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Methodologies For Maintaining the Softwood Component in Boreal Mixedwoods

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ABSTRACT

White spruce (*Picea glauca* [Moench] Voss) seedlings were operationally outplanted in May 1993 on a boreal mixedwood site in Biggs Township, Ontario. A factorial randomized block design with four replications accommodated three main treatments for establishing white spruce: namely, corridoring, mounding, and pelleted hexazinone. Plots (50 m x 100 m) were split longitudinally between bareroot and containerized stock types. Immediately after planting and at the end of the first three growing seasons, 2 400 trees (100 in each half of each split plot) were assessed for performance. Since establishment, photosynthetically active radiation (PAR) was determined 14 times at 1 m above ground level at 360 outplant locations (60 per half split plot) in Block I and nine times at leader-tip level of surviving outplants at those locations. Significantly lower (P <0.01) survival rates for bareroot stock than for containerized stock in both the hexazinone and corridor treatments are attributed to low vigor of the bareroot stock; the virtual absence of first-year mortality among containerized stock in each of the main treatments shows that outplants were not endangered by pelleted hexazinone used as described. Through three growing seasons, mounding gave the highest survival. The effectiveness of the hexazinone treatment may have been diminished by excessive soil moisture and insufficient herbicide dosage. The height increment of containerized stock was significantly greater (P<0.01) than that of bareroot stock in 1994, and significantly smaller (P <0.01) in 1995. PAR values were generally lowest in the hexazinone treatment and highest in the mounding treatment, but differences in PAR between the hexazinone and corridoring treatments decreased markedly during the third growing season. In a supplementary study to compare Gridball® and Power Pellet® formulations of hexazinone in relation to white spruce establishment, third year height increment, total height, and ground level stem diameter were significantly greater (P <0.01) in the Power Pellet® treatment than in the other treatments. Total height after three growing seasons was unaffected by stock type, but survival was significantly lower (P<0.01) among bareroot stock than among containerized stock. Again, the vigor of the former was suspect.

RÉSUMÉ

Des épinettes blanches (*Picea glauca* [Moench] Voss) ont été plantées opérationnellement en mai1993 dans une station de la forêt mixte boréale du township de Biggs en Ontario. Un plan factoriel en blocs aléatoires à 4 répétitions a été utilisé, avec 3 traitements pour l'établissement des épinettes : établissement de corridors, aménagement de buttes et application d'hexazinone granulaire. Les parcelles (50mx100m) ont été subdivisées longitudinalement en plants à racines nues et plants en récipients. Immédiatement après la plantation et à la fin de chacune des 3 premières saisons de croissance, la performance de 2400 arbres (100 dans chaque demi-parcelle) a été évaluée. Le rayonnement photosynthétiquement utilisable (RPU) a été mesuré 14 fois à 1m au-dessus du sol à 360 endroits (60 plants par demi-parcelle) dans le bloc I et 9 fois au niveau de l'extrémité de la pousse apicale des plants survivants aux mêmes endroits. Les taux de survie des plants à racines nues ont été significativement plus faibles (P<0,01) que ceux des plants en récipients dans les parcelles aménagées en corridors et celles traitées à l'hexazinone, ce qui serait attribuable à la faible vigueur des plants à racines nues. L'absence à toutes fins pratiques de mortalité la première année chez les plants en récipients pour tous les traitements indiquent que les plants n'ont pas été affectés par l'hexazinone granulaire appliqué de la façon décrite. Pendant 3 saisons de croissance, le plus haut taux de survie a été obtenu pour la plantation sur buttes. L'efficacité de l'application d'hexazinone a pu être affectée par l'humidité excessive du sol et l'insuffisance de la dose. L'accroissement en hauteur des plants en récipients a été significativement plus élevé (P<0,01) que celui des plants à racines nues en 1994, et ce fut le contraire (P<0,01) en 1995. Les valeurs mesurées pour le RPU étaient généralement plus faibles dans les parcelles traitées à l'hexazinone et plus élevées dans celles plantées sur buttes, mais les différences entre les premières et celles en corridors ont diminué de façon marquée au cours de la troisième saison de croissance. Une étude supplémentaire visant à comparer les formulations d'hexazinone Gridball et Power Pellet dans le contexte de l'établissement des épinettes blanches a indiqué que l'accroissement en hauteur, la hauteur totale et le diamètre au niveau du sol après 3 ans étaient significativement supérieurs (P<0,01) pour le traitement avec Power Pellet que pour les autres traitements. Aucun effet du type de plant sur la hauteur totale après 3 saisons de croissance n'a été observé, mais la survie a été significativement moindre (P<0,01) chez les plants à racines nues.Là encore, la vigueur des plants à racines nues pourrait être en cause.

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METHODOLOGIES FOR MAINTAINING THE SOFTWOOD COMPONENT IN BOREAL MIXEDWOODS

INTRODUCTION

NODA Project No. 4043, funded under the Northern Forestry Program of the Canada–Ontario Northern Ontario Development Agreement signed in 1991 (Macnaughton 1993, 1994), was conceived collaboratively between the McChesney Lumber Division of E.B. Eddy Forest Products Ltd. and the Canadian Forest Service.

Objective

The objective was to evaluate three methods of site preparation and two stock types for establishing white spruce (*Picea glauca* [Moench] Voss) on competitive mixedwood sites.

Problem Description

The mixedwood management program of the McChesney Lumber Division of E.B. Eddy Forest Products, Ltd., current in the early 1990s, annually involved applying artificial renewal treatments to approximately 450 ha and planting about 800 000 bareroot spruce. This program is expected to expand. Heavy slash, sizable volumes of residual unmerchantable hardwoods, and vigorous shrub and other vegetative competition escalate the cost of postharvest silvicultural treatment of mixedwood sites on McChesney's Pineland Forest near Foleyet, Ontario.

In this study, three methods of renewing white spruce on mixedwood sites are evaluated: namely, corridoring, mounding, and pelleted hexazinone. Corridored planting of white spruce has been used by McChesney since 1982 to rehabilitate more than 4 000 ha of mixedwoods. Mounding has shown promise in Scandinavia and, to some extent, elsewhere (Sutton 1993a). Small-scale trials using only pelleted hexazinone in a grid pattern have successfully promoted the establishment of white spruce in competitive mixedwoods in Ontario (Sutton 1986). Quantification of the amount of light received by outplanted spruce, as influenced by the main treatments and resurgence of weed growth, and the relationship between this and white spruce performance should help guide future silvicultural prescription for white spruce establishment.

A small supplementary study relates current Power Pellet® work to earlier research (Sutton 1986) with the former DPW 3674-A Gridball® formulation of hexazinone pellets, i.e., 2-cm^3 10 percent active ingredient lozenges averaging about 3.75 g each (0.375 g hexazinone/pellet). Power Pellets® are smaller (4.5 mm thick, 12.8 mm diameter, 0.58 cm^3) but contain 75 percent hexazinone, and, thus, about 40 percent more active ingredient per Power Pellet® than per Gridball®.

METHODS

Main Experiment

A randomized block, split plot experiment accommodating four replications of three main treatments was established in residual, unmerchantable hardwoods and shrubs on a fertile mixedwood site in Biggs Township south of Foleyet, Ontario, in the spring of 1993. Each block contains one 50-m x 100-m plot for each of the main treatments: (a) corridoring site preparation, (b) mounding site preparation, and (c) no treatment other than the application of pelleted hexazinone Power Pellets® concurrently with planting. Plots were split longitudinally between bareroot and containerized planting stock. Treatments were allocated at random (Fig. 1).

Site preparation treatments (a) and (b) were carried out in April–May 1993 soon after harvesting of merchantable aspen (*Populus tremuloides* Michx.) stems. These operations, at a time when the site was unusually wet, produced deep ruts in parts of the study area. White spruce were operationally planted 27–29 May 1993 at nominal 2-m x 2-m spacing. Two stock types were used: namely, $1\frac{1}{2}+1\frac{1}{2}$ bareroot stock from the Swastika Nursery, overwintered in a snow-cache close to the planting site until withdrawn for planting; and overwintered containerized stock of Provenance 3231 (Ontario Ministry of Natural Resources) from the Thessalon Nursery. In the hexazinone blocks, within 2 days after planting, four pellets were dropped equidistantly on the forest floor 70 cm from each outplant.

The performance of 2 400 trees (five 20-tree randomly determined subplots in each half split plot) was determined at the end of each of the first three growing seasons. A tagged pin identified each monitored tree. Vegetation was surveyed qualitatively in July 1993 (Appendix I) in subjective frequency classes ranging from a (abundant) to r (rare).

The amount of photosynthetically active radiation (PAR) was determined at 360 outplant locations (in three 20-tree subplots in each half split plot in Block I) 14 times from August 1993 through September 1995. At each outplant location, PAR was measured using a Ceptometer® (Decagon Devices, Inc., Pullman, Washington, USA). A radiation-sensing wand 82 cm long, 1 cm wide, and 1.5 cm

Main experiment

Block II Mounding cont <> br	Block II Hexazinone cont <> br	Block II Corridor br <> cont	Block IV Hexazinone cont <> br	Block IV Corridor br <> cont	Block IV Mounding cont <> br
Block I Hexazinone cont <> br	Block I Corridor cont <> br	Block I Mounding br <> cont	Block III Corridor br <> cont	Block III Hexazinone cont <> br	Block III Mounding cont <> br

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Supplementary (Gridball® vs. Power Pellet®) experiment

South Control Rep 3	South Control Rep 4	South Power Rep 3	North Gridball Rep 2	North Power Rep 2	North Power Rep 1
South Gridball Rep 4	South Power Rep 4	South Gridball Rep 3	North Gridball Rep 1	North Control Rep 2	North Control Rep 1

Figure 1. Layout (not to scale) of main and supplementary experiments on white spruce establishment, Biggs Township, Ontario; cont <> br and br <> cont indicate splits between containerized (cont) and bareroot (br) stock types, and rep = replication. South and North identify geographical locations, but have no statistical significance.

high, the Ceptometer® contains 80 sensors positioned 1 cm apart. Of two readings taken centered over each outplant location, the first was with the Ceptometer® held horizontally 1 m above ground level, and the second was with the instrument held similarly but at right angles to its position for the first reading. In and after July 1994, additional determinations at those same locations were similarly made at the tip of the leader of surviving outplants. Ceptometer® readings were synchronized with PAR observations determined in an opening outside the stand using a Quantum Sensor® (LiCor, Inc., Lincoln, Nebraska, USA) and a CR-21 (Campbell Scientific, Edmonton, Alberta, Canada) microdatalogger.

Ceptometer® readings of PAR within a forest stand are affected by the incident solar radiation as modified by interception by vegetation. The amount of shading at any given point in a stand varies with the kind of radiation (direct vs. diffuse) and the amount, kind, distribution, and state of vegetation. Wind-sway of vegetation also affects readings, as does the phenological state of the various components of the flora. Any given measurement of incident radiation in a stand will be affected by the time of day, time of year, windiness, and the amount, kind, distribution, and rate of change of cloud cover. Values will also vary with the kind of instrument used; both the Ceptometer® and Quantum Sensor® are designed to measure PAR, yet they give different readings for a given exposure. However, a regression based on 88 paired instantaneous observations gave:

Ceptometer® value = -29.4 + 1.30 Quantum Sensor® value

with a coefficient of determination (R^2) of 100 percent. Unconverted values are reported here, with conversion giving no apparent advantage other than that of avoiding the anomaly of some inside-stand values exceeding synchronous outside-stand values; relationships would remain unchanged.

Supplementary (Gridball® vs. Power Pellet®) Experiment

Separated from the site of the main experiment only by the access road, a small randomized block experiment was initiated to determine the relative effectiveness of Gridballs® and Power Pellets® with respect to the establishment of white spruce. There were four replications (Fig. 1). Through both areas, alternate lines of bareroot and containerized white spruce of the same source as those used in the main experiment were operationally planted during the same period. Impediments to planting here were fewer than in the main experiment, and spacing more closely approached the nominal 2 m x 2 m. On 11 June 1993, three treatments were applied randomly to all outplants in 10-m x 10-m plots: (a) no herbicide, (b) pelleted hexazinone, Gridball® formulation, and (c) pelleted hexazinone, Power Pellet® formulation. In treatments (b) and (c), four equidistantly spaced pellets were placed on the forest floor 50 cm from each outplant; grid spacings equated with 107 cm x 107 cm for Gridballs® (3.3 kg/ha a.i.) and 102 cm x 102 cm (5.0 kg/ha a.i.) for Power Pellets®.

All 275 trees were assessed for performance immediately after planting and at the end of each of the first three growing seasons. A tagged pin identified each monitored tree.

RESULTS

Main Experiment

Survival

Survival rates among bareroot stock in the hexazinone and corridor treatments were significantly ($P < 0.01$) lower by chi-square test than were those of containerized stock (Table 1). This reinforces the initial visual impression that much of the bareroot planting stock lacked vigor. Perfect first year survival rates of containerized stock testifies to the high performance potential of the stock and suggests that the hexazinone treatment did not harm outplants.

Growth

By the end of the second growing season, the difference in mean total height between bareroot and containerized stock had shrunk to 1 cm. The second year mean height increment of bareroot stock averaged only 44 percent greater than did the first-year increment, compared with 88 percent greater for containerized stock then seemingly poised to overtake the bareroot stock (Table 2). However, third year mean height increment of bareroot stock was more than twice that of the previous year and 68 percent greater than the third year height increment of containerized stock. In all three main treatments, mean total height after 3 years was significantly greater ($P < 0.01$) for bareroot than for containerized stock. The differential between stock types (in total height after 3 years) was greatest (10 cm) in the hexazinone treatment.

After three growing seasons, trees of both stock types in the corridors were less vigorous than those in the other main treatments (Table 2). Among main treatments, differences in ground level stem diameter after three growing seasons were not significant ($P = 0.05$) within stock type, but for both bareroot and containerized stock stem diameters were greater in the mounding treatment than in the other main treatments. For both stock types, computed stem volumes were significantly greater ($P < 0.01$) in the mounding treatment than in either the hexazinone or corridoring treatments.

Table 1. Survival rates (percent) of outplanted white spruce at the end of each of the first three growing seasons by main treatment and stock type. Initially, n = 400 per main treatment x stock type combination.

Main treatment by stock type	First growing season	Second growing season	Third growing season
BAREROOT			
Corridoring	89	71	70
Mounding	99	98	98
Hexazinone	96	85	84
CONTAINERIZED			
Corridoring	100	97	96
Mounding	100	99	99
Hexazinone	100	94	93

Determinations of PAR

The PAR values are summarized in Table 3.

Supplementary (Gridball® vs. Power Pellet®) Experiment

Survival

All containerized white spruce survived the first growing season in all three treatments (Table 4). Survival rates at the end of the third growing season were significantly greater ($P < 0.01$) in the hexazinone treatments (94 percent and 100 percent, respectively) than in the untreated (86 percent). Clearly, the herbicide treatment was not detrimental to the survival of the containerized outplants, and the significant depression ($P < 0.001$) of survival rate of bareroot stock can hardly be attributed to the hexazinone treatment, especially when the survival rate was lowest in the untreated control. As in the main experiment, a lack of vigor was undoubtedly responsible for most of the mortality among the bareroot stock.

Growth

After two growing seasons, containerized stock had caught up in total height with the initially taller bareroot stock, and after three growing seasons total heights differed insignificantly between stock types. However, third year height increments were significantly greater ($P < 0.05$) in bareroot than in containerized stock (Table 5). After three growing seasons, total height, height increment, and stem diameter among stock of both types were significantly greater ($P < 0.01$) in the Power Pellet® treatment than in either of the other treatments.

Table 2. Initial total height (cm); first, second, and third annual height increments (cm); stem diameter at ground level (mm); computed stem volume (1/3 cross-sectional area at ground level x total height expressed as a percentage of the corridoring value); and total height (cm) after three growing seasons of white spruce by stock type and main treatment.

Main treatment by stock type	Initial total height	First growing season increment	Second growing season increment	Third growing season increment[1]	Diameter after third growing season[1]	Volume after third growing season[1]	Height after third growing season[1]
BAREROOT							
Corridoring	22	5	7	17a	9a	100a	48a[2]
Mounding	21	6	7	18b	10a	133b	52b
Hexazinone	22	5	9	19b[3]	9a[4]	106a[5]	52b
CONTAINERIZED							
Corridoring	18	6	10	12a	6a	100a	43a
Mounding	17	7	11	13b	7a	123b	46b
Hexazinone	19	4	11	13ab	6a	81a	42a
SIGNIFICANCE (ANOVA)							
Treatment	**	**	**	**	**	**	**
Stock	**	**	**	**	**	**	**

[1] Within stock type, values followed by the same letter do not differ significantly by t-test at P = 0.05; within stock type, and with two exceptions (*see* notes [2] and [5] below), values not followed by the same letter differ significantly at P <0.01.

[2] For bareroot stock, total heights after three growing seasons differ significantly at P <0.05 between the corridoring and mounding treatments.

[3] Rounded values for containerized stock mask minor but statistically significant differences identified by following letters.

[4] Notwithstanding the absence of significant t-test differences among treatments in either stock type, treatment was significant by analysis of variance.

[5] For bareroot stock, stem volumes after three growing seasons differ significantly at P <0.05 between the hexazinone and mounding treatments.

DISCUSSION

Main Experiment

All three main treatments were affected by factors that might have reduced silvicultural effectiveness. Harvesting and site preparation coincided with unusually wet site conditions and resulted in severe rutting. In those conditions, corridors could not be prepared with the usual finesse; corridoring in drier conditions would probably have created better microsites for planting. Smaller mounds might have been superior to the large mounds (mostly 70–100 cm high) that were made; but, although mounds are commonly allowed to settle overwinter before planting, the wetness of the soil here during mounding advantageously promoted settlement. Rutting caused by the logging was particularly unfortunate in the blocks that were to be treated only with herbicide pellets. Disturbed surface drainage tended to channel runoff, and herbicidal concentrations penetrating the soil from pellets would seem necessarily to have been diluted and probably reduced in silvicultural effectiveness.

Frost heaving has not been a problem so far in any of the treatments or with either stock type. Some browsing by snowshoe hare (*Lepus americanus*) has occurred. Typically, leading shoots are found lying on the forest floor. The problem so far affects only a small percent of the outplants, but these have invariably been good, vigorous trees. Such browsing is not vandalism; rather, it seems that the shoots are intended for consumption after softening and the loss of some of the volatile components have rendered them more palatable. A few outplants died after being trampled by moose (*Alces alces*), and a few were crushed beneath windfalls.

Table 3. Mean PAR values measured by Ceptometer® at 1 m above outplant locations as percent of Quantum Sensor® values measured in the open (*see* text). Figures in parentheses are mean PAR values measured at the leader tip of surviving white spruce at the 360 outplant locations.

Date	Julian day	Corridoring	Mounding	Hexazinone
1993				
14 August	226	75	106[1]	70
30 September	273	85	106	73
27 October	300	106	108	95
1994				
15 May	135	119	109	85
22 June	173	97	11	74
25 July	206	80 (35)	99 (72)	67 (38)
24 September	267	87 (49)	105 (77)	73 (45)
8 November	312	97 (75)	101 (90)[2]	—[3]
9 November	313	81 (55)	—[3]	70 (52)
1995				
16 May	136	108 (90)	110 (104)	—[3]
6 June	157	93 (66)[2]	113 (104)	—[3]
1 August	213	73 (32)	96 (59)	58 (31)
31 August	243	73 (35)	110 (74)	61 (27)[2]
29 September	272	68 (39)	92 (61)	63 (41)

[1] See text re values >100 percent.
[2] Incomplete data.
[3] Missing data.

The following comments are based on observations to the end of the third growing season.

Hexazinone

The Power Pellets®, particularly in the main experiment, may have been diminished in effectiveness by an excess of surface water present at the time of treatment. Soil moisture conditions must have influenced the pattern of herbicide release, notably by diluting the concentration and broadening the plume of herbicide released from each pellet. Certainly, much of the site was saturated during planting and pellet placement, and it was clear that a generalized "wash" effect had occurred in some places. Previous work in mixedwoods with granular (Sutton 1965a, b) and pelleted (Sutton 1986, 1995) herbicides suggests that a given amount of soil-acting herbicide is more effective when applied in local concentrations than when evenly broadcast. Thus, the effectiveness of the hexazinone treatment may well have been compromised by the unusual wetness of the site at the time of treatment.

Also, the dosage of hexazinone may have been insufficient to achieve results comparable with those obtained using pellets at spacings of 100 cm x 100 cm and 95 cm x 95 cm in the earlier Gridball® experiment. To have achieved a grid spacing of 100 cm x 100 cm throughout the hexazinone blocks of the main experiment, 20 000 pellets would have been required. About 14 000 Power Pellets® contain the same amount of active ingredient as would 20 000 2-cm^3 10 percent Gridballs® and might achieve

Table 4. Survival rates (percent) of white spruce at the end of each of the first three growing seasons as affected by pelleted hexazinone formulation. Initial n = 38–45 (bareroot) and 49–51 (containerized stock).

Main treatment by stock type	First growing season	Second growing season	Third growing season
BAREROOT			
None	90	67	67
Gridballs®	95	87	84
Power Pellets®	91	76	73
CONTAINERIZED			
None	100	96	86
Gridballs®	100	100	100
Power Pellets®	100	96	94

Table 5. Initial total height (cm); first, second, and third annual height increments (cm); stem diameter at ground level (mm); computed stem volume (1/3 cross-sectional area at ground level x total height, expressed as a percentage of the control value); and total height (cm) after three growing seasons of white spruce, by stock type and treatment.

Main treatment by stock type	Initial total height	First growing season increment	Second growing season increment[1]	Third growing season increment[1]	Diameter after third growing season[1]	Volume after third growing season[1]	Height after third growing season[1]
BAREROOT							
Control	22	4	7a	11a	7ab	100ab	41a
Gridballs®	21	3	7a	12a	7a[2]	91a[3]	41a
Power Pellets®	21	4	9a	17b	8b	165b	50b
CONTAINERIZED							
Control	18	5	9a[4]	9a	5a	100a	38a
Gridballs®	18	5	11b	10a	5a[5]	122a[6]	41a[7]
Power Pellets®	17	6	13c	15b	6b	191b	48b
SIGNIFICANCE (ANOVA)							
Treatment	n.s.	n.s.	**	**	**	**	**
Stock type	**	**	**	**	**	**	n.s.

[1] Within stock type, values followed by the same letter do not differ significantly by t-test at $P = 0.05$; within stock type, and excluding the exceptions noted in notes[2-7], values not followed by the same letter differ significantly at $P < 0.01$.

[2] For bareroot stock, third-year diameters differ significantly at $P < 0.05$ between the Gridball® and Power Pellet® treatments.

[3] For bareroot stock, third-year volumes differ significantly at $P < 0.05$ between the Gridball® and Power Pellet® treatments.

[4] For containerized stock, second year height increments differ significantly at $P < 0.05$ between the control and Gridball® treatments.

[5] For containerized stock, third-year diameters differ significantly at P „0.05 between the Gridball® and Power Pellet® treatments.

[6] For containerized stock, third-year volumes differ significantly at $P < 0.05$ between the Gridball® and Power Pellet® treatments.

[7] For containerized stock, third year total heights differ significantly at $P < 0.05$ between the Gridball® and Power Pellet® treatments.

comparable results; but, in fact, calculated on the basis of amount of product used, only about 9 600 pellets were applied. In the earlier Gridball® experiment, a grid spacing of 163 cm x 163 cm gave results substantially inferior to those given by the closer grid spacings mentioned above. In the current NODA study, 9 600 Power Pellets® would equate with a grid spacing of 145 cm x 145 cm.

Therefore, the effectiveness of the treatment may have been diminished by two factors: namely, dilution of the herbicide plumes descending from individual pellets, and insufficient dosage.

Mounding

Marked differences in foliage color among white spruce planted on mounds were evident early in the second growing season. Many outplants were rooted solely in C-horizon material, and the foliage of these trees was a pallid yellowish green, verging on greenish yellow, 10Y5-6/6 in Munsell notation. Trees having glaucous green (Munsell 7.5GY6-7-7/1-4) foliage could reasonably be supposed to have accessed more fertile, possibly organic, material. Off-color foliage had become much less evident by the end of the second growing season, presumably as root systems extended into zones of relatively greater fertility. By the third growing season, foliage color throughout the mounding treatment had returned to that typical of nutritionally adequate trees.

Mounds lower than those in this study would have had the double advantage of placing root systems closer to soil organic matter and offering less topographic impediment to future operations on the site. Also, the future stability of trees on low mounds might be greater than that of trees on higher mounds.

Corridoring

Excessive wetness at the time of corridoring and planting provided microsites inimical to the survival and growth of outplants, particularly so for plants of low vigor. By the third growing season, weed growth was vigorously encroaching on the corridors from the sides, engulfing many of the edge located white spruce. Had less rutting been caused during corridor preparation, a proportion of these spruce might have been planted somewhat further from the edges, although the respite from encroaching weeds would have been brief. Vigorous weed growth, including blue-joint grass (*Calamagrostis canadensis* [Michx.] Beauv.), drooping wood reed grass (*Cinna latifolia* [Trev.] Griseb.), and a variety of sedges and other vegetation, had also developed in much of the central part of the corridors. Many of the centrally located white spruce were already dominated by weeds <2 m high. Growth of crop trees is already constrained by weeds, and early silvicultural intervention seems essential to save the crop.

Stock Type

The value of using more than one stock type in silvicultural experimentation is well illustrated in the present study. At least some of the bareroot stock lacked vigor, and much, perhaps most, of the mortality among such seedlings is attributable to that cause.

Differences in survival rates of bareroot stock among the main treatments are interpreted as the result of differential stressfulness (mounding<hexazinone<corridoring) on newly planted stock of low vitality. For instance, stock planted on mounds must have had relatively warm and well drained rooting zones more conducive to root growth than provided by the other main treatments. Survival rates for both stock types were greatest in the mounding treatment. The rooting zone of outplants in the corridors was undoubtedly wetter and cooler than in the other treatments. Had only the bareroot stock been used, erroneous conclusions might well have been drawn.

In contrast, the containerized stock has performed well. Many of these seedlings were damaged by frost the very night after planting, but recovery was vigorous and virtually complete.

Frost damage was least on mounds, where the foliage color of some containerized outplants in the first growing season suggested nutrient stress. This may reflect the restriction of some root systems to C-horizon soil, exacerbated by the high nutrient demands of vigorously growing stock. However, foliage color returned to normal during the third growing season.

Light Levels

The aggregate amount of light received by a given outplant for photosynthesis is exceedingly difficult to quantify. Similarly difficult is the characterization of light level by main treatment. However, throughout the three growing seasons, highest levels of light have occurred in the mounding treatment, both at 1 m above the forest floor and at the tip of the leading shoot of outplants. After three growing seasons, containerized stock was significantly taller ($P<0.01$) in the mounding treatment than in the other treatments. Bareroot stock performed as well on mounds as in the hexazinone treatments; corridored bareroot stock performed significantly more poorly ($P<0.01$).

Initially, for the first couple of years of the study, less light on average was reaching outplants in the hexazinone treatment than in the other treatments. But, by the latter part of the third growing season, as much light was reaching these outplants as in the corridors. Strong regrowth of competition in the corridors was obviously reducing the amount of light reaching the white spruce. Also, it can be assumed that competition for nutrients, and in a dry season, water, would be intensifying.

Supplementary (Gridball® vs. Power Pellet®) Experiment

Operational planting in the supplementary experiment produced spacings closer to the nominal 2 m x 2 m than in the main experiment. In consequence, 88 percent of the number of Gridballs® and 96 percent of the number of Power Pellets® needed to give 1-m x 1-m coverage were applied in those treatments.

By the end of the third growing season, total height, annual height increment, and ground level stem diameter of white spruce in the Power Pellet® treatment were significantly greater ($P<0.01$) than in the other treatments.

Here, the apparent absence of a positive response to the Gridball® treatment, in spite of pellet spacings close to those proving successful in the earlier Gridball® experiment, may be a consequence of the saturated forest floor conditions at the time of planting. In the earlier study, however, success did not become clear for several years after treatment (Sutton 1986). Thus, it may still be too early to conclude that Gridballs® have been ineffective here.

Containerized stock in the no-hexazinone treatment was the only category incurring significant mortality between the second and third growing seasons. Browsing by snowshoe hare, and crushing under windfalls, were no more prevalent here than in other treatments. The main cause of mortality seemed to be competition from shrubs and aspen root suckers invigorated by disturbance during harvesting.

In neither of the hexazinone treatments did placement of four pellets 50 cm away from newly outplanted white spruce increase mortality compared with that of untreated trees. This suggests that a fair degree of latitude in pellet placement is possible without penalty. In the earlier Gridball® work, four equidistant pellets caused mortality in outplanted white spruce only when placed closer than 50 cm from the tree. No spruce survived when placement was closer than 40 cm and, at 40 cm, the survival rate was 50 percent after 3 years (Sutton 1986).

CONCLUSIONS

Newly outplanted white spruce were not harmed by Power Pellets®, even when four were applied within 50 cm of the plant. A positive effect on the performance of white spruce outplants would seem to require sufficient hexazinone pellets to equate with a grid spacing of approximately 1 m x 1 m. Rigid adherence to placement of pellets on a regular grid is probably not critical provided that a separation of 50 cm or more is maintained between pellets and newly outplanted white spruce, given sufficient dosage.

Corridoring when soil was wet provided inhospitable conditions for outplants. Planting near the edges of corridors, in order to avoid ruts, rendered the white spruce more susceptible to encroaching weeds than might have been the case had planting been less close to the edges. However, even in much of the central part of the corridors, weed regrowth had developed strongly by the third growing season, and PAR levels had already been affected. A silvicultural release treatment would seem to be necessary within a year or two.

Mounding produced the most hospitable conditions for outplants, and indications of nutrient stress had vanished by the end of the third growing season. Regrowth of shrubs and aspen root suckers has been very strong and can be expected to reduce PAR levels in the future. Questions of tree stability remain to be answered.

The bareroot stock used in this study lacked vigor. The value of using more than one stock lot in field experimentation is amply illustrated.

White spruce performance and PAR data do not yet reveal strong relationships, in part because of the difficulty of characterizing light regimes in the forest. Indications may strengthen as weed growth develops further.

RECOMMENDATIONS

Evidence from this study warrants the following recommendations:

- Test the viability of planting stock used in each planting operation by taking a small random subsample of each stock lot <u>at the time of planting</u>, and then watch how it performs after planting in a favorable environment.
- After corridoring in mixedwoods, monitor the growth of weeds and outplants, and be prepared to release crop trees perhaps within 3 to 5 years after planting.
- Mounding site preparation is effective for establishing white spruce in mixedwoods, but the effect of aspen suckering and shrub layer stimulation will require monitoring, beginning about 4 or 5 years after planting. Mounds smaller than those used in this study might give comparable results. Smaller mounds would be less expensive, somewhat less disruptive of the site, and might possibly improve the long-term stability of crop trees growing on them.
- Do not apply hexazinone pellets when the forest floor is awash; surface runoff will dilute and spread the herbicidal plume and probably diminish its effectiveness. Rather, apply pellets before a significant extension of outplant root systems has occurred. Also, it is important to apply enough pellets per unit area to secure the requisite dosage over the treatment area, notwithstanding the density of planting. Pellets can be applied to the forest floor to within 50 cm of newly outplanted white spruce without adverse effects.
- Comparisons among methods of site preparation need to take account of not only the initial cost of site preparation and initial crop tree performance, but also the cost of subsequent tending.

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APPENDIX 1. Vegetation Survey (July 1993) of NODA Experimentation Areas, Biggs Township, Ontario.*

	BLOCK				Frequency
	I	II	III	IV	
Trees and shrubs					
Acer rubrum L.			+		
Acer spicatum Lam.	+	+	+	+	c
Alnus rugosa (Du Roi) Spreng.	+	+	+	+	c
Amelanchier Med. sp.	+	+			o
Amelanchier bartramiana (Tausch) Roem.	+	+			
Betula papyrifera Marsh.	+	+	+	+	c
Cornus stolonifera Michx.		+		+	
Corylus cornuta Marsh.	+	+	+	+	c–o
Diervilla lonicera Mill.	?	+	+		
Lonicera canadensis Bartr.	+	+			
Picea glauca (Moench) Voss	?	?	+		
Picea mariana (Mill.) B.S.P.	+	+	+	+	o
Pinus banksiana Lamb.	?	?	+	+	
Populus tremuloides Michx.	+	+	+	+	c
Prunus pensylvanica L.fil.	+	+	+	+	c–o
Prunus virginiana L.fil.	?			+	
Ribes hirtellum Michx.				+	
Ribes glandulosum Grauer	+	?	+	+	c
Ribes lacustre (Pers.) Poir.	+	+		+	c
Ribes triste Pall.	?				
Rosa acicularis Lindl.	+	+	+	+	o
Rubus idaeus L. var. *strigosus* (Michx.) Maxim	+	+	+	+	c
Rubus pubescens Raf.	+	+	+	+	c
Salix L. sp.	+	+	?	+	o
Sambucus pubens Michx.	+	?	+	+	
Sorbus decora (Sarg.) Schneid.	+	+		+	
Viburnum alnifolium Marsh.	?				
Viburnum edule (Michx.) Raf.		+		+	
Other vegetation					
Actaea pachypoda Ell.	?	?	?	?	
Actaea rubra (Ait.) Willd.	?	+	?	?	
Anemone canadensis L.	?				
Apocynum androsaemifolium L.			+		
Aralia hispida Vent.				+	
Aralia nudicaulis L.	+	+	+	+	c
Aster macrophyllus L.	+	+	+	+	c
Aster spp.			+	+	
Athyrium filix-femina (L.) Roth	??				a
Calamagrostis canadensis (Michx.) Beauv.	+	+	+	+	
Carex L. spp.	+	+	+	+	c
Carex deflexa Hornem.	?	?			
Carex intumescens Rudge	?	?			
Carex trisperma Dew.		?	?		
Carex vaginata Tausch.	?	?			

	BLOCK I	II	III	IV	Frequency
Other vegetation (cont'd)					
Cinna latifolia (Trev.) Griseb.	??	??	??	??	
Circaea alpina L.				+	
Clintonia borealis (Ait.) Raf.	+	?	+	+	o–la
Coptis groenlandica (Oeder) Fern.	?				c
Cornus canadensis L.	?	?		?	
Dryopteris disjuncta (Ledeb.) C.V.Mort. cf. *Gymonarpium dryopteris*			+		
Dryopteris spinulosa (O.F. Muell.) Watt.	??	??	+	+	
Epigaea repens L.	?				
Epilobium angustifolium L.	??	??	+		
Equisetum sylvaticum L.	+		+	?	
Galium triflorum Michx.	+	+	+	+	c
Gaultheria hispidula (L.) Bigel.	?				
Gramineae L. spp.	+	+	+	+	
[*Gymnocarpium dryopteris* (L.) Newm. Baldwin & Sims field guide. See Dryopteris disjuncta (Ledeb.) C.V.Mort. Gray]					
Hieracium aurantiacum L.				?	
Linnaea borealis L.	?				
Lycopodium clavatum L.	?		+		
Lycopodium obscurum L.	+		+	+	o
Onoclea sensibilis L.	?				
Maianthemum canadense Desf.	+	+	+	+	o–c
Mertensia paniculata (Ait.) G. Don	+				o
Mitella nuda L.	?		+	+	
Osmunda claytoniana L.	+	+	+	?	a
Petasites palmatus (Ait.) Gray	+			+	o
Polygonum cilinode Michx.	?				
Pteridium aquilinum (L.) Kuhn	?		+	+	
Pyrola elliptica Nutt.	?				
Solidago spp.	?	?	?	?	
Solidago hispida Muhl.	?				
Sonchus arvensis L.	??	??	??		o
Streptopus roseus Michx.	+	+	+	+	
Taraxacum officinale Weber	?				
Thalictrum polygamum Muhl.				+	
Trientalis borealis Raf.	+	?	+	+	c
Trillium cernuum L.	?		+	+	
Viola spp.	+	?	+	+	a
Viola canadensis L.	?	?			
Viola renifolia Gray	?	?			
Waldsteinia fragarioides (Michx.) Tratt.			?		

Supplementary **GRIDBALL**© vs. **POWER PELLET**© study (12 July 1993 vegetation survey)

Trees and shrubs	North	South	Frequency
Acer rubrum L.		+	
Acer spicatum Lam.	+	+	
Alnus rugosa (Du Roi) Spreng.	+	?	c
Amelanchier Med. sp.	+	+	o
Betula papyrifera Marsh.	+	+	c
Cornus stolonifera Michx.	+		
Corylus cornuta Marsh.	+	+	c–o
Diervilla lonicera Mill.	+		
Picea mariana (Mill.) B.S.P.	+	+	o
Populus tremuloides Michx.	+	+	c
Prunus pensylvanica L. fil.	+	+	c–o
Ribes glandulosum Grauer	+	+	c
Ribes lacustre (Pers.) Poir.	+	?	c
Rubus idaeus L. var. *strigosus* (Michx.) Maxim	+	+	c
Sambucus pubens Michx.	+	+	
Sorbus decora (Sarg.) Schneid.	+		
Viburnum edule (Michx.) Raf.	+		
Other vegetation			
Actaea pachypoda Ell.	?		
Actaea rubra (Ait.) Willd.	?		
Apocynum androsaemifolium L.	+	+	
Aralia nudicaulis L.	+	+	c
Aster macrophyllus L.	+	+	c
Aster spp.		+	
Athyrium filix-femina (L.) Roth		?	a
Carex L. spp.	+	+	c
Cinna latifolia (Trev.) Griseb.	??	??	
Circaea alpina L.	+		
Clintonia borealis (Ait.) Raf.	+	+	o–la
Dryopteris disjuncta (Ledeb.) C.V.Mort. cf. *Gymonarpium dryopteris*	+	+	
Equisetum sylvaticum L.	+	+	
Galium triflorum Michx.	+	+	c
Gramineae L. spp.	??	??	
[*Gymnocarpium dryopteris* (L.) Newm. Baldwin & Sims field guide *see Dryopteris disjuncta* (Ledeb.) C.V.Mort. Gray]			
Lycopodium annotinum L.	+		
Lycopodium obscurum L.	+	+	o
Maianthemum canadense Desf.	+	+	o–c
Osmunda claytoniana L.	+	+	a
Pteridium aquilinum (L.) Kuhn	+	+	
Sonchus arvensis L.	+		o
Streptopus roseus Michx.	+	+	
Trientalis borealis Raf.	+	+	c
Trillium cernuum L.		+	
Viola spp.	+	+	a

* Nomenclature is in accordance with that of Hosie (1969) for trees, Soper and Heimburger (1982) for shrubs, Ireland and Cain (1975) for mosses, and Gray (1970) for other vegetation. + = present in the Block indicated, ? = presence probable but unsubstantiated, and ?? = tentative identification. In the last column, subjective frequencies of occurrence (a = abundant, c = common, o = occasional, r = rare, and l = local) are **NOT** from the study area but from similar stands near Chapleau, Ontario (Sutton, 1993b). They are included here for comparison only.