clay	moderately wet	<8	high	high
(*P80*)	Foleyet	48°24'	82°26'	335	silty loam/silty clay loam	wet/moderately wet	9	moderate	high
	Savant Lake	50°19'	90°43'	450	loam/sandy loam	very moist/moderately wet	10-16	low	moderate
	White River	48°38'	85°22'	404	loam/silt loam	wet	<32	moderate	high
1981	Ignace	49°49'	92°03'	427	clay	moist	<7	moderate	high
(*P81*)	Thunder Bay	49°34'	89°54'	457	sandy loam/loamy sand	moist	4-8	moderate	moderate/high
	White River	48°27'	85°10'	389	sandy loam	wet	9	moderate	high
1982	Ignace	49°54'	92°00'	427	loamy sand/sandy loam	fresh	6-10	low	moderate
(*P82*)	Savant Lake	50°15'	90°58'	450	loamy sand/sandy loam	fresh	5-13	low	moderate
	Thunder Bay	48°48'	89°12'	427	sandy loam	fresh	6	low	moderate
	White River	48°43'	85°15'	411	sand/loamy sand	very fresh	8-15	moderate	high

[a] Note that site names merely denote the broad geographical location of the sites.
[b] By the methods of Hills (1955).
[c] By the method of Hills and Pierpoint (1960).
[d] The Chapleau planting was destroyed inadvertently by operational site preparation in the summer of 1983.

Appendix C. Departures (%) from the 30-year norms for mean monthly precipitation and departures (°C) from mean monthly temperature at selected weather stations representing regional weather for the *P80*, *P81* and *P82* growing seasons.

	PRECIPITATION (%)						TEMPERATURE (°C)					
Planting year/station	Apr.	May	June	July	Aug.	Sept.	Apr.	May	June	July	Aug.	Sept.
P80												
Cochrane	-16	+12	0	+43	+46	+49	+1.0	+1.2	-2.7	-0.3	+1.5	-2.3
Timmins	+12	-22	-71	+14	+24	+21	+1.7	+1.4	-2.7	-0.3	+1.8	-1.9
Sioux Lookout	-74	-65	-19	- 5	+ 4	+15	+2.9	+4.6	-0.6	+0.3	0.0	-1.4
Marathon	-41	-42	-14	- 1	+ 1	+71	+0.7	+1.6	-1.5	+0.5	+1.4	-0.9
P81												
Ignace	-59	-44	+74[a]	-73	-54	-11	+2.0	+1.3	-0.8[a]	+2.2	+2.6	-0.1
Upsala	-36	-12	+29	-31	-36	-42	+1.4	+0.6	-0.6	+0.1	+0.6	-1.3
Marathon	-15	-27	+27	-94	-94	-34[b]	-0.7	-0.2	-0.1	-0.2	+1.7	-1.7[b]
P82												
Ignace	-53	-42	+ 2[a]	+ 82	-35[a]	-21	-0.2	+2.6	-3.0[a]	+0.5	-2.3[a]	0.0
Sioux Lookout	-46	+53	+19	- 6	+ 9	-26	-1.8	+2.8	-2.5	+0.5	-1.9	+0.2
Thunder Bay	-17	+5	- 4	+166	+52	-44	-1.4	+1.3	-1.5	-0.4	-2.0	-0.2
Marathon	-10[b]	- 2	- 5	+ 66[b]	+ 8	+21[b]	-2.7[b]	+1.8	-2.4	-0.4[b]	-2.2	-0.3[b]

[a] Data from Dryden weather station used to substitute for data missing from Ignace.
[b] Data from Manitouwadge weather station to subsitute for data missing from Marathon.

Appendix D. Nursery test plantings: stock size and first-year performance (n = 60).

Planting year[a]	Stock lot[b]	Initial height (cm)	Initial height (CV)[c]	Initial stem diameter at ground level (mm)	Initial stem diameter at ground level (CV)[c]	Height increment (cm)	Height increment (CV)[c]	Stem diameter increment (mm)	Stem diameter increment (CV)[c]
				JACK PINE[e]					
P80	Cochrane[d]	14.9a	0.20	3.7a	0.21	14.2ab	0.19	3.0b	0.35
	Foleyet	15.3a	0.22	3.5a	0.24	12.2a	0.28	2.5b	0.32
	Savant Lake	15.9a	0.19	4.8b	0.22	14.7b	0.31	1.6a	1.03
	White River	16.3a	0.18	3.8a	0.23	14.5ab	0.33	2.9b	0.40
P81	Chapleau	12.8a	0.21	3.5ab	0.22	9.9a	0.49	1.0a	0.59
	Ignace	15.5b	0.19	3.5ab	0.28	13.1b	0.37	1.5b	0.55
	Thunder Bay	13.4a	0.22	3.8b	0.22	11.9ab	0.39	0.7a	1.29
	White River	13.4a	0.24	3.3a	0.28	11.1ab	0.38	1.1ab	0.55
P82	Ignace	20.8a	0.15	3.8b	0.20	13.1b	0.20	3.0ab	0.26
	Savant Lake	20.5a	0.19	3.8b	0.22	12.0ab	0.27	2.9ab	0.38
	Thunder Bay	19.8a	0.17	3.0a	0.24	10.2a	0.34	3.3b	0.33
	White River	19.8a	0.19	3.6b	0.28	12.2b	0.32	2.6a	0.29
				BLACK SPRUCE[e]					
P80	Cochrane	19.4a	0.19	3.5b	0.23	8.6a	0.46	1.7a	0.45
	Foleyet	17.8a	0.19	3.0a	0.20	8.3a	0.41	1.8a	0.50
	Savant Lake	18.5a	0.25	4.2c	0.24	17.0b	0.28	3.4b	0.42
	White River	17.4a	0.20	3.1ab	0.21	8.0a	0.37	1.6a	0.45
P81	Ignace	20.5a	0.20	4.3a	0.25	10.4a	0.33	1.4b	0.46
	Thunder Bay	23.7b	0.23	5.6b	0.21	10.4a	0.44	0.7a	1.16
	White River	21.6ab	0.19	4.7a	0.24	10.8a	0.37	1.5b	0.58
P82	Ignace	23.8a	0.23	4.2b	0.15	11.8a	0.37	1.4a	0.72
	Savant Lake	23.0a	0.20	4.2b	0.21	12.0a	0.32	1.9b	0.46
	Thunder Bay	22.7a	0.24	3.6a	0.28	12.7a	0.25	2.6c	0.44
	White River	21.9a	0.24	4.1ab	0.25	11.4a	0.29	1.8ab	0.41

[a] *P80*, *P81*, and *P82* = planted in 1980, 1981 and 1982, respectively.
[b] Subsamples of stock lots en route to outplantings at the sites indicated.
[c] Coefficient of variation.
[d] Stock lot names merely denote the broad geographical location of the sites.
[e] Within columns within year of planting, values not followed by the same letter differ significantly (P=0.01) by Tukey's Studentized Range Test.

Appendix E. Root growth capacity tests: stock specifications, numbers of roots < 1 cm and ≥ 1 cm produced during a 30-day test, and mean aggregate and mean average length of new roots ≥ 1 cm, n = 60 (=30 with *P81* stock).

		RGC subsample, initial				Roots produced in test			
						< 1 cm	≥ 1 cm		
Planting year[a]	Stock lot[b]	Height (cm)	Stem diameter, ground level (mm)	Root vol. (cm^3)	RAI[c] (cm^2)	Mean no. (no.)	Mean no. (no.)	Mean total length (cm)	Mean mean length[d] (cm)
				JACK PINE					
P80[e]	Savant Lake	17.0	3.9	3.4	36	> 25	59.3	438.2	7.4
	White River	18.0	3.2	1.9	24	> 25	16.2	84.0	5.2
P81	Ignace	14.3	3.9	2.9	19	45	14.3	44.9	3.1
	White River	14.1	3.8	2.9	20	156	20.4	73.3	3.6
P82	Thunder Bay	21.1	3.5	2.1	16	45	13.2	63.6	4.8
	White River	19.8	3.1	1.5	13	108	6.1	148.2	5.7
				BLACK SPRUCE					
P80	Savant Lake	20.4	4.2	3.4	31	> 25	44.5	157.2	3.5
	White River	19.8	3.4	3.0	26	> 25	0.0	0.0	0.0
P81	Ignace	20.9	5.0	8.1	52	455	19.5	59.0	3.0
	White River	19.9	4.4	7.2	49	413	31.7	101.0	3.2
P82	Thunder Bay	23.6	3.7	6.3	38	422	18.3	70.9	3.9
	White River	23.3	4.2	8.0	46	622	25.4	111.7	4.4

[a] *P80*, *P81* and *P82* = planted in 1980, 1981, and 1982, respectively.

[b] Subsamples of stock lots en route to outplantings at the sites indicated.

[c] RAI = root area index

[d] i.e., the mean value of mean length, among treatments.

[e] In 1980 only, when 25 or more roots < 1 cm long were produced, this was reported as > 25 rather than the actual number.

Appendix F. Survival rates (%) in jack pine outplantings after five (and three) growing seasons, by planting year, site and microsite.

Planting year/site[a]	Microsite[b] *a*		*b*		*c*		*d*		*e*		*a-e* mean	
P80												
Cochrane	99	(100)	100	(100)	95	(99)	99	(99)	99	(99)	98.4	(99.4)
Foleyet	86	(93)	92	(97)	84	(94)	98	(98)	89	(89)	89.8	(94.2)
Savant Lake	94	(95)	92	(99)	94	(97)	95	(96)	93	(95)	93.6	(96.2)
White River	73	(79)	91	(93)	94	(97)	93	(95)	94	(94)	88.8	(91.6)
P81												
Ignace	96	(97)	95	(96)	92	(95)	84	(85)	49	(49)	83.2	(84.4)
Thunder Bay	80	(92)	90	(99)	90	(97)	89	(89)	76	(76)	85.0	(90.6)
White River	80	(82)	93	(94)	94	(95)	89	(89)	76	(76)	86.4	(87.2)
P82												
Ignace	86	(91)	98	(98)	93	(98)	96	(96)	96	(97)	93.8	(96.0)
Savant Lake	88	(92)	89	(95)	88	(99)	97	(98)	99	(99)	92.2	(96.6)
Thunder Bay	78	(81)	94	(97)	86	(93)	100	(100)	98	(98)	91.2	(93.6)
White River	79	(84)	97	(97)	88	(95)	100	(100)	98	(98)	92.4	(94.8)
P80 (n = 400)	88	(92)	94	(97)	92	(97)	96	(97)	94	(94)	92.8	(95.4)
P81 (n = 300)	85	(90)	93	(96)	92	(96)	87	(88)	67	(67)	84.8	(87.4)
P82 (n = 400)	83	(87)	94	(97)	89	(96)	98	(99)	98	(98)	92.4	(95.4)
P80-P82 (n = 1100)	85	(90)	94	(97)	91	(96)	95	(95)	88	(88)	90.6	(93.2)

[a] *P80*, *P81* and *P82* = planted in 1980, 1981 and 1982, respectively; site names merely denote the broad geographical location of the sites; see Appendix B.

[b] Values in parentheses represent values after three growing seasons.

Appendix G. Ratio of fifth-year to third-year survival rates in jack pine outplantings, by planting year, site and microsite.

Planting year/site[a]	Microsite *a*	*b*	*c*	*d*	*e*	*a-e*
P80						
Cochrane	0.99	1.00	0.96	1.00	1.00	0.990
Foleyet	0.92	0.95	0.89	1.00	1.00	0.953
Savant Lake	0.99	0.93	0.97	0.99	0.98	0.973
White River	0.92	0.98	0.97	0.98	1.00	0.969
P81						
Ignace	0.99	0.99	0.97	0.99	1.00	0.991
Thunder Bay	0.87	0.91	0.93	1.00	1.00	0.938
White River	0.98	0.99	0.99	1.00	1.00	0.991
P82						
Ignace	0.95	1.00	0.95	1.00	0.99	0.977
Savant Lake	0.96	0.94	0.89	0.99	1.00	0.954
Thunder Bay	0.96	0.97	0.92	1.00	1.00	0.974
White River	0.94	1.00	0.93	1.00	1.00	0.975
P80 (n = 400)	0.96	0.97	0.95	0.99	1.00	0.973
P81 (n = 300)	0.94	0.97	0.96	0.99	1.00	0.970
P82 (n = 400)	0.95	0.97	0.93	0.99	1.00	0.969
P80-P82 (n = 1100)	0.94	0.97	0.95	1.00	1.00	0.972

[a] *P80*, *P81* and *P82* = planted in 1980, 1981 and 1982, respectively; site names merely denote the broad geographical location of the sites; see Appendix B.

Appendix H. Jack pine field growth, by site, microsite and for the microsites over all.

	Mean height increment (cm) Year				Mean total height (cm)			Mean ground-level stem diameter after growing season (mm)				Mean stem volume computed by conic formula (cm^3)	
Planting year/site	1	2	3	5	Initial	3rd yr	5th yr	1	2	3	5	3rd yr	5th yr
MICROSITES *a* through *e* (over all)													
P80													
Cochrane	6.3	10.1	18.7	32.1	16.1	50.6	103.0	4.9	7.1	11.0	23.3	19.2	182.5
Foleyet	9.5	27.8	45.1	60.0	16.6	97.9	209.5	4.9	10.4	17.4	34.9	90.8	754.6
Savant Lake	9.5	24.9	35.5	42.5	16.4	86.4	164.4	5.0	8.6	13.3	26.0	48.1	381.5
White River	7.8	20.9	37.1	51.9	17.0	83.3	178.7	4.8	9.8	17.6	36.3	84.5	752.4
P81													
Ignace	7.3	9.9	8.1	24.5	14.0	37.4	75.9	4.4	5.4	7.1	16.0	6.2	67.0
Thunder Bay	7.7	12.5	21.7	45.6	13.7	52.5	137.8	4.0	7.1	15.6	36.3	41.5	538.0
White River	6.5	13.3	19.7	31.4	13.9	52.2	111.8	3.9	6.2	9.6	20.3	16.5	170.9
P82													
Ignace	8.4	14.9	33.7	35.4	20.2	75.0	144.9	4.8	9.5	16.8	35.0	63.8	521.3
Savant Lake	8.5	11.4	31.1	37.7	20.5	68.7	135.2	4.5	8.3	14.5	29.8	46.6	367.7
Thunder Bay	9.8	15.8	35.4	43.6	19.5	77.5	157.6	4.6	8.7	14.7	17.5	51.3	481.7
White River	9.5	9.7	26.8	35.6	18.4	61.9	123.6	4.4	7.7	13.1	30.3	34.5	359.9
MICROSITE *a*, unscarified													
P80													
Cochrane	6.5	9.9	14.8	26.8	15.7	46.9	89.1	4.8	6.3	8.8	18.0	12.0	109.1
Foleyet	8.7	29.5	46.4	60.5	16.4	100.1	212.9	4.9	10.1	16.7	35.2	82.1	756.8
Savant Lake	6.4	22.6	30.1	38.4	15.4	74.9	145.4	4.5	7.3	11.0	21.5	31.2	264.7
White River	7.7	19.6	35.4	47.7	16.1	78.7	167.2	4.7	9.2	15.8	32.6	67.5	622.5
P81													
Ignace	9.0	10.5	8.8	31.3	14.0	39.4	89.4	4.4	5.1	6.9	17.3	5.8	83.5
Thunder Bay	6.8	11.6	20.5	41.3	13.7	49.0	127.7	4.1	6.4	13.4	31.9	27.9	394.7
White River	6.9	15.0	22.9	31.8	13.3	56.5	120.2	3.9	5.8	9.3	19.4	16.4	160.8
P82													
Ignace	7.2	13.4	32.8	35.1	20.9	71.5	141.2	4.6	8.5	14.8	32.6	50.5	463.8
Savant Lake	7.5	7.8	25.1	32.8	19.8	58.2	114.6	4.3	6.6	11.1	23.0	24.3	191.2
Thunder Bay	8.2	14.1	34.7	41.5	19.4	73.3	149.7	4.4	7.9	12.8	29.0	37.6	378.0
White River	8.5	8.9	24.5	33.9	18.1	57.7	115.2	4.1	6.6	11.1	26.2	23.9	257.7

(cont'd)

Appendix H. Jack pine field growth, by site, microsite and for the microsites over all (cont'd).

	Mean height increment (cm) Year				Mean total height (cm)			Mean ground-level stem diameter after growing season (mm)				Mean stem volume computed by conic formula (cm^3)	
Planting year/site	1	2	3	5	Initial	3rd yr	5th yr	1	2	3	5	3rd yr	5th yr
MICROSITE *b*, upper slope (shoulder) of Bracke patch													
P80													
Cochrane	6.3	10.9	20.4	34.3	15.8	52.8	110.6	4.8	7.1	11.0	24.1	19.8	201.3
Foleyet	9.0	28.1	47.8	60.0	16.7	100.2	212.4	4.9	10.3	17.5	34.6	92.9	753.0
Savant Lake	9.8	25.5	37.0	43.6	16.2	88.9	169.3	5.0	8.6	13.2	26.4	47.9	397.3
White River	9.3	23.8	40.4	53.3	17.1	90.7	188.1	5.0	10.4	18.2	37.5	98.7	834.8
P81													
Ignace	8.4	10.2	7.3	22.4	13.6	37.3	73.6	4.3	5.3	6.6	14.6	5.6	59.4
Thunder Bay	8.8	14.3	24.2	46.9	14.2	57.6	145.5	3.9	7.2	16.5	37.6	52.6	587.2
White River	7.4	17.3	25.6	34.7	13.4	61.4	128.5	4.1	6.9	10.9	23.0	24.0	235.6
P82													
Ignace	8.4	17.3	36.7	35.9	19.6	79.7	151.2	4.8	9.4	16.6	34.9	63.8	525.5
Savant Lake	8.4	13.1	34.7	37.9	21.6	74.9	140.5	4.6	8.4	14.8	29.4	49.1	354.1
Thunder Bay	10.0	16.4	36.5	43.8	19.5	79.4	161.4	4.6	8.0	13.7	30.8	44.1	445.2
White River	10.0	12.3	29.7	36.6	19.5	69.1	133.0	4.5	7.8	13.6	31.5	39.9	412.1
MICROSITE *c*, bottom of Bracke patch													
P80													
Cochrane	5.8	9.7	24.9	34.3	16.7	53.7	111.3	4.7	6.9	10.8	22.7	18.6	176.8
Foleyet	10.3	26.2	43.5	57.3	16.6	93.9	199.8	4.6	9.2	15.4	30.7	69.0	571.8
Savant Lake	11.1	28.3	38.3	41.3	17.1	93.5	168.4	5.3	9.0	13.5	25.6	55.3	409.3
White River	6.9	19.2	36.5	52.3	17.0	79.6	175.4	4.4	8.3	15.0	32.1	59.6	586.9
P81													
Ignace	7.2	10.2	4.8	16.7	13.7	34.5	58.4	4.3	5.4	5.9	11.2	3.7	25.7
Thunder Bay	8.2	13.4	23.0	48.3	13.4	54.4	142.7	4.0	6.8	14.4	35.6	36.1	528.1
White River	7.9	14.2	16.8	25.8	14.3	49.6	99.0	4.0	5.9	8.3	16.1	10.9	98.1
P82													
Ignace	9.5	14.6	35.6	37.2	19.7	75.5	147.5	4.5	7.8	14.1	32.1	44.4	451.6
Savant Lake	8.4	11.0	29.8	38.1	20.3	64.4	130.7	4.2	6.8	11.9	25.5	28.7	253.0
Thunder Bay	10.5	17.0	36.2	40.7	18.8	77.3	150.5	4.3	7.4	12.4	25.9	36.9	319.9
White River	10.9	11.0	28.0	34.1	18.0	61.6	119.0	4.3	6.7	11.0	26.9	24.7	286.5

(cont'd)

Appendix H. Jack pine field growth, by site, microsite and for the microsites over all (concl.).

Planting year/site	Mean height increment (cm) Year 1	2	3	5	Mean total height (cm) Initial	3rd yr	5th yr	Mean ground-level stem diameter after growing season (mm) 1	2	3	5	Mean stem volume computed by conic formula (cm^3) 3rd yr	5th yr
MICROSITE *d*, mineral mound on Bracke patch shoulder													
P80													
Cochrane	6.8	10.9	18.5	34.4	16.6	53.4	109.6	5.2	8.0	12.7	27.5	25.7	249.0
Foleyet	10.6	27.2	43.1	60.4	17.0	97.7	209.5	5.2	11.2	18.7	36.4	103.6	810.8
Savant Lake	10.4	24.1	36.8	43.9	16.6	88.8	171.9	5.2	9.0	14.0	27.6	51.3	404.0
White River	8.4	21.6	38.2	53.0	16.9	85.6	184.6	5.0	10.6	19.6	40.0	102.5	893.5
P81													
Ignace	6.6	9.6	10.0	24.1	14.6	39.4	77.5	4.4	5.9	8.4	17.8	9.3	82.3
Thunder Bay	7.5	12.2	20.3	46.1	13.4	52.7	139.4	4.4	8.0	17.6	39.7	49.4	643.2
White River	5.4	10.9	14.7	30.6	13.7	47.8	106.1	3.8	6.3	9.8	20.8	15.8	177.5
P82													
Ignace	8.5	13.6	32.9	36.4	21.0	75.0	146.4	5.0	10.9	19.2	38.3	78.7	610.8
Savant Lake	8.9	12.1	31.5	38.8	21.1	71.7	140.1	4.8	9.4	16.6	34.4	57.3	473.8
Thunder Bay	10.3	16.1	37.6	47.2	19.8	82.1	169.4	4.9	10.2	17.7	37.9	72.8	674.2
White River	9.0	8.0	24.8	36.6	17.8	58.7	123.8	4.4	8.4	14.5	32.5	39.9	406.1
MICROSITE *e*, mineral mound on organic minimound													
P80													
Cochrane	6.0	9.0	14.8	30.6	15.6	46.4	94.6	4.9	7.5	11.7	24.1	19.8	175.8
Foleyet	8.7	28.0	44.6	62.0	16.1	97.6	212.6	5.0	11.4	19.0	37.3	106.6	866.9
Savant Lake	9.6	23.8	35.2	45.6	16.5	85.6	166.9	5.1	9.3	14.6	28.9	54.4	432.7
White River	6.8	20.1	34.9	52.5	17.8	81.3	176.1	5.0	10.7	18.9	38.5	92.3	799.6
P81													
Ignace	3.0	8.2	11.8	29.7	14.0	36.1	84.5	4.2	5.6	8.4	19.4	8.0	101.0
Thunder Bay	6.9	10.1	19.5	45.3	13.8	47.7	131.0	3.8	7.2	16.4	36.2	41.1	514.2
White River	4.1	8.3	18.4	34.6	14.8	44.4	105.0	3.9	6.2	10.0	22.7	15.4	185.4
P82													
Ignace	8.6	15.3	30.6	32.3	19.9	73.0	137.7	5.1	11.0	19.4	36.9	81.2	546.3
Savant Lake	9.3	13.0	33.9	40.4	19.8	74.0	148.0	4.8	10.4	18.1	35.6	72.2	535.0
Thunder Bay	9.5	15.2	31.9	43.8	20.2	74.7	154.6	4.8	9.6	16.6	34.7	61.6	544.5
White River	9.1	8.2	26.8	36.3	18.8	62.0	125.3	4.4	8.8	15.0	33.2	42.5	410.0

Appendix I. Field performance: black spruce survival rates (%) in outplantings after five (and three) growing seasons, by planting year, site, and microsite [based on total number of trees planted, not plot means].

Planting year/site[a]	Microsite[b] *a*		*b*		*c*		*d*		*e*		*a-e*	
P80												
Cochrane	91	(95)	88	(89)	80	(83)	91	(92)	72	(73)	84.4	(86.4)
Foleyet	90	(93)	94	(99)	85	(89)	93	(94)	88	(90)	90.0	(93.0)
Savant Lake	82	(86)	95	(95)	79	(81)	96	(97)	82	(82)	86.8	(88.2)
White River	91	(92)	69	(73)	33	(36)	80	(83)	95	(97)	73.6	(76.2)
P81												
Ignace	100	(100)	92	(93)	70	(78)	94	(95)	79	(79)	87.0	(89.0)
Thunder Bay	81	(89)	95	(98)	94	(97)	97	(97)	85	(86)	90.4	(93.4)
White River	91	(93)	95[c]	(97)[c]	56[d]	(60)[d]	100	(100)	86	(86)	83.6	(85.4)
P82												
Ignace	87	(91)	98	(100)	94	(99)	98	(98)	94	(94)	94.2	(96.4)
Savant Lake	92	(98)	92	(99)	85	(97)	98	(99)	99	(99)	93.2	(98.4)
Thunder Bay	84	(90)	93	(99)	93	(98)	98	(98)	95	(95)	92.6	(96.0)
White River	95	(97)	96	(98)	96	(99)	100	(100)	99	(99)	97.2	(98.6)
P80	88	(92)	86	(89)	69	(72)	90	(92)	84	(86)	83.7	(85.9)
P81	91	(94)	94	(96)	72	(77)	97	(97)	83	(84)	87.4	(89.6)
P82	89	(94)	95	(99)	92	(98)	98	(99)	97	(97)	94.2	(97.4)
P80-P82	89	(93)	91	(95)	78	(83)	95	(96)	89	(89)	88.4	(91.2)

[a] *P80*, *P81* and *P82* = planted in 1980, 1981 and 1982, respectively; site names merely denote the broad geographical location of the sites; see Appendix B.

[b] Values in parentheses represent survival rates after three growing seasons.

[c] Values are from n = 75 instead of n = 100.

[d] Values are from n = 125 instead of n = 100.

Appendix J. Ratio of fifth-year to third-year survival rates in black spruce outplantings, by planting year, site and microsite [based on total number of trees planted, not plot means].

Planting year/site[a]	Microsite *a*	*b*	*c*	*d*	*e*	*a-e*
P80						
Cochrane	0.96	0.99	0.96	0.99	0.99	0.977
Foleyet	0.97	0.96	0.96	0.99	0.99	0.968
Savant Lake	0.95	1.00	0.98	0.99	1.00	0.986
White River	0.99	0.95	0.92	0.96	0.98	0.966
P81						
Ignace	1.00	0.99	0.90	0.99	1.00	0.978
Thunder Bay	0.91	0.97	0.97	1.00	0.99	0.968
White River	0.98	0.98[b]	0.93[c]	1.00	1.00	0.979
P82						
Ignace	0.96	0.98	0.95	1.00	1.00	0.978
Savant Lake	0.94	0.93	0.88	0.99	1.00	0.947
Thunder Bay	0.93	0.94	0.95	1.00	1.00	0.965
White River	0.98	0.98	0.97	1.00	1.00	0.986
P80	0.96	0.97	0.96	0.98	0.98	0.970
P81	0.97	0.98	0.94	1.00	0.99	0.974
P82	0.95	0.96	0.94	0.99	1.00	0.968
P80-P82	0.96	0.96	0.94	0.99	1.00	0.970

[a] *P80*, *P81* and *P82* = planted in 1980, 1981 and 1982, respectively; site names merely denote the broad geographical location of the sites; see Appendix B.
[b] Values are from n = 75 instead of n = 100.
[c] Values are from n = 125 instead of n = 100.

Appendix K. Black spruce field growth, by site, microsite and for the microsites over all.

	Mean height increment (cm) Year				Mean total height (cm)			Mean ground-level stem diameter after growing season (mm)				Mean stem volume computed by conic formula (cm^3)	
Planting year[a]/site	1	2	3	5	Initial	3rd yr	5th yr	1	2	3	5	3rd yr	5th yr
MICROSITES *a* through *e* (over all)													
P80													
Cochrane	3.4	8.7	9.3	16.6	18.9	39.0	65.6	4.3	5.0	6.3	10.6	4.9	25.5
Foleyet	4.7	7.5	10.7	17.7	18.4	40.5	72.6	4.0	6.0	8.5	14.5	8.9	50.1
Savant Lake	5.7	6.7	14.6	18.8	20.0	46.9	75.4	4.8	7.0	10.4	16.5	16.9	74.5
White River	3.6	7.7	10.0	11.7	19.4	40.2	59.6	3.9	5.0	6.3	9.0	5.0	18.5
P81													
Ignace	7.3	5.1	7.1	13.3	20.7	39.9	63.0	5.5	7.0	8.5	13.0	9.5	43.2
Thunder Bay	7.8	7.8	14.8	22.3	22.1	50.8	93.2	6.0	8.2	11.9	20.5	22.2	123.4
White River	6.4	4.2	6.2	8.6	22.8	38.7	52.7	5.8	7.3	9.5	14.9	10.8	40.4
P82													
Ignace	6.0	6.2	15.6	21.1	23.3	50.9	88.6	4.8	7.7	12.0	21.8	22.9	141.5
Savant Lake	6.6	8.9	21.0	20.3	23.3	57.9	100.6	5.0	7.9	12.0	20.6	24.4	128.9
Thunder Bay	7.2	8.0	14.6	19.0	23.4	52.8	85.9	5.0	7.1	10.1	17.5	15.6	81.3
White River	7.4	8.4	16.9	21.4	21.3	52.6	87.8	5.3	8.5	12.7	23.1	25.9	143.8
MICROSITE *a*, unscarified													
P80													
Cochrane	3.9	9.1	9.3	16.7	19.2	40.4	66.8	4.2	5.0	6.2	10.7	4.8	26.3
Foleyet	4.1	7.4	10.2	17.3	18.7	39.8	70.7	4.0	5.6	8.2	14.0	8.4	45.2
Savant Lake	5.4	7.7	13.8	17.8	19.6	45.5	72.6	4.5	6.2	9.5	15.0	13.6	58.8
White River	3.0	10.7	11.6	13.8	19.2	44.7	67.5	3.6	5.0	6.5	9.4	5.8	22.7
P81													
Ignace	7.3	5.5	8.8	15.0	21.2	41.9	70.9	5.5	6.7	8.5	14.1	9.9	51.3
Thunder Bay	6.4	8.0	14.0	20.8	23.7	49.9	86.5	5.9	8.1	11.4	18.9	19.5	100.9
White River	5.8	4.4	6.3	9.2	22.2	38.9	53.7	5.6	6.9	8.8	13.9	9.3	35.3
P82													
Ignace	5.9	6.8	16.2	20.0	23.3	52.5	88.6	4.9	7.7	11.9	20.0	23.8	124.9
Savant Lake	6.4	8.5	21.3	19.0	23.4	57.3	95.7	4.8	7.5	11.4	19.0	22.2	106.2
Thunder Bay	6.7	9.5	16.5	19.9	22.6	55.3	89.2	5.0	6.7	9.5	16.1	14.4	71.2
White River	7.5	8.2	18.2	20.7	22.1	55.6	88.0	5.2	8.2	12.3	23.0	25.7	143.4

(cont'd)

Appendix K. Black spruce field growth, by site, microsite and for the microsites over all (cont'd).

Planting year[a]/site	Mean height increment (cm) Year				Mean total height (cm)			Mean ground-level stem diameter after growing season (mm)				Mean stem volume computed by conic formula (cm^3)	
	1	2	3	5	Initial	3rd yr	5th yr	1	2	3	5	3rd yr	5th yr
MICROSITE *b*, upper slope (shoulder) of Bracke patch													
P80													
Cochrane	3.5	9.2	10.3	17.9	19.3	40.3	69.5	4.3	5.0	6.7	11.3	6.0	31.3
Foleyet	5.0	8.8	10.9	19.2	18.7	42.0	77.4	4.0	6.2	9.0	15.5	9.8	54.9
Savant Lake	5.7	6.8	16.1	20.2	20.4	48.6	79.3	4.8	7.0	10.6	17.0	17.6	77.1
White River	3.5	6.4	9.9	9.7	20.1	38.7	54.7	3.9	4.8	5.9	8.1	4.1	12.3
P81													
Ignace	7.8	4.3	5.4	12.0	21.0	38.3	57.7	5.4	6.8	7.7	10.3	7.0	23.9
Thunder Bay	8.3	9.8	16.5	23.1	22.0	54.1	99.3	5.9	8.2	11.8	20.7	22.4	128.1
White River	7.1	6.2	7.1	9.6	22.5	41.8	58.1	5.9	7.6	9.9	15.3	13.1	49.0
P82													
Ignace	6.8	8.2	18.2	22.4	23.3	56.2	99.0	5.0	8.1	12.2	22.1	26.2	163.3
Savant Lake	7.2	9.8	23.2	22.2	23.4	62.1	107.9	5.2	8.2	12.1	20.8	26.7	141.5
Thunder Bay	7.7	9.6	17.0	20.1	23.0	57.5	91.9	4.8	7.2	9.8	16.8	16.4	81.1
White River	8.2	11.3	21.5	23.6	21.5	61.8	102.1	5.7	9.4	14.4	24.9	37.2	185.5
MICROSITE *c*, bottom of Bracke patch													
P80													
Cochrane	3.3	8.2	8.8	13.7	18.8	37.3	59.4	4.2	4.9	5.7	8.7	3.6	15.3
Foleyet	4.8	7.0	9.3	13.6	18.5	38.7	62.8	4.0	5.5	7.2	11.4	6.1	29.5
Savant Lake	4.8	5.6	11.4	14.6	19.8	41.0	60.6	4.9	6.5	8.8	13.0	10.7	38.2
White River	3.4	5.6	8.2	9.5	19.4	35.5	51.1	3.6	4.4	5.9	7.9	4.0	14.6
P81													
Ignace	7.1	3.0	3.0	7.3	19.6	32.1	40.7	5.1	5.9	6.4	7.8	3.9	9.6
Thunder Bay	8.3	8.0	14.5	20.4	22.3	50.8	91.8	5.7	7.4	10.4	18.0	16.6	91.9
White River	7.6	6.1	7.6	10.2	22.5	41.7	59.1	5.9	7.4	9.5	14.8	11.5	43.8
P82													
Ignace	6.7	6.8	19.4	24.3	23.9	54.4	96.6	4.7	6.8	10.6	20.4	18.9	128.9
Savant Lake	7.2	10.4	23.2	19.3	22.9	60.9	102.6	4.6	7.1	10.8	19.1	20.2	107.0
Thunder Bay	8.0	9.4	16.7	17.4	23.1	55.2	84.3	4.5	6.6	9.4	15.7	14.8	65.1
White River	7.7	10.5	20.0	21.1	21.6	57.1	89.5	5.2	8.2	12.4	23.5	25.6	148.3

(cont'd)

Appendix K. Black spruce field growth, by site, microsite and for the microsites over all (concl.).

	Mean height increment (cm) Year				Mean total height (cm)			Mean ground-level stem diameter after growing season (mm)				Mean stem volume computed by conic formula (cm^3)	
Planting year[a]/site	1	2	3	5	Initial	3rd yr	5th yr	1	2	3	5	3rd yr	5th yr
MICROSITE *d*, mineral mound on Bracke patch shoulder													
P80													
Cochrane	3.7	9.7	9.3	17.5	18.6	40.6	68.6	4.5	5.3	6.7	11.3	5.7	29.2
Foleyet	5.2	7.6	11.0	19.3	18.0	41.3	76.7	4.0	6.5	9.3	16.3	10.5	63.2
Savant Lake	6.8	7.1	16.2	20.3	19.4	50.1	81.3	4.9	7.5	11.0	17.7	21.0	96.3
White River	3.7	8.3	12.0	13.8	19.0	43.6	67.5	4.2	5.4	7.1	10.2	6.9	27.0
P81													
Ignace	7.6	6.4	8.3	14.3	20.8	42.8	67.7	5.8	7.6	9.6	15.3	12.8	59.4
Thunder Bay	8.6	7.5	15.5	23.7	21.0	52.5	96.8	6.2	8.6	13.5	23.3	30.5	168.5
White River	5.9	2.7	5.4	6.8	23.4	37.3	49.7	5.9	7.6	10.1	15.8	11.9	44.7
P82													
Ignace	5.5	4.7	13.3	20.8	23.6	47.4	84.9	4.8	8.1	12.7	24.0	24.3	162.7
Savant Lake	6.2	8.0	18.9	20.7	23.9	56.1	100.6	5.2	8.4	12.7	22.0	26.8	148.2
Thunder Bay	7.0	6.1	11.5	18.2	23.8	47.7	81.2	5.4	7.3	10.7	18.4	15.4	83.5
White River	7.0	6.1	12.9	21.4	21.6	46.0	83.8	5.2	8.8	12.7	23.2	23.2	139.4
MICROSITE *e*, mineral mound on organic minimound													
P80													
Cochrane	2.5	7.0	8.8	16.9	18.7	35.6	62.4	4.1	4.8	6.3	10.7	4.5	24.4
Foleyet	4.4	6.6	12.1	18.6	17.9	40.5	74.8	4.0	6.1	8.8	15.2	9.8	56.3
Savant Lake	6.0	6.4	15.1	20.7	20.6	48.6	80.9	5.1	7.6	11.8	19.2	20.8	96.7
White River	4.3	6.2	7.4	10.0	19.5	35.9	51.5	4.2	5.2	5.9	8.4	3.8	13.1
P81													
Ignace	6.5	6.2	9.6	15.6	20.7	43.4	73.6	5.7	7.7	10.2	16.8	13.5	65.8
Thunder Bay	7.1	5.2	12.9	23.3	21.7	46.3	90.1	6.0	8.6	12.5	21.5	21.7	122.8
White River	5.1	1.4	5.3	7.7	23.2	34.8	45.6	5.6	6.9	9.1	14.8	8.5	31.1
P82													
Ignace	5.4	4.6	10.4	17.6	22.2	43.8	73.7	4.8	7.8	12.6	22.0	21.5	124.6
Savant Lake	6.2	7.6	18.2	20.3	23.0	53.3	96.6	5.2	8.0	12.8	21.9	26.0	137.8
Thunder Bay	6.6	5.4	11.2	19.4	24.4	48.3	83.5	5.5	7.9	11.2	20.1	17.2	104.3
White River	6.6	5.4	11.7	20.2	19.8	42.7	76.3	5.1	8.1	11.5	20.9	17.7	103.6

[a] *P80* = planted in 1980, *P81* = planted in 1981, etc.