RESEARCH REPORT

11

Mackay River Herbicide Trial: Conifer Response 9 Years Post-treatment

G.J. Harper, B.S. Biring, and
J. Heineman

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ABSTRACT

In 1986, glyphosate, 2,4-D amine, 2,4-D ester, and manual brushing treatments were applied to a 4-year-old fireweed/shrub community in the ESSFwk1 biogeoclimatic subzone, for the purpose of releasing *Picea glauca* × *engelmannii* (hybrid spruce) seedlings. Competing vegetation was heavily affected for at least 1 year following application of glyphosate at a rate of 2.1 kg ai/ha. Spruce seedlings were also damaged by the herbicide, resulting in a net reduction in growth rates for 1986–1987. Manual brushing and 2,4-D amine treatments reduced vegetation cover less than glyphosate, while 2,4-D ester had little effect.

The trial was remeasured in 1995, 9 years post-treatment, to determine whether there were any long-lasting effects of treatment on growth and condition of planted spruce seedlings. Spruce seedlings in plots treated with glyphosate were significantly larger overall than seedlings located in the other treatments. Statistical analysis showed significant differences in spruce seedling root collar diameter, crown diameter, and height. Analysis of spruce height growth increments suggested that from 1989 to 1995 the glyphosate-treated seedlings were outperforming seedlings from all other treatments.

Of the original target species (fireweed, black twinberry, Sitka alder, elderberry) of 1986, only fireweed continued to have significant cover within all treatments in 1995. Prominent vegetation species in 1995 were fireweed, thimbleberry, lady fern, and oak fern.

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Funding for this 1995 remeasurement project was provided by Forest Renewal B.C. under the B.C. Ministry of Forests Research Branch experimental project (ep) 1195, which was designed to obtain longer-term conifer and vegetation response information from previously established vegetation management research trials.

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1 INTRODUCTION

Research on the silvicultural implications of vegetation management treatments has historically focused on short-term information needs to support successful plantation establishment. Longer-term implications have received minimal attention. However, due to recent changes in provincial forestry legislation and policy (*Forest Act, 1988* and *The Forest Practices Code of B.C. Act, 1995*) and societal concern over the management of Crown lands and environmental sustainability of forest practices, the demand for long-term information has increased substantially. Not only does the forest industry have a requirement to maintain the survival and growth of young forests, social change has put pressure on land managers to reduce herbicide use and develop brushing treatment alternatives that are both effective and minimally intrusive on other forest resources. These developments have intensified the need for long-term information on the impact of brushing activities. Information is required for timber growth and yield projections, to assess impacts on non-timber resources and resource user groups, to expand our knowledge of forest biology, and ultimately to improve forest management practices.

A research project (EP 1195) was initiated to remeasure previously established vegetation management research trials in response to operational and land management needs for long-term data on crop tree response to vegetation management treatments. During 1994 and 1995, several vegetation management trials were evaluated (>5 years post-treatment) for the possibility of remeasurement to obtain long-term conifer response data based on published and unpublished reports, experimental design, field surveys, and communications with operational and research staff. The Mackay River herbicide trial (SX85702C) was selected for remeasurement. Field surveys during the summer of 1994 and spring of 1995 suggested that although it had been approximately 9 years since treatment and technically the trial had been abandoned, the trial plots had not been compromised and were intact. This report summarizes the data collected during August 29–31, 1995 and those data available from earlier assessments in 1986 and 1987.

The Mackay River herbicide trial was established in 1986 in the Horsefly Forest District of the Cariboo Forest Region

(Figure 1) to study the effects of three herbicides and a manual brushing treatment applied for the purpose of conifer release. The trial was established on a cutblock south of the Mackay River located in the Engelmann Spruce–Subalpine Fir wet cool subzone (ESSFwk), where planted *Picea glauca* × *engelmannii* (hybrid spruce) seedlings were experiencing heavy competition from a mixed shrub/fireweed community. The trial was assessed at the time of treatment and again 1 year post-treatment. Results were presented by Newsome (1987, 1988).

FIGURE 1 *Study area location.*

2 OBJECTIVES

The original objective of this trial was to compare the effectiveness of 2,4-D amine (Forestamine®), 2,4-D ester (For-ester®), glyphosate (Roundup®), and a manual brushing treatment for reducing vegetation competition and releasing crop trees.

The objective of remeasurement in 1995 was to determine long-term treatment impacts (9 years post-treatment) on spruce seedling growth and vigour, stocking levels, and the cover and height of non-crop vegetation.

3 METHODS

3.1 SITE DESCRIPTION

The research trial is situated at approximately 1200 m elevation in the ESSFwk1/05 (old ESSFh1) on a 24-ha cutblock (opening 93A-037-24, TSL A07015 CP 17 CB3). The site has a northerly aspect, and is on rolling terrain with an average slope of 15%. Soil texture is a clay-loam. The site was clearcut during the winter of 1981–1982 using a grapple yarder and, except for landings being burned, there was no further site preparation. During June of 1984 the block was planted with spruce (PBR 1+1 seedlings, seedlots 4000 + 4040, average height 35 cm) at approximately 1300 stems per hectare (sph). One year later, survival was 82% (1090 sph) with severe brush competition noted (dense canopy of fireweed and shrubs affecting plantation survival and growth).

3.2 TRIAL ESTABLISHMENT

The trial used an incomplete block design (IBD) consisting of five treatments replicated three times (Table 1) for a total of 15 treatment plots. Plots were situated across the entire cutblock grouped into three blocks with an additional single plot (O) on its own (Figure 2). Two of the 2,4-D amine treatment plots were found in one block but were absent in the other two blocks. In general, plots south of the road (A–J) were situated on slightly convex terrain, and plots north of the road (K–O) were situated on slightly concave terrain.

TABLE 1 *Treatments*

Treatment	Rate/method	Plot (Block)**
control	untreated	B(1) I(2) N(3)
2,4-D amine (Forestamine®)†	2.2 kg ai/ha (backpack sprayer)‡	A(1) F(1) O(4)
2,4-D ester (For-ester®)†	3.0 kg ai/ha (backpack sprayer‡	C(1) H(2) L(3)
glyphosate (Roundup®)†	2.1 kg ai/ha (6 l/ha Roundup®) (backpack sprayer)‡	D(1) G(2) M(3)
manual brushing	brush saws*	E(1) J(2) K(3)

**plot map Figure 2
†pesticide use permit no. 400-007-85/86
‡treatments applied August 7, 1986
*brushing completed August 19, 1986

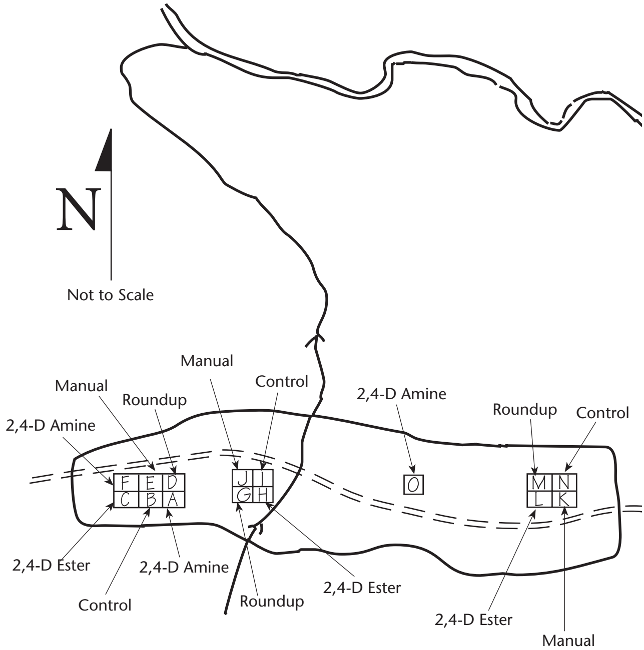

FIGURE 2 *Plot layout map* (*from Newsome 1987*).

Each treatment plot was 0.3 ha (60 x 50 m), including a 5-m herbicide-free buffer zone inside the perimeter. During 1986 and 1987, 20 seedling-centred subplots were established within each plot to assess the size and vigour of spruce seedlings and the height and condition of four target species: *Lonicera involucrata* (black twinberry), *Alnus viridis* (Sitka alder), *Sambucus racemosa* (elderberry), and *Epilobium angustifolium* (fireweed).

Herbicides were applied by backpack sprayer on August 7, 1986 and manual cutting with brush saws took place on August 19, 1986.

3.3 MEASUREMENTS

Six weeks after treatment, on September 23–24, 1986, spruce seedlings were measured for total height, leader length, and root collar diameter. Target species were assessed for height, percent cover, and condition. These measurements were repeated 1 year later on September 23–24, 1987. Procedures used followed those recommended for silviculture SX trials (Silviculture Manual, B.C. Ministry of Forests). No pretreatment data were collected.

During August 29–31, 1995, 20 spruce seedlings were selected and tagged (systematic selection with a random start) within each plot. In plots K and N only 17 and 12 seedlings, respectively, could be found for remeasurement. Selected spruce seedlings were required to be old enough to have been present during treatment (1986). Each seedling was measured for total height as well as height to branch whorls representing growth to 1993, 1991, 1989, and 1987. Root collar diameter, crown diameter (average of N-S and E-W crown dimensions), and condition were also assessed. Non-crop vegetation was assessed at a point approximately 10 m north of the estimated centre of each plot. Percent cover and modal height were estimated for all vascular species within a 5-m^2 area (radius=1.26 m). Silviculture survey data (total stems/ha of conifer and deciduous components, stems/ha of well-spaced free-growing crop trees) were collected within three 50-m^2 (radius=3.99 m) subplots within each plot (N, S, and SW 10 m from plot centre). See the Silviculture Branch publication (B.C. Ministry of Forests 1990) for more information on free-growing stocking standards and silviculture surveys.

3.4 DATA ANALYSIS

Treatment and plot means from the 1986–1987 assessments were taken from Newsome 1988 (Appendix 1).

1995 data were analyzed using the statistical programs SYSTAT (Systat Inc. 1992) and SAS (SAS Institute Inc. 1985). Statistical analysis included an analysis of variance (ANOVA)(Table 2), t-tests, and planned contrasts (Appendices 5 and 6). Upon consideration of the plot layout, working plan (Trigg 1985), and apparent field observations of block vegetation differences, the trial was analyzed as an incomplete block design (IBD) (Bergerud 1996). The original working plan (Trigg 1985) suggested a randomized block design (RBD); however, due to statistical constraints, this design was not followed.

The 15 treatment plots were grouped into four blocks of 6, 4, 4, and 1 plot each. All treatments except the 2,4-D amine treatment are present in each of the three primary blocks. The block containing six plots also had two of the three 2,4-D amine treatment plots. The analysis was run using an incomplete block design (IBD) shown in Table 2. Note that degrees of freedom do not necessarily add up as they would for a balanced design. The missing cells in the IBD result in a lack of information about part of the interactions between block and treatment (this is indicated by the fewer degrees of freedom for the interaction: 6 instead of

TABLE 2 *Incomplete Block Design ANOVA*

Source of Variation	Factor type	Level	Degrees of freedom (df)	Expected F-test (df)
Treatment (T)	Fixed	k=5	k-1=4	MS_T/MS_{BxT} (4,6)
Block (B)	Random	n=4	n-1=3	MS_B/MS_E
Interaction (Block x Treatment) (BxT)	Random		(k-1)(n-1)=6	MS_{BxT}/MS_E
Plot (Block x Treatment) (P)	Random	p=1 or 2	Σ(p-1)=1	MS_P/MS_E
(Seedlings): Error (E)	Random	s=20	Σ (s-1)=285 (all plots)	
Total			kns-1=299	

8 or 12). In particular, there is no information about the interaction of blocks with respect to the fifth treatment (2,4-D amine). This analysis must assume that this part of the interaction is similar to that which can be estimated (this is the usual homogeneity of variance assumption). On the other hand, the replication of 2,4-D amine within one block allows an estimate of variability within the one block and has been identified in Table 2 with just 1 degree of freedom (W. Bergerud, pers. comm., July 1996).

4 RESULTS

4.1 1986–1987 SPRUCE SEEDLING GROWTH ASSESSMENT (NEWSOME 1987, 1988)

One year after treatment, spruce seedlings treated with glyphosate had significantly less leader growth than seedlings in the control ($p \leq 0.05$), largely as a result of herbicide damage to foliage and leaders (Figure 3). Sixty percent of the seedlings in the glyphosate treatment and 29% of the seedlings in the 2,4-D ester treatment were affected to less than moderate vigour. The number of dead trees recorded in 1987 suggested 13.5% and 6.7% mortality for the glyphosate and 2,4-D ester treatments, respectively. By comparison, there was 2.4% mortality among seedlings in the control areas and 0% mortality in the manual cutting and 2,4-D amine treatment plots. Approximately 20% of seedlings in the 2,4-D amine and manual treatments were rated at less than moderate vigour, as were 15% of seedlings in the control.

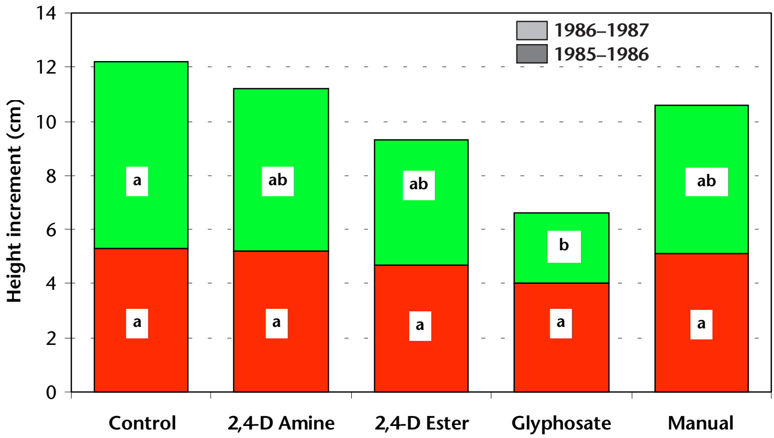

FIGURE 3 *Height increment for spruce seedlings from 1985–1986 and 1986–1987 (Newsome 1988). Within each year, treatments with different letters signify statistical difference at p≤0.05.*

4.2 1995 SPRUCE SEEDLING GROWTH

4.2.1 Height, root collar diameter, and crown diameter

Table 3 summarizes the 1995 spruce seedling measurement data collected 9 years after the treatment applications. In addition, individual plot means are presented in Appendix 2. Figure 4 illustrates the spruce seedling height development over time. Comparisons of treatment and plot means suggested a high amount of variation. However, statistical analysis using the IBD found the block effect to be highly significant (p≤ 0.0003) in all cases with all seedling parameters measured. There were no significant treatment x block interactions found.

In 1995, glyphosate-treated spruce seedlings were significantly taller than spruce seedlings from any of the other four treatments (p≤ 0.05). Root collar diameter and crown diameter of glyphosate-treated spruce were also significantly greater than those from the control, manual, and 2,4-D ester treatments. The spruce seedling root collar diameter of the 2,4-D amine treatment was not significantly different from any other treatments.

In general, analysis of height data (1995, 1993, 1991, 1989, and 1987) suggested increasing differentiation in height development between the seedlings from the glyphosate treatment and seedlings from other treatments. ANOVA suggested no significant

TABLE 3 *1995 spruce seedling measurements*

	Root collar diam. (mm)	Crown diam. (cm)	Ht. (cm) 1995	Ht. (cm) 1993	Ht. (cm) 1991	Ht. (cm) 1989	Ht. (cm) 1987
Control							
	41.4*b†	96.2bc	199.8b	141.0bc	102.9a	69.7a	42.4a
	*13.2***	*25.1*	*58.5*	*40.7*	*29.1*	*19.7*	*11.7*
2,4-D Amine							
	45.7ab	106.5ab	201.1b	142.4b	103.2a	68.0ab	39.9a
	9.3	*18.5*	*33.8*	*25.1*	*20.6*	*14.6*	*9.5*
2,4-D Ester							
	38.9b	95.3c	189.6b	131.8bc	95.6b	65.0b	40.1a
	12.7	*26.9*	*55.9*	*35.9*	*27.7*	*18.4*	*12.5*
Glyphosate							
	50.4a	111.2a	226.0a	156.8a	109.0a	66.0ab	39.1a
	17.2	*30.1*	*70.7*	*47.7*	*32.7*	*20.8*	*13.5*
Manual							
	40.9b	94.2c	189.0b	130.4c	95.2b	64.6b	40.3a
	11.5	*22.4*	*44.3*	*29.8*	*21.1*	*15.5*	*9.7*

*mean. †means followed by different letters within each column signify statistical difference at $p \leq 0.05$. **standard deviation. See Appendix 5 for sum of squares, mean squares, and probability values.

height differences between treatments in 1987 ($p = 0.52$). By 1989 (3 years post-treatment), seedlings from the control treatment had become significantly taller than those found in the 2,4-D ester and manual treatments ($p \leq 0.07$). The 2,4-D amine- and glyphosate-treated spruce had moved to second and third place in height behind the control seedlings. During 1991, the 2,4-D amine and glyphosate seedlings surpassed the control seedlings in height although there was no significant difference noted. The 2,4-D ester and manual treatment had become significantly smaller than the glyphosate, 2,4-D amine, and control treatments ($p \leq 0.05$). This relative height ranking continued to be maintained through to August 1995. In 1993, seedlings from the 2,4-D amine plots were significantly taller than those from the manual cutting plots; however, this was not the case in 1995. In 1993 and 1995, the glyphosate-treated seedlings were significantly taller than all other treatments.

Analysis of 2-year height increment data (Table 4 and Appendix 6) shows that seedling height increased significantly more in the glyphosate treatment than in any of the other treatments between 1989 and 1995. There were no significant differences in height growth rate (increment) between the

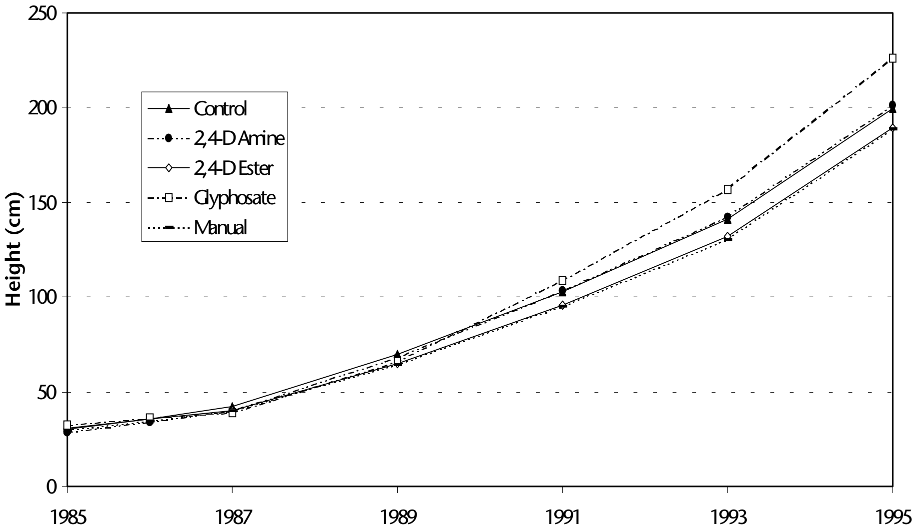

FIGURE 4 *Spruce seedling height (cm) from 1985 to 1995.*

TABLE 4 *1987 – 1995 spruce seedling height increments*

	Ht. increment 1987–89 (cm)	Ht. increment 1989–91 (cm)	Ht. increment 1991–93 (cm)	Ht. increment 1993–95 (cm)
Control				
	27.3*a†	33.2 b	38.1 b	58.7 b‡
	*11.1***	*12.7*	*15.6*	*21.6*
2,4-D Amine				
	28.0a	35.2 b	39.2 b	58.7 b‡
	8.1	*9.1*	*8.9*	*16.5*
2,4-D Ester				
	24.9a	30.5 b	36.3 b	57.8 b‡
	10.2	*11.8*	*12.2*	*23.6*
Glyphosate				
	26.9a	43.0 a	47.8 a	69.3 a‡
	10.4	*14.6*	*19.2*	*25.6*
Manual				
	24.3a	30.6 b	35.2 b	58.6 b‡
	9.0	*9.2*	*11.0*	*17.7*

*mean. †means followed by different letters within each column signify statistical difference at $p \leq 0.05$. ‡means followed by different letters signify statistical difference at $p \leq 0.08$. **standard deviation.

treatments from 1987 to 1989. Planned contrast probability values (p-values) showed a reduced level of significance for the 1993–1995 height increment (i.e., glyphosate vs control $p=0.0563$). Treatment differences in height growth from 1989 to 1991 and from 1991 to 1993 were highly significant ($p \leq 0.01$).

4.2.2 1995 silviculture survey data

Stand density and species composition information was collected in the 3.99-m radius silviculture survey subplots (three per plot). Survey information indicated that the majority of conifers present were spruce (62–89%) with some small *Thuja plicata* (western redcedar) and *Abies lasiocarpa* (subalpine fir) natural regeneration (Table 5). The planted spruce were by far the largest and tallest conifers present with the exception of a few natural cedar.

Survey results indicated that stocking was extremely variable between plots (Figure 5). Plots in the western part of the cutblock had better stocking regardless of treatment than plots in the eastern end of the cutblock. This observation was confirmed by IBD ANOVA results, which resulted in a significant block effect with all stocking parameters tested. There were no significant treatment differences found in stocking between treatments (Table 5). Stocking levels ranged from 133 to 6200 sph in various plots (Appendix 3). There was also no significant difference between treatments in the number of well-spaced free-growing spruce, cedar, or subalpine fir (Table 5).

The number of free growing stems in some of the treatment

TABLE 5 *Total conifer stems per hectare and free-growing stems per hectare*

	Total conifers (sph)	Spruce (sph)	Subalpine fir (sph)	Cedar (sph)	Free growing (sph)
Control	2289	1422	756	111	400
2,4-D Amine	2244	1622	444	178	600
2,4-D Ester	800	711	89	0	400
Glyphosate	1689	1444	222	22	533
Manual	1578	1156	400	22	689
p-value†	*0.34*	*0.46*	*0.13*	*0.47*	*0.24*

†treatment test probability value from IBD ANOVA

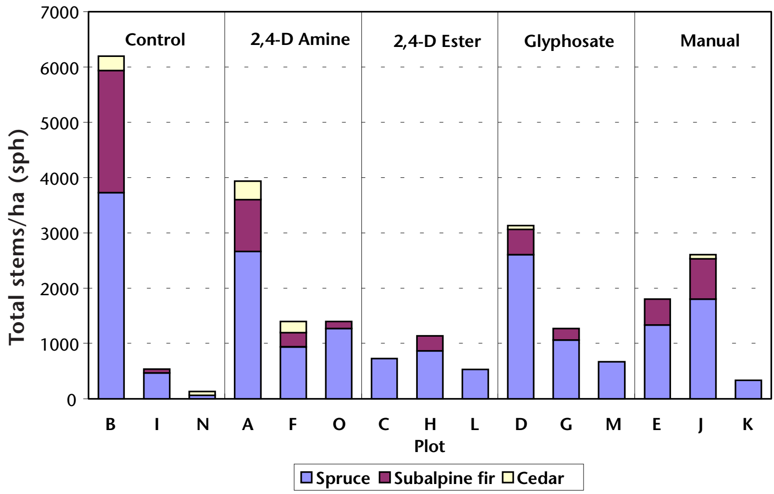

FIGURE 5 *1995 total stems per hectare by plot and treatment.*

plots will reach minimum requirements (700 sph free growing) within 3 years. However, some areas were not sufficiently restocked (plots I, K, L, M, and N) while other areas (west end of cutblock) contain large numbers of natural regeneration (plots A, B, D, and E). The naturals tended to occur in areas where stocking was already adequate, and appeared to be associated with somewhat drier, less brushy conditions, and the existence of mineral soil patches.

Condition of the surviving planted spruce seedlings was, in general, good. Some infection by *Adelges cooleyi* (Cooley spruce gall adelgid) was noted at the western end of the block. A considerable number of spruce stems in all treatment plots were bent at the base, probably as a result of early vegetation and/or snowpress. The proportion of spruce with bent stems was 25–30% in the chemically treated plots (2,4-D amine, glyphosate, and 2,4-D ester plots), 37% in the manually brushed plots, and 38.5% in the control plots.

4.3 1986–1987 VEGETATION

Selected vegetation data collected during 1986 and 1987 are summarized in Appendix 4. Six weeks after treatment (September 1986), total vegetation cover in the manual cutting treatment was 9%; however, percent cover in the herbicide treatment plots remained high (77–95%). After 1 year, percent cover of the glyphosate treatment had been reduced to 11% vegetation cover,

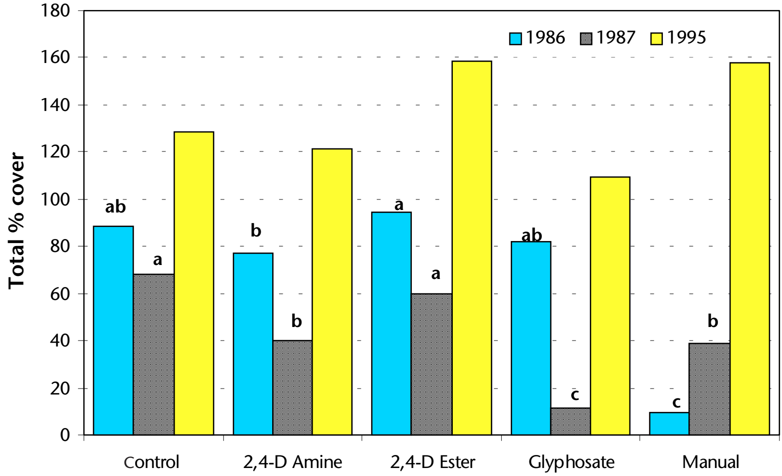

FIGURE 6 *Total vegetation cover in 1986 (post-treatment), 1987(Newsome 1988), and 1995. Within each year, treatments with different letters signify statistical difference at p≤0.05.*

whereas the manual cutting treatment recovered to 39%. Reduction in cover of the 2,4-D amine and 2,4-D ester treatments was 37% and 35%, respectively (Figure 6).

4.4 1995 VEGETATION

Only one 1.26-m radius vegetation assessment subplot was installed within each plot (due to time constraints). This lack of within-plot replication restricted the interpretation of the 1995 vegetation data. As a result, an analysis of treatment vegetation differences other than a discussion of apparent differences was not attempted.

Table 6 lists all species found in August 1995 and their height and percent cover. Full species lists for 1986–1987 were unavailable; however, of the original four main target species (fireweed, black twinberry, Sitka alder, elderberry), fireweed was the only one found with significant cover (>10% cover). Of the top five species by cover in 1995, fireweed and *Rubus parviflorus* (thimbleberry) were found consistently through all treatments. *Gymnocarpium dryopteris* (oak fern) was present above 30% cover in all except the glyphosate treatment (4%). *Athyrium filix-femina* (lady fern) was found above 20% in all but the glyphosate and 2,4-D amine treatment areas. *Veratrum viridis* (Indian hellebore) and *Heracleum lanatum* (cow parsnip) were in the top five of the glyphosate treatment areas only.

TABLE 6 *1995 species list*

Scientific name	Common name	Control		2,4-D Amine		2,4-D Ester		Glyphosate		Manual	
		Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)
Abies lasiocarpa	Subalpine fir	170	1								
Actaea rubra	Baneberry	6	Tr							35	Tr
Alnus viridis	***Sitka alder****					***248***	***3***			***300***	***8***
Anaphalis margaritacea	Pearly everlasting	35	Tr			45	Tr	21	Tr	56	Tr
Aruncus dioicus	Goat's beard	22	Tr	80	2						
Athyrium filix-femina	Lady fern	103	23	58	7	100	22	60	4	100	27
Carex spp.	Sedge									12	1
Clintonia uniflora	Queen's cup	15	1	7	3	10	1				
Cornus canadensis	Bunchberry	9	5	10	6	12	Tr	10	3	11	4
Dryopteris expansa	Spiny wood fern					50	5				
Epilobium angustifolium	***Fireweed***	***112***	***13***	***108***	***20***	***143***	***30***	***106***	***37***	***140***	***28***
Equisetum spp.	Horsetail	24	Tr			40	Tr	55	5		
Galium triflorum	Bedstraw	9	Tr	5	Tr	5	Tr	9	Tr	5	Tr
Grass spp.	Grass	40	Tr	63	8			78	8	72	8
Gymnocarpium dryopteris	Oak fern	19	32	23	35	21	57	13	4	20	37
Heracleum lanatum	Cow parsnip	110	Tr	50	Tr	65	2	143	9	110	5
Hieracium albiflorum	White flw. hawkweed	53	Tr					55	Tr		
Listera cordata	Heart-leaved twayblade	8	Tr								

TABLE 6 *Continued*

Scientific name	Common name	Control		2,4-D Amine		2,4-D Ester		Glyphosate		Manual	
		Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)
Lonicera involucrata	***Black twinberry***										
Mitella nuda	Mitrewort							7	1		
Oplopanax horridus	Devil's club	80	1			65	1			45	3
Picea glauca × engelmannii	Spruce hybrid	300	13	105	1	225	4			155	2
Rhododendron albiflorum	White-flw. rhododendron			75	2					130	1
Ribes lacustre	Black gooseberry	51	8	65	8	90	10			69	3
Ribes viscosissimum	Sticky currant	75	3	65	3	45	1				
Rubus idaeus	Trailing raspberry	58	2	45	Tr	53	2	52	4	85	4
Rubus parviflorus	Thimbleberry	72	19	53	13	50	13	70	12	39	11
Rubus pedatus	Five-leaved bramble			5	Tr						
Sambucus racemosa	***Elderberry***			***65***	***2***	***30***	***Tr***	***24***	***Tr***	***30***	***Tr***
Smilacina racemosa	False Solomon's seal	90	1	58	1	80	5	40	1		
Sorbus scopulina	Western mountain ash			200	2	185	1				
Streptopus amplexifolius	Clasping twisted stalk			67	Tr						
Streptopus roseus	Rosy twisted stalk	14	Tr	30	Tr	17	Tr	14	Tr	26	Tr
Taraxacum officinale	Dandelion							7	Tr		
Thuja plicata	Western redcedar	350	3								
Tiarella trifoliata	Three-leaved foamflower	8	1	6	5	5	2	5	7	10	4

TABLE 6 *Concluded*

Scientific name	Common name	Control		2,4-D Amine		2,4-D Ester		Glyphosate		Manual	
		Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)
Tiarella unifoliata	One-leaved foamflower	5	Tr	6	Tr			4	1		
Urtica dioica	Stinging nettle	83	Tr	71	Tr			73	Tr		
Vaccinium membranaceum	Black huckleberry	40	1	85	3					100	3
Valeriana sitchensis	Sitka valerian	22	1	20	1			18	1	45	Tr
Veratrum viride	Indian hellebore	143	5	33	2	215	1	180	11	220	8
Viola spp.	Violet	5	Tr					8	1		

* 1986 target species are indicated by ***bold italics.***

5 DISCUSSION

During the 1995 assessment, the research area appeared to be heterogeneous with regard to moisture regime, in that there were noticeable differences in levels of both non-crop vegetation and conifer stocking between the western and eastern ends of the cutblock. This site variation was accounted for in the trial design and statistical analysis by blocking of the treatments. However, because the 2,4-D amine treatment was not present in all blocks, the analysis considered an incomplete block design.

The original objective of this trial was to study the effects of various brushing treatments on spruce seedlings and target vegetation (Trigg 1985). Early reported results (Newsome 1987, 1988) showed that the glyphosate treatment had reduced vegetation cover significantly; however, significant seedling damage was also incurred, resulting in a net decrease in seedling height and root collar diameter in comparison to the control. Although not statistically significant, the 2,4-D ester treatment appeared to have also resulted in seedling damage (reduced diameter and height increment).

Glyphosate seedling damage may be an indication that the treatment was applied prior to cessation of spruce bud activity. Coates et al. (1994) suggest that shoot elongation usually has ended by early August; dormancy, however, is not complete until mid-October. Historically, glyphosate treatment of spruce plantations does result in some damage (usually less than 25% injury) when treatment takes place from July to mid-August (Boyd et al. 1985; Biring et al. 1996). However, annual variation in climate can have a significant influence on the duration of the growing season at higher elevations where vegetation and spruce development is largely dependent on temperature, especially the occurrence of early frost.

On the basis of the 1995 assessment, it can be concluded that the 1986 glyphosate treatment resulted in a statistically significant improvement in seedling growth over all the other treatments. In 1995, the surviving spruce seedlings from the glyphosate treatment plots were larger overall than seedlings from any other treatment. Between 1989 and 1995, 2-year spruce height growth was significantly greater in the glyphosate treatment seedlings than similar height growth from any of the other treatments. These differences are all the more convincing since the glyphosate treatment had resulted in seedling damage in

1986–1987. This observed greater size of the glyphosate-treated seedlings 9 years post-treatment suggests successful recovery from the herbicide damage, and that the glyphosate treatment had long-term, long-lasting positive effects on seedling growth. The 2,4-D ester and manual treatments appeared to have no significant long-term effect on spruce seedling diameter, crown dimensions, and height. (2,4-D amine treatment seedling data also suggest no effect; however, due to incomplete block replication of this treatment, the results are less certain.)

Vegetation assessments and field observations indicated that the vegetation community is a mixed shrub complex with scattered patches of Sitka alder. The amount of total vegetation cover was considered moderate to very high, creating a similar level of competition in all plots for light and space. Planted spruce seedlings that had survived the early establishment period and were present in 1995 were either growing within the top half of, or above, the vegetation canopy (in the absence of Sitka alder).

Although this remeasurement project did not address spruce seedling survival, silviculture survey results did suggest that there were no significant treatment differences in stocking and number of free-growing seedlings. However, plot data and field observations suggested that some plots were not satisfactorily restocked (NSR) and that these plots were found within areas of high vegetation competition. The large variation in stocking encountered between plots and the apparent block effect (significant block differences) suggests confounding of stocking and free-growing treatment differences and that more information is required for further interpretation.

Lastly, it is important to note that the interpretation of results from a single study are applicable to that site only and that repeated studies located at different sites are necessary to increase the confidence in generalizing results. Treatment response may be affected directly, or in interaction with a host of factors other than the treatments. Variations in stock quality, stock development, climate, soil nutrient and moisture regime, vegetation competition, soil type, etc. may influence conifer/vegetation response to treatments. Herbicide efficacy is affected by such factors as phenology of target species, weather, application rate, date, and application method. Continued monitoring and research into crop tree and vegetation response to operational treatments across a variety of sites is essential to improving our understanding of the long-term effects of forest vegetation management practices.

APPENDIX 1 1987 spruce seedling data (Newsome 1988)

	Plot	Root collar diam. (mm)	Ht. increase 1986–87 (cm)	Ht. increase 1985–86 (cm)	Crop trees damaged (%)	Mortality (%)
Control						
	B	12.9	7.9	5.9		
	I	7.5	6.2	3.8		
	N	14.5	6.5	6.3		
Mean		11.6	6.9	5.3	14.6	2.4
2,4-D Amine						
	A	10.5	4.6	5.2		
	F	12.4	6.0	6.0		
	O	12.8	7.5	4.5		
Mean		11.9	6.0	5.2	21.4	0
2,4-D Ester						
	C	10.4	5.8	4.5		
	H	7.0	5.8	5.1		
	L	6.7	2.3	4.5		
Mean		8.0	4.6	4.7	28.9	6.7
Glyphosate						
	D	7.6	1.9	4.1		
	G	8.5	2.4	4.0		
	M	11.7	3.5	3.9		
Mean		9.3	2.6	4.0	59.6	13.5
Manual						
	E	10.9	4.3	3.6		
	J	8.9	4.3	4.9		
	K	21.2	7.9	6.8		
Mean		13.7	5.5	5.1	20.0	0

APPENDIX 2 1995 spruce seedling data

	Plot	Root collar diam. (mm)	Crown diam. (cm)	Ht. (cm) 1995	Ht. (cm) 1993	Ht. (cm) 1991	Ht. (cm) 1989	Ht. (cm) 1987
Control	B	**44.6***	**102.9**	**203.3**	**141.8**	**103.5**	**69.0**	**41.8**
		*9.3***	*13.3*	*40.2*	*29.6*	*26.0*	*20.4*	*10.6*
	I	**45.8**	**104.3**	**220.9**	**155.6**	**113.9**	**77.5**	**46.1**
		13.5	*27.2*	*61.6*	*39.9*	*26.2*	*17.6*	*12.7*
	N	**32.5**	**81.3**	**170.8**	**123.1**	**89.4**	**61.5**	**38.9**
		12.9	*27.2*	*64.0*	*47.5*	*31.6*	*18.6*	*11.2*
Mean		**41.4**	**96.2**	**199.8**	**141.0**	**102.9**	**69.7**	**42.4**
SD		*13.2*	*25.1*	*58.5*	*40.7*	*29.1*	*19.7*	*11.7*
2,4-D Amine	A	**44.0**	**100.3**	**189.3**	**132.9**	**97.3**	**64.6**	**39.4**
		9.8	*16.0*	*26.5*	*18.9*	*15.2*	*12.4*	*9.8*
	F	**46.6**	**106.6**	**202.3**	**148.5**	**109.6**	**72.9**	**43.4**
		8.6	*13.2*	*27.4*	*22.4*	*20.2*	*13.3*	*8.5*
	O	**46.5**	**112.7**	**211.8**	**145.8**	**102.7**	**66.4**	**37.1**
		9.7	*23.6*	*42.9*	*30.7*	*24.3*	*16.9*	*9.7*
Mean		**45.7**	**106.5**	**201.1**	**142.4**	**103.2**	**68.0**	**39.9**
SD		*9.3*	*18.5*	*33.8*	*25.1*	*20.6*	*14.6*	*9.5*
2,4-D Ester	C	**39.4**	**94.9**	**184.8**	**129.4**	**97.4**	**67.7**	**40.4**
		11.7	*23.9*	*51.7*	*37.4*	*31.4*	*21.3*	*12.8*
	H	**44.1**	**108.4**	**213.2**	**145.3**	**104.5**	**69.9**	**45.5**
		27.9	*12.2*	*53.0*	*34.5*	*26.4*	*15.4*	*9.8*
	L	**33.1**	**82.7**	**170.8**	**120.8**	**84.9**	**57.6**	**34.4**
		12.4	*23.4*	*56.9*	*32.9*	*22.4*	*16.4*	*12.5*
Mean		**38.9**	**95.3**	**189.6**	**131.8**	**95.6**	**65.0**	**40.1**
SD		*12.7*	*26.9*	*55.9*	*35.9*	*27.7*	*18.4*	*12.5*
Glyphosate	D	**46.4**	**105.6**	**203.4**	**147.3**	**105.7**	**67.5**	**43.3**
		11.6	*22.5*	*51.9*	*35.4*	*26.2*	*17.3*	*12.5*
	G	**60.2**	**126.2**	**256.5**	**172.4**	**117.5**	**70.1**	**40.6**
		16.3	*25.9*	*60.2*	*41.2*	*29.6*	*18.8*	*9.6*
	M	**44.5**	**101.9**	**216.3**	**150.7**	**103.7**	**60.4**	**33.5**
		19.1	*35.8*	*87.6*	*61.0*	*40.4*	*25.2*	*16.3*
Mean		**50.4**	**111.2**	**226.0**	**156.8**	**109.0**	**66.0**	**39.1**
SD		*17.2*	*30.1*	*70.7*	*47.7*	*32.7*	*20.8*	*13.5*
Manual	E	**42.9**	**98.9**	**190.0**	**133.0**	**98.2**	**66.4**	**42.7**
		11.5	*20.0*	*42.6*	*27.4*	*18.9*	*13.4*	*9.9*
	J	**42.7**	**98.7**	**201.2**	**138.3**	**101.0**	**68.9**	**41.4**
		10.2	*19.7*	*40.7*	*26.0*	*17.7*	*13.8*	*8.8*
	K	**34.8**	**79.0**	**166.9**	**112.9**	**80.4**	**54.6**	**34.7**
		12.1	*25.4*	*47.9*	*34.5*	*24.6*	*18.2*	*9.3*
Mean		**40.9**	**94.2**	**189.0**	**130.4**	**95.2**	**64.6**	**40.3**
SD		*11.5*	*22.4*	*44.3*	*29.8*	*21.1*	*15.5*	*9.7*

* =mean (**bold**); ** = *standard deviation (italic)*

APPENDIX 3 1995 silviculture survey data by plot*

	Plot	Spruce		Subalpine fir		Cedar		Total	
		Total	FTG	Total	FTG	Total	FTG	Total	FTG
Control	B	3733	1133	2200	0	267	67	6200	1200
	I	467	0	67	0	0	0	533	0
	N	67	0	0	0	67	0	133	0
	Mean	1422	378	756	0	111	22	2289	400
2,4-D Amine	A	2667	467	933	0	333	0	3933	467
	F	933	533	267	67	200	67	1400	667
	O	1267	667	133	0	0	0	1400	667
	Mean	1622	556	444	22	178	22	2244	600
2,4-D Ester	C	733	400	0	0	0	0	733	400
	H	867	533	267	0	0	0	1133	533
	L	533	267	0	0	0	0	533	267
	Mean	711	400	89	0	0	0	800	400
Glyphosate	D	2600	600	467	0	67	0	3133	600
	G	1067	733	200	0	0	0	1267	733
	M	667	267	0	0	0	0	667	267
	Mean	1444	533	222	0	22	0	1689	533
Manual	E	1333	733	467	0	0	0	1800	733
	J	1800	800	733	333	67	67	2600	1200
	K	333	133	0	0	0	0	333	133
	Mean	1156	556	400	111	22	22	1578	689

* target stocking=1200 sph; minimum stocking=700 sph

APPENDIX 4 1986–1987 height and condition of target vegetation (Newsome 1988)

		Fireweed		Black twinberry		Sitka alder		Elderberry	
		Height (cm)	Condition* (%)	Height (cm)	Condition (%)	Height (cm)	Condition (%)	Height (cm)	Condition (%)
Control									
	1986	87	98	103	100	78	99	108	98
	1987	93	100	94	76	99	100	85	96
2,4-D Amine									
	1986	89	8	91	87	147	67	107	16
	1987	69	51	92	33	135	100	79	56
2,4-D Ester									
	1986	99	11	87	33	149	66	124	24
	1987	86	53	87	0	180	90	111	62
Glyphosate									
	1986	92	26	106	0	202	40	94	0
	1987	39	15	106	0	200	10	53	24
Manual									
	1986	80	1	92	8	84	17	88	11
	1987	65	41	52	53	53	19	63	17

* 0=dead; 100=excellent condition

APPENDIX 5 Type III sum of squares, mean squares and probability values from SAS IBD ANOVA

Source of variation	Root collar diam. (mm)	Crown diam. (cm)	Ht. (cm) 1995	Ht. (cm) 1993	Ht. (cm) 1991	Ht. (cm) 1989	Ht. (cm) 1987
Model (Total)	11755.87†	37897.23	137924.55	57147.65	24524.36	8518.52	4020.47
	839.71‡	*2706.95*	*9851.75*	*4081.98*	*1751.74*	*608.47*	*287.18*
Treatment (T)	5029.28	12679.18	56839.57	28104.60	8686.80	1071.29	337.23
	1257.32	*3169.80*	*14209.89*	*7026.15*	*2171.70*	*267.82*	*84.31*
	0.032**	**0.032**	**0.025**	**0.0068**	**0.012**	**0.066**	**0.52**
Block (B)	5203.73	20722.33	69841.01	25429.51	13973.69	6441.24	2843.05
	1734.57	*6907.44*	*23280.34*	*8476.50*	*4657.90*	*2147.08*	*947.68*
	0.0001	**0.0001**	**0.0001**	**0.0003**	**0.0002**	**0.0002**	**0.0001**
Interaction (Block x Treatment)(BxT)	1346.81	3428.76	13691.19	3947.43	1555.63	407.64	566.75
	224.47	*571.46*	*2281.86*	*657.90*	*259.27*	*67.94*	*94.46*
	0.19	**0.41**	**0.55**	**0.80**	**0.89**	**0.97**	**0.60**
Plot (Block x Treatment) (P)	65.54	403.23	1677.03	2449.23	1512.90	697.23	156.03
	65.54	*403.23*	*1677.03*	*2449.23*	*1512.90*	*697.23*	*156.03*
	0.51	**0.40**	**0.44**	**0.17**	**0.14**	**0.13**	**0.26**
Error (Seedlings) (E)	41802.65	152783.77	753710.64	354200.91	186800.05	84416.90	34159.23
	152.56	*557.61*	*2750.77*	*1292.70*	*681.75*	*308.09*	*124.67*

†type III sums of squares ‡mean square (*italics*) *probability value (**bold**)

From the results of the IBD ANOVA (partial table given opposite), of particular note is the amount of variation (sum of squares) that the Block term contributes to the Total. Between 44 and 76% of the variation is accounted for by Block. This is additional evidence of the strong significance of blocking in this design.

As one of the assumptions of ANOVA, the Plot(Block x Treatment) term is normally assumed to be zero (variation between plots is homogenous). In this IBD design, the test of between-plot equal variance is possible due to the presence of the two 2,4-D amine plots in one of the blocks. While this test is weak, the results do support the between-plot homogeneous variance assumption.

APPENDIX 6 SAS mean squares and probability values for planned contrasts of height increment from SAS IBD ANOVA

Contrast	Ht. increment 1987–89 (cm)	Ht. increment 1989–91 (cm)	Ht. increment 1991–93 (cm)	Ht. increment 1993–95 (cm)
Glyphosate vs control	*1.12*‡	*2946.95*	*2855.16*	*3576.75*
	0.93*	**0.0048**	**0.0063**	**0.056**
2,4-D Ester vs control	*132.15*	*171.73*	*79.53*	*5.18*
	0.35	**0.33**	**0.52**	**0.93**
Manual vs control	*296.46*	*239.32*	*242.34*	*1.29*
	0.18	**0.26**	**0.28**	**0.97**
Glyphosate vs manual	*269.80*	*4613.84*	*4516.32*	*3447.63*
	0.20	**0.0016**	**0.0021**	**0.060**

‡mean square (*italics*) *probability value (**bold**)

Planned contrasts (shown above) and t-tests (LSD) provided additional information on treatment mean spread. The 2,4-D amine treatment, due to its incomplete block placement, could not be used within the planned contrasts.

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