



FOREST RESEARCH REPORT

NOVA SCOTIA DEPARTMENT
OF LANDS AND FORESTS
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NORWAY SPRUCE RELEASE WITH GLYPHOSATE: 10 YEAR RESULTS

INTRODUCTION

Many reports and studies have been published on the short term vegetation control achieved as a result of using glyphosate¹, but few long term studies on the relationship between crop growth and vegetation management have been undertaken. This report summarizes the 10 year results of a glyphosate conifer release trial. The

focus of the study is two herbicide trials, established in August, 1979 on a hardwood clearcut site planted with Norway spruce (*Picea abies* (L.) Karst.) in Georgefield, Nova Scotia.

¹ Glyphosate is the active ingredient in Roundup®, manufactured by Monsanto Company Ltd. This product is now marketed as Vision®.

SITE DESCRIPTION

The experimental area, located on Crown land in Georgefield, Hants County (45°12'N, 63°34'W), supported a 70 percent hardwood stand prior to harvesting in 1975-1977. The site was prepared with a Rome disc in 1977, and planted with 3+0 Norway spruce in 1978. Planting on mineral soil microsites created by the Rome disc resulted in frost heaving and

reduced plantation survival. Prior to herbicide treatments in September, 1979, the two major competitors were red maple (*Acer rubrum* L.) and raspberry (*Rubus* spp.). Red maple covered 20% of the area, and averaged 2 metres in height; raspberry covered 40% of the area and averaged 0.6 metres.

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GROUND TRIAL

Eight 0.04 hectare blocks were permanently established in 1979. These blocks were placed in an area of extreme competition in order to obtain a "worst case scenario". Two blocks were left for control, and 2 sets of 3 blocks were each treated with Roundup® at rates of 6.29 l/ha, 7.86 l/ha, and 9.44 l/ha¹. Roundup was applied in a 224 l/ha total solution, using hydraulic back pack sprayers, in the first week of September 1979. Competing vegetation was remeasured annually for 5 years with the results reported in 1988 (NSDLF, 1988). For the tenth year re-measurement, blocks were divided into 4 rectangular assessment plots, each approximately 19 m² in size. The 4 plots, located adjacent to one another in the centre of each block, were surrounded by a buffer strip at least 3 metres wide.

AERIAL TRIAL

The aerial trial consisted of three, 8 hectare blocks. The first was treated with 4.72 l/ha Roundup®; the second with 6.29 l/ha¹, both in a 56 l/ha total solution, and the third was left as a control. Application was by helicopter on the evening of September 13, 1979. Wind speed was negligible and the temperature was 15° C. The tenth year data were collected from 10 circular assessment plots, each 3.1 metres in radius, established systematically along a bearing line in each of the 3 areas.

1 The 6.29, 7.86 and 9.44 l/ha rates are higher than the presently recommended rate of 6 l/ha for maple and *Rubus* species as stated on the product label.

PLOT MEASUREMENTS AND CALCULATIONS

Total height (cm), and diameter (in mm, 5 cm above ground level) of all Norway spruce within each plot were recorded. In addition, the height class (m), diameter class (cm), and percent cover (visual estimate) for each hardwood stem by species were recorded along with the average height class (dm) and percent cover for each shrub and ground cover species. Small numbers of naturally regenerated red spruce (*Picea rubens* Sarg.) and balsam fir (*Abies balsamea* (L.) Mill.) were also present on most sites, but have not been included as competition or as crop trees in this report.

In this study a free to grow crop tree is defined as a Norway spruce that is taller than the average height of the hardwood trees in the same plot.

The severity of competing vegetation was evaluated on the basis of cover and height according to the following formula:

$$CI = H \times C$$

where CI = competition index

H = average height of competing vegetation, by species

C = percent of ground covered by competing vegetation of the same species (visual estimate)

The volume of each Norway spruce tree was calculated using the following formula (Husch, Miller and Beers, 1972):

$$Vol = 1/3 \times (\pi \times D^2/4) \times H$$

where Vol = average tree volume (cm³)

D = tree diameter (cm) measured at 5 cm above root collar

H = total height (cm)

π = 3.141592

RESULTS

COMPETING VEGETATION

One application of glyphosate successfully controlled the competing vegetation and allowed the Norway spruce to become established and free to grow in the early years of the plantation (NSDLF, 1988). Ten years following treatment, the Norway spruce are still free to grow in the treated areas, whereas in the control blocks, they have not yet been able to break free of the vegetative competition. The average competition index (CI) for the control is more than 4 times that of treated blocks in the ground trial and 3 times greater in the aerial trial (Figures 1 & 2). The decrease in CI for the treated areas is due to the effect of glyphosate on the height and cover of the hardwood species. For example, in the ground controls, the hardwood competition covers almost 80% of the area and is so severe that the average height of the Norway spruce (2.0m) is only about 1/2 that of the hardwood trees (3.8m). In the treated blocks the reverse is true; the hardwood trees are less than

one half as tall as the Norway spruce and cover less than 20% of the area (Appendix I). The hardwood competition (average height 3.5m) is less severe in the aerial control as compared to the ground control, covering 54% of the area and approximately 80% as tall as the average Norway spruce (4.3m). In the aerially treated blocks, hardwood trees cover less than 20% of the area and are less than one half as tall as the crop trees (Appendix II).

Treatment with glyphosate caused a species shift from mainly hardwood trees to a greater percentage of ground vegetation in both aerial and ground applications (Figures 1 & 2, Appendix III). Hardwood trees in the treated plots make up only approximately 50% of the competition index compared to about 90% in the controls. Ground vegetative species account for approximately 50% of the total competition index in the treated blocks as opposed to less than 10% in the controls. The shrub species, mainly raspberry, account for less than 10% of

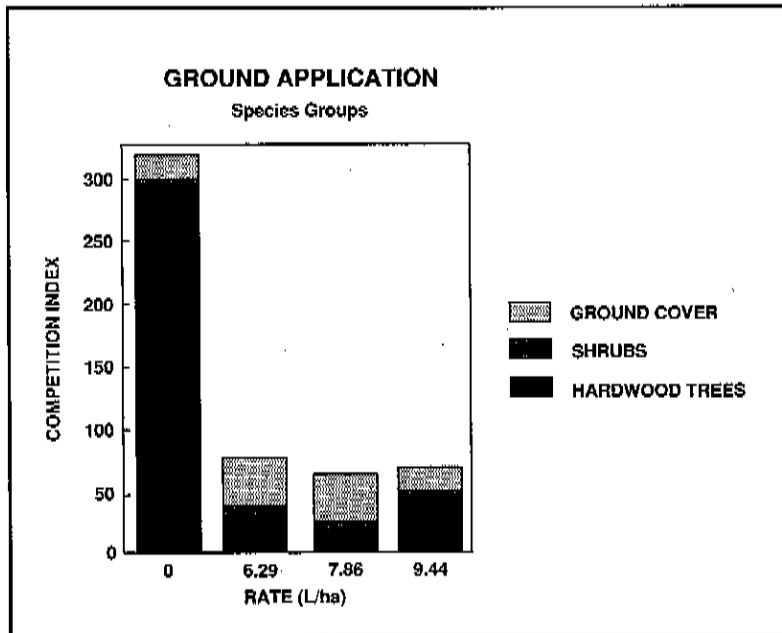


Figure 1. Total competition index by species groups for different treatment rates of glyphosate - ground application.

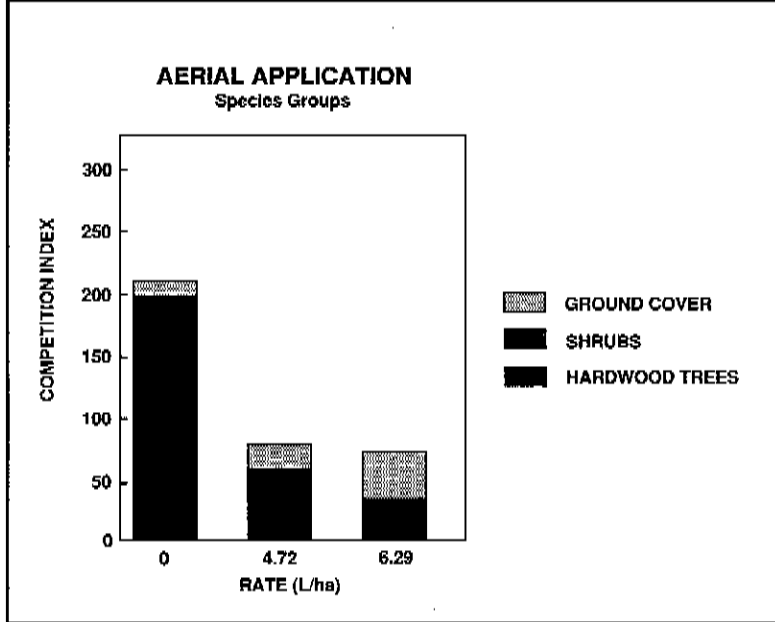


Figure 2. Total competition index by species groups for different treatment rates of glyphosate - aerial application.

the total CI in both treated and control blocks, despite being a major competitor prior to treatment (NSDLF, 1988). Although the shrub and ground vegetative species groups account for approximately 1/2 the competition index in the treated areas, they now offer very little overhead competition to the Norway spruce. In fact, the average height of these 2 vegetative groups is approximately 0.5m compared to 4.0m for Norway spruce (Appendices I & II).

CROP TREES

Norway spruce on treated sites outperformed crop trees in the control block with respect to height, diameter and volume growth. In fact, for ground treated sites, the average Norway spruce volume is 6-13 times greater than that of the control, and the height is double, increasing from 2 metres to 4 metres, on average. On the aerially treated sites, the average crop tree volume exceeded the volume in the control by 2 to 3 times (Figures 3 & 4).

In the ground control block, none of the surviving Norway spruce had managed to get through the dense cover of hardwood trees, while in the treated blocks 96% of the Norway spruce were free to grow. Similarly, in the aerial control, only 50% of the Norway spruce were taller than the average hardwood competition while 94% were free to grow in the treated blocks (Appendices I and II).

Crop tree results for the ground application blocks were more dramatic than those for the aerial blocks. The difference is attributed to the greater competition from hardwood species in the ground controls than in the aerial controls (CI of 295 versus 190).

Overall survival was poor due to frost heaving as previously discussed. However, in the ground trial, the number of planted trees that survived in the treated areas was approximately twice that of the control (Table 1). Since initial plantation spacing varied by treatment blocks in the aerial trial, a meaningful survival comparison could not be made.

**AVERAGE TREE VOLUME - NORWAY SPRUCE
GROUND TREATMENT**

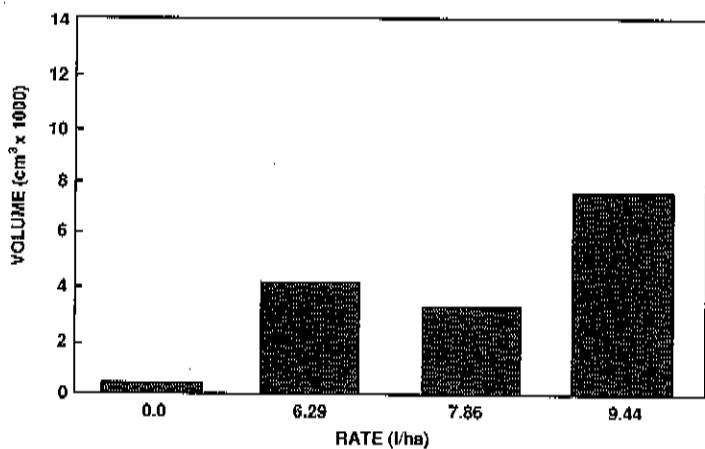


Figure 3. Mean tree volume by glyphosate rate - ground application.

**AVERAGE TREE VOLUME - NORWAY SPRUCE
AERIAL TREATMENT**

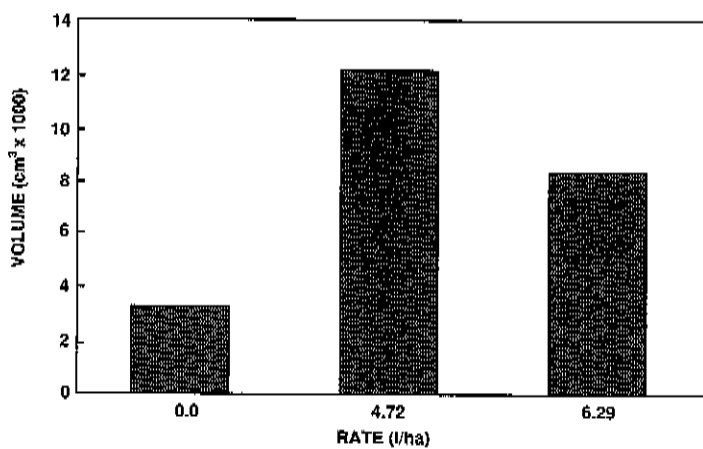


Figure 4. Mean tree volume by glyphosate rate - aerial application.

Table 1. Number of surviving Norway spruce and hardwood trees per hectare, 10 years following ground and aerial applications of glyphosate.

GROUND APPLICATION			AERIAL APPLICATION		
DENSITY OF SURVIVING TREES stems/ha			DENSITY OF SURVIVING TREES stems/ha		
RATE (l/ha)	NORWAY SPRUCE	HARDWOOD TREES	RATE (l/ha)	NORWAY SPRUCE	HARDWOOD TREES
0.00	527	23182	0.00	1524	11759
6.29	966	6636	4.72	994	5432
7.86	1358	4849	6.29	1656	3378
9.44	1107	13696			

SUMMARY

Ten year results of a glyphosate trial established on a hardwood cutover planted to Norway spruce are as follows:

- 1) A single application of glyphosate successfully controlled the competing vegetation and allowed the planted Norway spruce to become established and free to grow.
- 2) Treatment resulted in a shift in the composition of competing vegetation. After ten

years, the controls contained mainly hardwood tree competition, while in the treated areas the percentage of hardwood was considerably lower and ground vegetation considerably higher.

- 3) Average crop tree volume increased from 2 to 13 times, over the first 10 year period, following glyphosate treatment at rates ranging from 4.7 to 9.44 l/ha.

LITERATURE CITED

Husch, B., C.I. Miller, and T.W. Beers, 1972. Forest Mensuration. Toronto: John Wiley and Sons. 410 pp.

NSDLF, 1988. Efficacy of glyphosate in controlling competing vegetation in Nova Scotia. N.S. Dept. of Lands and Forests. Forest Research Report No. 3. 8 pp.

APPENDIX I

Growth of crop trees and amount of vegetative competition, 10 years following ground applications of glyphosate: Georgefield, Hants County, Nova Scotia, 1989.

Treatment (t/ha)	Norway Spruce						Hardwood			Shrubs			Ground Vegetation			All Species Combined		
	Dia (cm)	Lorhei (m)	Vol (cm ³)	Inc (%)	FG (%)	TR (#)	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI
Control	3.2	2.00	537	0	0	4	78.5	3.8	295.0	7.3	0.28	2.1	65.0	0.27	17.6	150.9	1.44	314.7
6.29	6.4	4.14	4447	728	93	15	15.0	2.0	30.1	11.9	0.65	7.7	82.1	0.48	39.2	109.0	1.05	77.0
7.86	6.2	3.46	3497	551	95	21	6.2	2.0	16.1	11.8	0.34	4.1	132.9	0.34	45.2	153.0	0.88	65.4
9.44	7.8	4.62	7456	1288	100	16	18.4	2.4	44.0	4.3	0.54	2.3	48.4	0.45	21.9	71.1	1.13	68.2

Dia - Quadratic mean diameter.
 Lorhei - Lorey's mean height.
 Vol - Average tree volume.
 Inc - Percent increase in tree volume compared to the control.
 FG - Percent of the crop trees that are taller than the average height of the hardwood competition within the same measurement plot (free to grow).
 TR - Number of Norway spruce trees sampled.
 Cover - Percent of ground covered by species group.
 CI - Competition Index (Cover * Height).

APPENDIX II

Growth of crop trees and amount of vegetative competition, 10 years following aerial applications of glyphosate: Georgefield, Hants County, Nova Scotia, 1989.

Treatment (t/ha)	Norway Spruce						Hardwood			Shrubs			Ground Vegetation			All Species Combined		
	Dia (cm)	Lorhei (m)	Vol (cm ³)	Inc (%)	FG (%)	TR (#)	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI	Cover (%)	Height (m)	CI
Control	5.4	4.32	3249	0	50	46	54.0	3.5	189.5	5.0	0.95	4.7	50.4	0.27	13.4	109.4	1.58	207.7
4.72	9.9	4.75	12269	278	90	30	21.3	2.3	50.0	22.0	0.22	4.7	58.6	0.34	19.8	102.1	0.96	74.5
6.29	8.3	4.64	8452	160	96	50	15.6	1.8	28.4	4.0	0.44	1.8	95.7	0.40	38.7	115.3	0.89	68.8

Dia - Quadratic mean diameter.
 Lorhei - Lorey's mean height.
 Vol - Average tree volume.
 Inc - Percent increase in tree volume compared to the control.
 FG - Percent of the crop trees that are taller than the average height of the hardwood competition within the same measurement plot (free to grow).
 TR - Number of Norway spruce trees sampled.
 Cover - Percent of ground covered by species group.
 CI - Competition Index (Cover * Height).

APPENDIX III

Species identified by group and order of dominance on the ground, and aerial glyphosate trial sites in Georgefield, Hants County, Nova Scotia, 1989.

HARDWOOD TREES

red maple	<i>Acer rubrum</i> L.
yellow birch	<i>Betula alleghaniensis</i> Britt.
white birch	<i>Betula papyrifera</i> Marsh.
sugar maple	<i>Acer saccharum</i> Marsh.
grey birch	<i>Betula populifolia</i> Marsh.
pin cherry	<i>Prunus pensylvanica</i> L.f.
trembling aspen	<i>Populus tremuloides</i> Michx.
balsam poplar	<i>Populus balsamifera</i> L.
large tooth aspen	<i>Populus grandidentata</i> Michx.
mountain maple	<i>Acer spicatum</i> Lam.
beech	<i>Fagus grandifolia</i> Ehrh.
willow	<i>Salix</i> spp.

SHRUBS

raspberry/blackberry	<i>Rubus</i> spp.
lambkill	<i>Kalmia angustifolia</i> L.
red berried elder	<i>Sambucus rubens</i> Michx.

GROUND COVER

ferns	<i>Polypodiaceae</i> spp.
goldenrod	<i>Solidago</i> L. spp.
aster	<i>Aster</i> spp.
sedge	<i>Cyperaceae</i> spp.
mosses	<i>Bryophyte</i> spp.
grass	<i>Gramineae</i> spp.
pearly everlasting	<i>Anaphalis margaritacea</i> L.
bunchberry	<i>Cornus canadensis</i> L.
willow herb	<i>Epilobium</i> L. spp.

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