COST EFFECTIVENESS OF FOUR METHODS OF ESTABLISHING WHITE SPRUCE ON A CUT-OVER MIXEDWOOD SITE IN THE GOULAIS RIVER AREA, ONTARIO

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ABSTRACT

A small-scale trial of herbicide spraying was superimposed on a portion of a cut-over mixedwood site where operational trials of site preparation by angle-dozer blade and shark-fin drums (both followed by hand planting) had previously been conducted. Spray was applied to seven representative plots containing 270 seedlings; five similar plots totalling 193 seedlings were designated as controls. Survival and growth were assessed for five years after spraying (seven growing seasons after planting) and these were related to the total cost of treatment to determine the relative cost effectiveness of each treatment. Both in terms of survival and growth and in terms of cost effectiveness, site preparation by angle-dozer blade, without subsequent herbicide spraying, was clearly the best treatment. Although herbicide spraying significantly (P.05) increased height growth on plots scarified by shark-fin drums, this advantage was balanced by the increased cost. In this instance spraying was clearly detrimental on the angle-dozed area, reducing survival and growth significantly (P.01) as well as increasing treatment cost.

RÉSUMÉ

Les auteurs expérimentèrent l'arrosage à petite échelle d'herbicide dans un secteur de station de bois mixtes déjà récoltés, peu après des essais opérationnels de préparation du sol avec un angledozer et des barils à "nageoires de requins" (suivis tous les deux par le plantage à la main). Ils arrosèrent ainsi sept parcelles typiques contenant 270 semis; et cinq parcelles semblables contenant au total 193 semis furent choisies comme témoins. Les auteurs évaluèrent la survie et la croissance durant cinq ans après l'arrosage (sept saisons de croissance après le plantage) et les comparèrent au coût total du traitement, en vue de déterminer le rapport coût-efficacité de chaque traitement. En termes de survie et de croissance et en termes de coût-efficacité, le traitement à l'angledozer suivi d'arrosage à l'herbicide s'avéra le meilleur. Bien que l'arrosage à l'herbicide augmentât significativement (P.05) la croissance dans les parcelles scarifées avec les barils à nageoires de requins, cet avantage fut annulé par les coûts plus élevés. Dans ce cas, l'arrosage devint nettement mauvais pour le secteur traité à l'angledozer, réduisant la survie et la croissance significativement (P.01) tout en augmentant le coût du traitement.

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INTRODUCTION

Between 1965 and 1967 operational trials of several methods of site preparation and planting were carried out on three important forest site types in the Goulais River area of Ontario. On the basis of treatment cost and first-year survival of planted stock, the relative efficiency of the various treatments was determined (Haig 1969).

By the summer of 1968 minor vegetation was reinvading the plantations, and on the cut-over and burned mixedwood site the rapid increase in competition was an apparent threat to the success of the plantings. Although the initial objective of the trials had been achieved, it was decided that additional useful information might be obtained by superimposing a herbicide treatment on a portion of the planted area. The treatment was applied in August, 1968 and its effects were assessed annually until the fall of 1973. This report presents the results of the latter study, providing comparisons of the cost effectiveness of site preparation by shark-fin drums and by angle-dozer blade (each followed by hand planting of white spruce (*Picea glauca* [Moench] Voss) seedlings) with and without subsequent herbicide spraying.[1]

THE AREA

The work was carried out in the Goulais River Valley about 45 miles northeast of Sault Ste. Marie, Ontario, in the Algoma Section L.10 of the Great Lakes-St. Lawrence Forest Region (Rowe 1972). The site type on which reinvasion of minor vegetation appeared critical is a river terrace adjacent to the Goulais River, and the soil is a complex of deep, well-drained, water-laid sands and gravels (Lacate and Wang 1963). Until 1964 the area was occupied by a mature mixedwood stand of white spruce, balsam fir (*Abies balsamea* [L.] Mill), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). The softwoods were clear-cut for pulpwood in 1964-1965, and a prescribed burn (to reduce slash) was carried out in the spring of 1967, followed immediately by the site preparation and planting trials (Fig. 1).

METHODS

Site Preparation and Planting

In the original trials, areas of similar site conditions were divided into convenient operating blocks and one method of site preparation was applied to each. On the cut-over mixedwood site three blocks

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[1] No spraying appeared necessary on the blocks site-prepared by V-blade, because this treatment was carried out one growing season later than the others, and the furrows were still relatively free of minor vegetation.

Fig. 1. General view of experimental area (cut-over mixedwood) immediately after prescribed burn in May, 1967

totalling 23.4 acres (9.5 ha) were treated with the angle-dozer blade and four blocks totalling 30.5 acres (12.3 ha) with the shark-fin drums. The tractor started at the outside edge of each block and worked toward the middle in a concentric pattern, producing a series of alternate strips of treated and untreated ground.

The shark-fin drums were 4-ft (1.2-m) water-filled cylinders 24 in. (61 cm) in diameter, with 6-in. (15.2-cm) steel fins mounted around the circumference in a quarter-spiral (Brown 1966). Two rows of two drums each were towed in tandem, producing a cleared strip 10-12 ft (3.0-3.6m) wide within which were two rough furrows 1-3 ft (.3-1m) wide, varying from several inches to more than 1 ft (30.48 cm) in depth (Fig. 2).

Fig. 2. Shallow furrows resulting from site preparation with shark-fin drums, May 1967

For the angle-dozer blade treatment the blade was set to scalp off all minor vegetation and duff and most of the humus layer. The tractor moved ahead until the blade was filled with debris, then turned slightly to permit the accumulation to slide off the trailing edge of the sharply angled blade. After backing a few feet, the tractor returned to its original course and moved ahead (Fig. 3).

The angle-dozer blade generally removed not only the above-ground portions of the minor vegetation, but their roots also. The relative severity of this treatment is indicated by the fact that nearly 95 percent of the seedlings were planted on a mineral soil seedbed, whereas on the drum-scarified area the comparable percentage was 70. With both methods of preparation, the aim had been to scarify about one third of the gross area, but in fact the shark-fin drums scarified about 24 percent and the angle-dozer blade about 42 percent.

Fig. 3. Site preparation with angle-dozer blade, May, 1967. Note relatively complete removal of duff, humus, and roots of potential competition.

Hand planting was carried out shortly after site preparation. On the drum-scarified area, a row of 3+0 white spruce seedlings was planted along the side of each furrow at a spacing of about 6 ft (2 m). On the angle-dozed area a row of 2+0 white spruce seedlings[2] was planted along each edge of the scalped strips at about 6 x 6 ft (2 x 2 m) spacing.

To assess survival, sample plots were located so as to obtain a representative sample of conditions in each of the treated blocks. The plots were 2 chains (40.2 m) in length and their width corresponded to the width of the scarified strips. The ends of the plots were marked by aluminum stakes, and a numbered wire pin was inserted beside each seedling. The first measurement was made in the fall of 1967 (the end of the first growing season) and this included recording the condition of each seedling, its height, and the soil horizon in which it was planted (Fig. 4).

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[2] The introduction of different age classes was not by design.

Fig. 4. Measuring height of spruce seedling at end of first growing season, on area site-prepared with angle-dozer blade

All plots on the three site types included in the original site preparation and planting trials were remeasured for the last time in August, 1968 and the results were reported (Haig 1969). At that time it was noted that minor vegetation was reinvading strongly on the burned, cut-over mixedwood site (Fig. 5). It consisted primarily of raspberry (*Rubus strigosus* Michx.), pin cherry (*Prunus pensylvanica* L.f.), bracken fern (*Pteridium aquilinum* [L.] Kuhn), trembling aspen suckers, bush-honeysuckle (*Diervilla lonicera* Mill.), and hazel (*Corylus cornuta* Marsh.), species whose growth may have been stimulated not only by logging but also by the fire. Although the original study had been completed, it was decided that a small-scale trial should be superimposed on a portion of the cut-over mixedwood site, to compare the cost effectiveness of site preparation by shark-fin drums and by angle-dozer blade, with and without subsequent herbicide spraying.

Fig. 5. Herbicide spraying, August, 1968, on plot site prepared with shark-fin drums. Note lush growth of minor vegetation.

Herbicide Spraying

This herbicide study was carried out in one typical 10.1-acre (4.1-ha) block scarified by angle-dozer blade and in a similar 9.1-acre (3.9-ha) block scarified by shark-fin drums.

On August 13, 1968 three representative assessment plots in the angle-dozed area and four in the drum-scarified area were sprayed with a 1:1 mixture of 2,4-D and 2,4,5-T esters in water (Fig. 5). At the same time, two similar control plots (unsprayed) were selected in the angle-dozed area and three in the drum-scarified area. Each plot was about .36 acres (.14 ha) in size, and at the time of establishment (1967) the 12 plots included a total of 463 seedlings.

Spray was applied with a motorized mist-blower at a formulation of 20 oz of concentrate per Imperial gal (0.57 liters per 4.54 liters) of mixed spray. Foliage was sprayed to the "glistening point" and about

7.5 gal of mixed spray were applied per acre (84.2 liters per ha). The application of approximately 4.7 lb of acid equivalent per acre (5.27 kg per ha) represents a considerably higher rate than that commonly applied in spraying operations in Ontario.[3]

On both sprayed and unsprayed plots the condition, total height, and current height increment of each seedling were recorded immediately prior to spraying in 1968, and at the end of each subsequent growing season from 1969 to 1973 inclusive.[4] At these same intervals,[5] minor vegetation competition was assessed subjectively on a scale ranging from 0 to 5 ("nil" to "heavy") with respect to each individual seedling, and the average competition rating was calculated for each of the four combinations of site preparation x herbicide spraying.

In the subsequent analysis of results, the significance of the survival figures was determined by the Chi-square test, and differences in mean heights were subjected to a t-test.

RESULTS AND DISCUSSION

The sprayed plots were examined briefly two weeks after treatment and at that time the top-kill of all species of competition (except grass) was almost complete. Virtually all seedlings appeared to be effectively released, but the herbicide had caused some minor needle browning of the planted stock, particularly on the angle-dozed plots where competing vegetation was relatively light and many of the seedlings were fully exposed. The first detailed assessment was made in the fall of 1969 and it was apparent that spraying had effectively reduced brush competition (Fig. 6). In every year, competition ratings were higher on the drum-scarified area than on the angle-dozed area, and after spraying, competition ratings were lower on the sprayed than on the unsprayed plots within the area site-prepared by each method (Table 1).

It is not possible to explain why the ratings made in 1969 (one year after spraying) show a reduction on the unsprayed as well as the sprayed plots. The ratings for subsequent years seem reasonable if we bear in mind the subjective way in which competition was assessed. The final competition ratings in 1972 ranged from "very light" (1.0) to "moderate" (3.0) and this would suggest that for all four treatments most of the surviving seedlings appeared safe from the threat of

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[3] J.D. Scott, Development Specialist, Forest Management Branch, Ontario Ministry of Natural Resources, personal communication.

[4] Only partial remeasurement of height was made in 1969.

[5] Competition was not assessed in 1973, because remeasurement was carried out late in the fall when minor vegetation was leafless.

Fig. 6. Sprayed plot, treated August, 1968, photographed September, 1969. Note complete kill of brush.

serious suppression.

At the end of the 1967 growing season, survival on the angle-dozed area (2+0 stock) was not significantly different from that on the drum-scarified area (3+0 stock) but the height advantage of the older stock was significant (P.01) (Table 2). Prior to herbicide spraying (which took place after the 1968 remeasurement) there was no significant difference in survival or height between the two groups of plots on the angle-dozed area, nor between the two groups on the drum-scarified area. Therefore, within the area site-prepared by a single method, it is reasonable to attribute subsequent differences in performance to the effect of herbicide spraying. It is also possible to compare the performance of the trees on each of the four groups of plots with that on each of the others.[6]

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[6] Note that some height comparisons are confounded by the smaller initial size of the stock planted on the angle-dozed area.

Table 1. Competition[a] from minor vegetation on plots site-prepared[b] by angle-dozer blade or by shark-fin drums, with and without subsequent herbicide spraying[c]. Goulais River Area, 1967-1972.

	Average competition per seedling from minor vegetation			
	Site preparation by angle-dozer blade		Site preparation by shark-fin drums	
Year	Herbicide (n=103)	No herbicide (n=67)	Herbicide (n=167)	No herbicide (n=126)
1967	0.8	0.6	1.7	2.4
1968	2.8	2.9	3.6	3.8
1969	1.3	1.4	2.8	3.0
1970	1.0	1.7	2.4	3.4
1971	1.1	1.7	2.1	3.3
1972	1.0	1.9	2.1	3.0

[a] Calculated on the basis of nil = 0, very light = 1, light = 2, moderate = 3, heavy = 4.

[b] Site preparation and planting carried out in spring, 1967.

[c] Herbicide applied August 13, 1968 after annual remeasurement was made.

Table 2. Survival and height of white spruce seedlings[a] planted on plots site-prepared by angle-dozer blade or by shark-fin drums, with and without subsequent herbicide spraying. Goulais River Area, 1967-1973.

Year	Site preparation by angle-dozer blade				Site preparation by shark-fin drums			
	Herbicide		No herbicide		Herbicide		No herbicide	
	Survival (n=103)	Avg ht	Survival (n=67)	Avg ht	Survival (n=167)	Avg ht	Survival (n=126)	Avg ht
	(%)	(in.)[b]	(%)	(in.)[b]	(%)	(in.)[b]	(%)	(in.)[b]
1967	82.5	4.5	83.6	4.4	81.4	5.1	74.6	5.7
1968	77.7	7.3	80.6	7.3	71.2	8.5	66.7	7.9
1969	61.2	c	80.6	10.3	66.5	c	64.3	11.3
1970	57.3	10.8	80.6	13.7	64.6	15.2	64.3	15.4
1971	57.3	14.6	80.6	19.0	62.9	19.8	62.7	19.7
1972	54.4	16.8	80.6	21.9	62.3	26.6	57.9	23.3
1973	54.4	20.9	79.2	27.6	59.9	32.9	57.9	28.7

[a] 2+0 seedlings planted on angle-dozed plots, 3+0 seedlings on shark-fin drum-scarified plots.

[b] 1 in. = 2.54 cm.

[c] Not recorded

As suggested earlier, it would appear that this herbicide spraying had a detrimental effect on the rather exposed seedlings on the angle-dozed area. Survival dropped sharply (from 78 to 61 percent) in the first year after spraying, while there was no loss on the unsprayed plots. This effect was not shown on the shark-fin drum-scarified area, where there was no significant difference between survival on the sprayed and unsprayed plots.

There were no further major changes in survival for the duration of the study. In 1973 survival was considerably higher for the unsprayed plots on the angle-dozed area than for any of the other treatment combinations (P.01). Within the angle-dozed area, heights were also greater on the unsprayed plots (Fig. 7 and 8). On the shark-fin drum-scarified area, there was no significant difference in survival between the sprayed and unsprayed plots, but the former had superior height growth (P.05) (Fig. 9 and 10). The height of the average seedling on the unsprayed angle-dozed plots was not significantly less than that on the unsprayed drum-scarified plots in spite of the fact that 2+0 seedlings were planted on the former and 3+0 seedlings on the latter.

These results seem quite reasonable in view of the different rates of reinvasion of minor vegetation on the angle-dozed and on the drum-scarified area, and the modification of these rates effected by herbicide spraying (Table 1). It would appear that reinvasion was not serious on the angle-dozed area, and that herbicide (applied at a higher than normal rate) was actually detrimental to both survival and growth.[7] On the drum-scarified area reinvasion was more rapid, and although herbicide spraying had little effect on survival, it had a positive effect on height growth.

To simplify further comparisons, the number of surviving trees per acre[8] was multiplied by the 1973 height of the average seedling, to produce a single figure representing survival and growth for each treatment (Table 3). The resulting figures, called the "aggregate height", can be used to rank the four treatments in terms of silvicultural success (in the manner suggested by Wang and Horton 1968, and Mullin 1971). On this basis, angle-dozing, without subsequent herbicide spraying, was clearly the most successful treatment, as the higher survival on these plots was more than sufficient to offset the somewhat superior height growth on the drum-scarified plots (with or without spraying).

If the total cost figures are divided by the aggregate height figures, the dividend is the cost per foot of aggregate height, which can be considered a measure of the relative cost effectiveness of each

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[7] Some of this was due to frost damage and insolation, which appeared to be particularly severe on the fully exposed seedlings on these plots.

[8] Assuming 600 seedlings planted per acre (1,483 seedlings per ha) in each treatment.

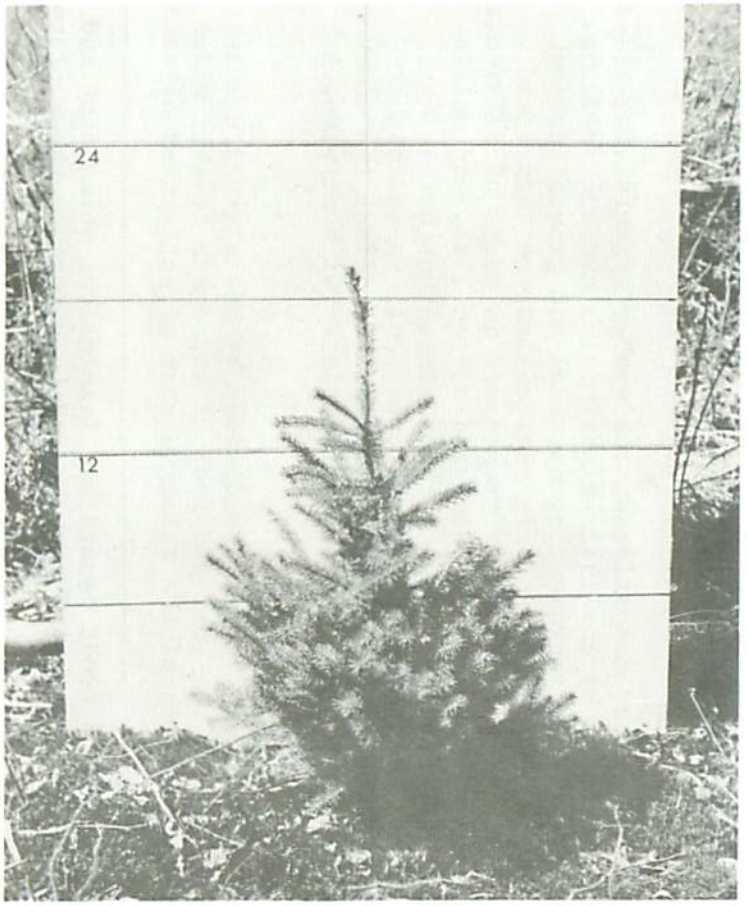

Fig. 7. Average seedling at end of seventh growing season after planting, fifth growing season after spraying on angle-dozed and herbicide-sprayed plot.

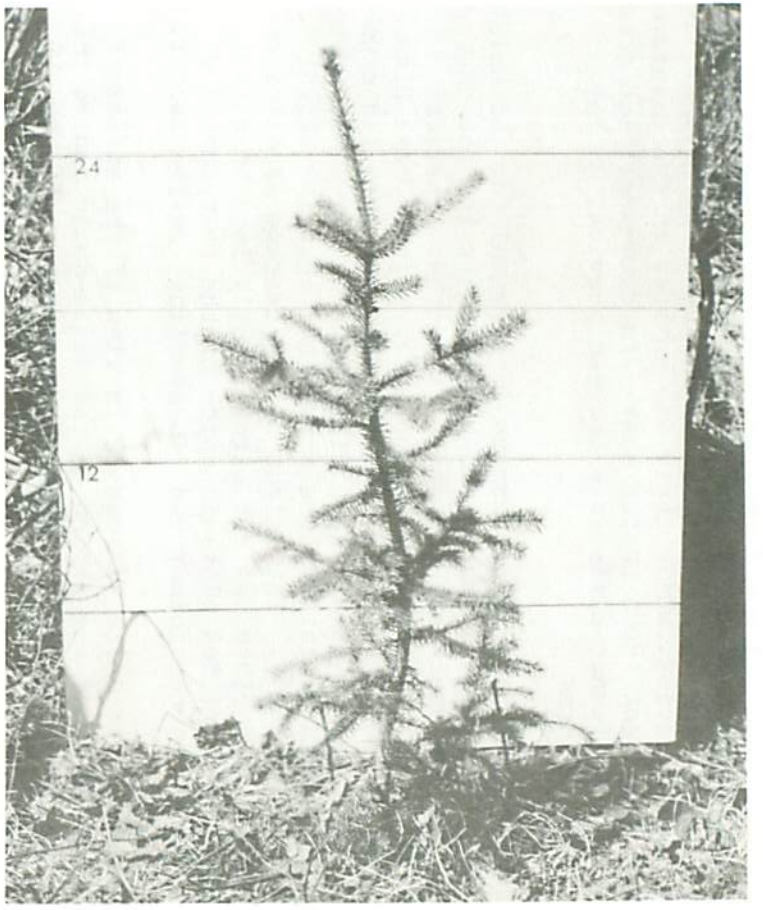

Fig. 8. Average seedling at end of seventh growing season after planting, on angle-dozed plot.

Fig. 9. Average seedling at end of seventh growing season after planting, fifth growing season after spraying, on shark-fin drum-scarified and herbicide-sprayed plot.

Fig. 10. Average seedling at end of seventh growing season after planting, on shark-fin drum-scarified plot.

Table 3. Silvicultural and economic comparisons of four methods of establishing white spruce on a cut-over mixedwood site in the Goulais River Area, 1967-1973.

Method[b]	Total cost per acre[a] ($)	Survival 1973 (%)	Survival 1973 trees/acre[c]	Avg ht 1973 (ft)[c]	Aggreg. ht 1973 (ft)[c]	Cost/ft of aggreg. ht (Col. 2÷Col. 6) ($)
Angle-dozer, herbicide spraying	30.10	54.5	327	1.7	554	0.05
Angle-dozer	24.10	79.2	475	2.3	1092	0.02
Shark-fin drum, herbicide spraying	32.60	59.9	359	2.7	969	0.03
Shark-fin drum	26.60	57.9	347	2.4	833	0.03

[a] Calculated on the basis of a standard degree of site preparation (35%), a standard number of trees planted per acre (600), 1¢ per tree for planting stock and 2¢ per tree for planting (Haig 1969). This trial was too small to produce a meaningful cost figure for herbicide spraying, but in Ontario the average cost of aerial spraying is about $6.00 per acre (J.D. Scott, Ontario Ministry of Natural Resources, personal communication).

[b] All methods include hand planting.

[c] 1 ft = 30.48 cm
1 acre = 0.4 ha (approximately)

treatment. As the angle-dozer treatment was the least expensive, and produced the greatest aggregate height, it had, of course, the lowest unit cost (2¢) and hence it ranked first in cost effectiveness.[9] In this instance, herbicide spraying apparently reduced both survival and height growth on angle-dozed plots and increased treatment cost; consequently, it was the least efficient treatment. On the drum-scarified area, the greater aggregate height on the sprayed plots was just sufficient to offset the additional cost of spraying, with the result that the cost effectiveness of the two treatments was the same.

Although these results are of interest in themselves, their chief value is in pointing up the need for more careful evaluation of the cost effectiveness of various reforestation techniques. One such study (Mullin and Howard 1973) indicated that for a reforestation program of the scale conducted in Ontario, the use of transplants instead of seedlings could produce annual savings in excess of $1.6 million. The current study suggests that savings of a similar magnitude might be achieved if the most efficient method of plantation establishment were selected in each instance.

SUMMARY AND CONCLUSIONS

In 1968, a small-scale trial of herbicide spraying was carried out on a portion of a cut-over mixedwood site that had been scarified and planted in 1967 as part of a larger series of trials. A mixture of 2,4-D and 2,4,5-T esters was applied with a portable mist-blower at a rate of 4.7 lb acid equivalent per acre (5.26 kg per ha) to four plots that had been scarified with shark-fin drums and three that had been scalped with an angle-dozer blade. Three unsprayed plots were designated as controls for the former and two for the latter treatment. For each seedling, survival and height were recorded annually from the fall of 1967 to the fall of 1973 inclusive. The results were combined with treatment cost data obtained from the earlier trials, to provide comparisons of the cost effectiveness of site preparation by shark-fin drums and by angle-dozer blade (followed by hand planting) with and without subsequent herbicide spraying.

For each treatment, the aggregate height in 1973 was divided into the total treatment cost, to produce a figure called the "cost per foot of aggregate height". Although these figures are not particularly meaningful in absolute terms, they clearly indicate the relative cost effectiveness of the various treatments.

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[9] No allowance was made for the fact that 3+0 stock would cost somewhat more to produce than 2+0 stock. This would increase the advantage shown for the angle-dozer treatment.

On this basis, site preparation with the angle-dozer blade (without subsequent herbicide spraying) was most efficient. In addition to its being the least costly treatment, the severity of the scalping action evidently favoured high survival and effectively reduced competition from minor vegetation. Cost effectiveness of shark-fin drum scarification was about the same with and without subsequent herbicide spraying, because increased height growth on the sprayed plots was just sufficient to offset the cost of spraying. Angle-dozer blade scalping plus herbicide spraying was the least efficient treatment, presumably because the competition from minor vegetation was insufficient to warrant spraying.

Although these results are based on one small trial on a single site type, they indicate the need for more intensive evaluation of the cost effectiveness of various reforestation techniques.

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