EFFECTS OF AN AERIAL APPLICATION OF VISION® ON MOOSE BROWSE - FIRST YEAR RESULTS

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ABSTRACT: Experimental aerial treatment of 7 mixedwood areas for conifer release with Vision® at 0.80, 1.06, and 1.60 kg a.e./ ha, decreased living stem densities after one winter by 36, 61 and 47% respectively on treated plots, while controls increased by 25%; thus, decreases in total numbers of living hardwood stems were not proportional to application rates. Hardwood shrub cover was reduced by application rates of 1.06 and 1.60 kg a.e. / ha, but not by 0.80 kg a.e. / ha. Although 1.06 kg a.e. / ha reduced cover almost twice as much as the highest concentration, differences were not significant. Herbaceous ground cover was reduced approximately 20% on all treated areas when compared with control plots. Browsing rates decreased on all plots after treatment and were twice as high on controls when compared with treated sub-blocks. However, neither differences among treatments, nor between treated and control plots were significant.

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Vision®, with the active ingredient N-(phosphonomethyl) glycine, or glyphosate, has become the herbicide most commonly used for releasing conifer crop trees from competitive non-crop vegetation in Ontario (Forestry on the Hill 1991). Glyphosate is relatively non-toxic to both terrestrial and aquatic animals (Newton *et al.* 1984, Atkinson 1985, Sullivan 1985, 1990). The formulated product, Vision® is also considered practically non-toxic to mammals but slightly to moderately toxic to aquatic invertebrates and fish (Hildebrand *et al.* 1980, Sullivan *et al.* 1981, Mitchell *et al.* 1987, Scrivener and Carruthers 1989). Although direct effects on moose (*Alces alces*) associated with the use of this herbicide seem unlikely, indirect effects (reduction of food and cover) should concern biologists, primarily because the competing hardwood species most often killed constitute a major source of winter food for moose. If all sprayed areas became less desirable for moose, available habitat for the animals might be substantially reduced. An additional concern is that very little is known about the effects of glyphosate on long term vegetation structure. If conifer release programs become entrenched in forestry practices, how will this policy alter plant and associated animal communities?

Hughes and Fahey (1991) concluded that, when compared with the natural process of regeneration (i.e. stand decay), clear cutting results in significantly larger, heavier twigs and more nutritious browse (higher levels of protein and soluble carbohydrates) than in uncut stands. It would be a waste of this high quality browse to spray at unnecessarily high concentrations of Vision®. Several recent studies have shown that current conifer release treatments greatly reduce the availability of these high quality moose foods (Kennedy and Jordan 1985, Hjeljord and Gronvold 1988, Cumming 1989 and Lloyd 1989, 1990*a*, *b*, Connor and McMillan 1990). Continued use of herbicides by forest managers may lead to significant losses of foods immediately after treatment.

Across Canada, approximately 200 000 ha of forest land are treated with herbicide annually. Quebec treats 20 - 35 000 ha, British Columbia 25 000 ha, New Brunswick >40 000 ha, whereas Ontario treats 60 000 - 100 000 hectares (Forestry on the Hill 1991). Of the five herbicides commonly used in Canadian forestry, glyphosate (Vision®) accounts for 81% of treated areas (Forestry on the Hill

1991). Apart from any wildlife considerations, foresters may want to reduce application rates, to reduce costs and to address public concerns regarding herbicides and chemicals in general. (A recent survey by Forestry Canada (1989) revealed that 70% of the Canadian public opposes the use of herbicides in forests).

The Ontario Government is complying with the public's demand to reduce dependence on herbicides. The 1991 sustainable forestry initiative (Canadian Council of Forest Ministers 1992) called for all provinces, including Ontario to reduce their dependency on herbicides. Glyphosate, as Vision®, has been the most common herbicide used by foresters because of it's environmental safety record and biological performance. However, this new initiative may lead to Vision® being targeted for reductions also.

Cumming (1989) demonstrated that glyphosate can act successfully as a conifer release at intermediate application rates. Crop trees treated with 1.07 kg a.e. /ha did not seem more vigorous than those treated with 2-7 kg a.e./ha for site preparation. There was significantly greater plant biomass at 1.07 kg a.e./ ha when compared to application rates of 2.7 kg a.e./ ha. Some of these plant species are of high value for moose winter browse (Cumming 1987). Therefore, a lower than standard application rate might be found that would successfully release conifer crop trees and leave foods for moose. Benefits associated with reduced rates could include: (1) increased production of browse on treated areas without compromising crop trees, (2) reduced constraints on where Vision® is applied, and (3) increased knowledge about the environmental effects of this chemical.

Ironically, with all the concern regarding herbicide related browse reduction, Lautenschlager (1990), referring to the long term work of Newton *et al.* (1989) suggested that there is likely a trade-off between the browse reduction which follows conifer release and increased browse availability which occurs several years after the herbicide application.

Perhaps management of the forest for wood products can be integrated with wildlife management; Lautenschlager (1986), Jordan *et al.* (1988), Cumming (1989) and Newton *et al.* (1989) believe so. This experiment is designed to continue for five years, therefore some of these concerns will be addressed. The objective of the study is to determine how varying application rates of herbicide affect moose browse production, moose use of the treated browse, and growth of the conifer crop trees.

STUDY AREA

Study areas, located 150 km northwest of Thunder Bay, were chosen in consultation with silviculturalists from Canadian Pacific Forest Products (CPFP) and the Ontario Ministry of Natural Resources (OMNR). The 7 chosen clearcuts ranged in size from 44 to 95 ha with an average of 71 ha. All study areas were mechanically site prepared, planted with black spruce (*Picea mariana* (Mill.) B.S.P.) or jack pine (*Pinus banksiana* Lamb.) between 1980 and 1989, and released with a single aerial application of glyphosate in early September, 1990. In case initial moose densities might affect reactions to the glyphosate, areas of low, medium and high density were sampled separately (Fig. 1).

Soils on these upland sites were generally dry, shallow glacial tills over granite bedrock (the Canadian Shield), although sphagnum / feathermoss bogs were common in the lower areas at the edges of clearcuts. Topography was rolling. Temperature was cold; mean daily temperatures for January and July were -18.5°C and +16.1°C, respectively. Precipitation averaged 50.5mm in January and 77.5mm in July (Environment Canada 1992). Table 1. provides a summary of soils, clearcut size, site preparation, sampling intensity, harvest dates and planting dates. These sites were chosen for Vision® application by CPFP because com-

Table 1. Descriptions of blocks on which Vision® was applied to find differences due to application rates.

Block	Soil	Total area	Treatment area	Harvest year	Method of site preparation	Planting year	Sampling browse	Intensity crop
1	coarse silty loam	85	21	1985	1988 barrel & chain	1989	2.9	1.5
2	coarse silty loam	50	13	1978	1980 bracke	1980-82	4.8	1.4
3	fine loam	83	21	1986	1987 barrel & chain	1988	1.9	1.0
4	fine loam	95	24	1986	1987 barrel & chain	1988	2.3	1.0
5	fine silt	60	15	1987	1989 barrel & chain	1989	2.6	1.3
6	coarse loam	80	20	1982	1985 angle blade	1986	2.1	0.9
7	coarse loam	44	11	1982	1985 power head	1986	4.4	0

petition was beginning to over-top the planted conifers. Residual dead white birch (*Betula papyrifera* Marsh.) and aspen (*Populus tremuloides* Michx.) over-topped the cut areas during spraying.

METHODS

Spraying

A baseline was established, and marked with posts, that approximately bisected each clearcut (block). The block was further subdivided into four sub-blocks. Sub-blocks were randomly chosen for spraying by helicopter in late August, 1990, such that each application rate (0.8, 1.06, and 1.60 kg acid equivalent (a.e.)/ha was applied to a block once, with 1 sub-block remaining as a control (0 kg a.e./ha). These application levels were determined from previous work (Bell 1989) and from discussions with foresters from CPFP, OMNR, and Monsanto Canada, Inc. Marking and spraying followed the OMNR Aerial Spraying for Forest Management Operational Manual (Carrow *et al.* 1981).

Spring Browse Surveys (Stem Counts)

Browse surveys were completed between early May and early July in 1990 (pre spray) and 1991 (first year post spray). Each of the four sub-blocks within each block was surveyed independently. Browse survey transect lines were run at right angles to the spray path and were similar to those described by Cumming (1987). Using a random start from the baseline, 1x20 m (1/500 ha) sample plots were examined every 20-40 m, depending on sub-block size, along transect lines. A minimum of 32 and a maximum of 64 sample plots were surveyed from each of the four sub-blocks in each block. On each sample plot, hardwood stems were counted by species and height class: 0.5-1 m, 1-2 m, 2+ m. All stems were classified as alive, alive browsed, dead or dead browsed.

Crop Tree Performance

To evaluate effects of application rates on crop tree growth, circular sample plots (diam.= 2.2m) were located along new transect lines. The crop tree (planted or volunteer) nearest the line at predetermined points served as the plot center. On each sample plot internode lengths for the current and two previous years were measured, and an index of competition from non-crop trees and herbs was estimated by recording percent cover and height for

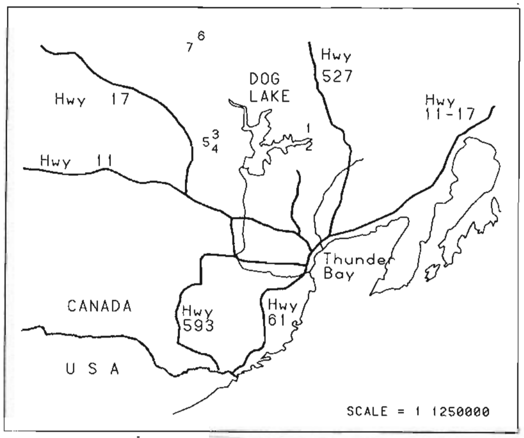

Fig. 1. Locations of seven cut areas near Thunder Bay, Ontario, where effects of conifer release with Vision herbicide on moose browse were measured.

each non-crop species. Dead stems were not counted as competition.

Data Analysis

For this initial report, numbers of stems in each sub-block were compared by year to find any differences that might have resulted from the spray application. The experiment was analyzed as a randomized complete block design. Analysis of variance was used for within years comparisons. To control for differences that existed prior to spray we used analysis of covariance, using pre spray data as a covariate. ANCOVA was not performed on herbaceous cover as pre pray data was inappropriate as a regressor. Residuals plotted against fitted values of the dependent variable were used to determine if normality and homogeneity of variance assumptions were met. Two dependent variables (growth 1990 and browsing 1990) did not fit the proper residual pattern. Thus, to be conservative, post-hoc tests were performed using the Games-Howell test at a= 0.05, with the exception of treatment means for herbaceous cover, which were compared using Fisher's protected LSD.

RESULTS

One growing season after application, densities of living stems/ha increased slightly on the control sub-blocks but decreased noticeably on all treated sub-blocks (Table 2). Decreases in available browse varied from 36-61%, but not strictly in order of application rate: 1.06 kg a.e./ha decreased browse availability more than 1.60 kg a.e./ ha (Table 2). ANOVA analysis for stem counts revealed no significant differences among total numbers of living stems on treatments or controls before spraying. Both ANOVA and ANCOVA demonstrated significantly fewer living stems on some treated sub-blocks than on controls after spraying. Differences between the two highest application rates were not significant, but both were significantly greater than 0.80 kg a.e./ ha (Table 3). This lowest application rate showed no significant difference from the control.

Changes in living stems/ha were the inverse of changes in numbers of dead stems (Table 2). Before treatment, percentages of dead stems did not differ among treatments or controls, but after treatment all sprayed areas showed significantly higher numbers of dead stems than control areas(Table 3). Although not statistically greater than other application rates, 1.06 kg a.e./ ha produced the highest recorded percentage of dead stems (Table 2). The percentage of stems browsed decreased from pre-treatment levels on all areas, to little more than half on controls and to about 1/3 on treatment sub-blocks. Browsing rates did not differ statistically among treated or control sub-blocks before or after treatment.

As expected crop trees did not show a height growth response during this short period. Hardwood and herbaceous cover, however, were reduced significantly on treated sub-blocks one growing season after spraying (Table 3). Herbaceous cover was controlled equally at all application rates, but hardwood cover was reduced more by 1.06 and 1.60 kg a.e. / ha than by 0.80 kg a.e./ha. Although the difference was not significant in these tests, 1.06 kg a.e. / ha reduced hardwood cover twice as much as the highest application rate (Table 2).

DISCUSSION

First year effects on plants

Our study demonstrated once more that browse availability on treated areas decreases significantly in the first growing season after glyphosate application. Kennedy and Jordan (1985) demonstrated that 1 growing season after treatment glyphosate treated areas contained about 1/2 the available browse biomass of areas treated with 2,4-D and 1/4 the browse present on areas not yet sprayed. Cumming (1989) showed that 1 growing season after applications of 1.07 kg a.e./ha (conifer release) and 2.7 kg a.e./ha (site preparation) moose browse availability decreased from 5-41% and 63-92% respectively. Connor and McMillan (1990) found that glyphosate reduced available browse on treated areas to 25% of controls 21 months after treatment. 12 months later (33 months post-spray) treated areas had recovered to 33% of controls. They also demonstrated moose preference for control areas (determined by winter track counts) was not clearly evident, although numbers of tracks indicated a preference for control areas 31 and 43 months post-spray. In British Columbia, Lloyd (1990 *a*) stated that in one study area moose winter use (determined from track counts) was 8 times higher in control than in treated areas. Hjeljord and Gronvold (1988) reported that glyphosate treated areas had less than 1% of the browse production before treatment and that moose use was significantly lower 3 years after application.

Hardwood density comparisons between treated and control sub-blocks demonstrate the efficacy of treatments but also show that when Vision® is used for conifer release it does not totally eliminate potential moose browse. With 8 620 to 16 300 living stems / ha remaining after treatment, food was still available on treated areas. Browse production (cover) on treated sub-blocks was reduced by 3-40% (hardwoods) and approximately 20% (herbaceous), while hardwood cover increased slightly and herbaceous cover decreased slightly on controls.

Table 2. Changes in treatment means for browse data and crop tree performance due to application of Vision® at three different rates (kg a.e. / ha).

	Browse data					
kg a.e./	# Living stems/ha		% Dead stems		% Browsed stems	
ha	1990	1991	1990	1991	1990	1991
0	21 400	26 700	0.711	5.96	22.5	12.20
0.80	25 600	16 300	0.788	51.4	18.6	6.36
1.06	22 200	8 620	0.864	62.1	21.6	5.92
1.60	18 800	10 000	0.942	55.8	24.6	7.34
	Crop tree performance					
kg a.e./	Height Growth (cm)		% Hardwood shrub cover		% Herbaceous cover	
ha	1990	1991	1990	1991	1990	1991
0	13.5	15.9	33	37.2	76.1	66.6
0.80	16.4	15.0	37.7	17.7	70.7	48.3
1.06	17.4	14.6	29.1	8.10	75.3	43.9
1.60	17.5	16.6	30.5	17.2	73.1	46.8

Table 3. Most effective Vision® application rates (kg a.e. / ha) as determined from ANOVA and ANCOVA. 1990 represents a comparison of pre spray conditions of experimental units.

	1990 ANOVA p value	1991 ANOVA p value	Application rate	ANCOVA p value	Strongest effect
#Live Stems/ha	0.3403	0.0011	1.06 & 1.60	0.0002	1.06 & 1.60
% Dead Stems	0.8309	0.0001	all treatments	0.0001	all treatments
% Browsed Stems	0.8150	0.3412	no effect	0.2646	no effect
Height growth	0.1990	0.6145	no effect	0.1483	no effect
Hardwood Cover	0.3590	0.0010	1.60 & 1.06	0.0001	1.60 & 1.06
Herbaceous Cover	0.4559	0.0192	1.60, 1.06 & 0.80	N/A	N/A

This study also suggested that plant response during the first winter might not be linear with application rate. The intermediate application rate of 1.06 kg a.e. / ha resulted in the greatest numbers of dead stems and controlled hardwood cover as effectively as the highest application rate. This result may be due to a phenomenon reported by Sutton (1978). If application rates are too high glyphosate will kill tissue on contact preventing translocation and / or inhibiting control.

Kennedy and Jordan (1985) also found that glyphosate encourages heavy stands of grasses, forbes and raspberries. Lloyd (1990 *a*) reinforced these findings as she reported vigorous herbaceous growth in treated areas, especially in moist zones where all shrubs had been killed. There are indications that similar increases in herbaceous vegetation are occurring in 1992 in our study as herbaceous cover increased on treated plots. Heavy stands of such vegetation concern wildlife and forest managers alike since such plants are not sources of winter food for ungulates and these herbs can quickly over-top young conifers.

Species differences

Plant species respond differently to glyphosate treatments. In our study, beaked hazel (*Corylus cornuta* Marsh.), mountain maple (*Acer spicatum* Lam.) and aspen seemed most susceptible, while other species were more resistant (Fig. 2.).In British Columbia, Balfour (1989) found great variance between species. She stated that particularly sensitive species included aspen, service berry (*Amelanchier* Med. spp.) and cherry (*Prunus* L. spp.). Lloyd (1989) added to this list maple (*Acer* L. spp.) and birch (*Betula* L. spp.). Lloyd (1989) also stated that willow (*Salix* L. spp.) and red-osier dogwood (*Cornus stolonifera* Michx.) seemed to tolerate spraying better than most species. Seasonal timing of spraying and weather conditions before, during, and after treatment may also influence the effectiveness of Vision®. Balfour (1989), for example, found substantial variation even within species. Pojar (1990) took the ultimate skeptical position by claiming that the response of browse plants to glyphosate application is impossible to predict. Certainly, glyphosate can change both species composition and relative abundance, can encourage vigorous herbaceous growth, and can either maintain (Timmermann *et al.* 1986, McMillan *et al.* 1990) or increase (Lautenschlager and McCormack 1989) plant species diversity.

Browsing

The reduction in moose browsing among all treatments and controls may have been due to a shift in the moose population unrelated to the spraying , or to a loss of interest by moose in large areas where browse availability was reduced. Belovsky (1978) suggested that moose should forage optimally. It may be that spraying reduced browse availability enough on the cut areas, despite the presence of controls, that these areas as a whole did not warrant the winter browsing intensity they had previously been given. Furthermore, when compared with controls, treatment sub-blocks were browsed less, suggesting that moose might have been browsing least where energy gained/energy expended was least.

Sources of Error

Although Lloyd (1989) and Bell (1989) present a range of possible effects on plant condition, all stems were classified as alive, alive browsed, dead or dead browsed. This could lead to erroneously high biomass estimates post spray as plants classed as alive could still be adversely affected by the herbicide. Often residual timber seemed to protect pockets of vegetation. Shorter hardwood browse was shielded from spray by taller browse stems, most often aspen. Additionally, during application some strips of ground were missed, which resulted in some strips of healthy vegetation amid that killed by the herbicide.

Although some would argue that this problem affected our results, we believe this result represents field conditions and is a necessary source of variance to measure. These realities allow sprayed areas to continue providing browse following conifer release, especially if application rates are moderate.

Need for further work

The long term effects of conifer release with herbicides, including Vision®, on ungulate populations are unclear. Lautenschlager (1986) states, "in treated areas, hardwood brush is reduced and therefore the habitat value and forage quality is lowered for several years following treatment. Of all the species examined, successful conifer release will likely reduce moose populations the most. However, any moose population decrease related to herbicide conifer release is unlikely to last long because some of the treated brush quickly sprouts, and some brush is missed during

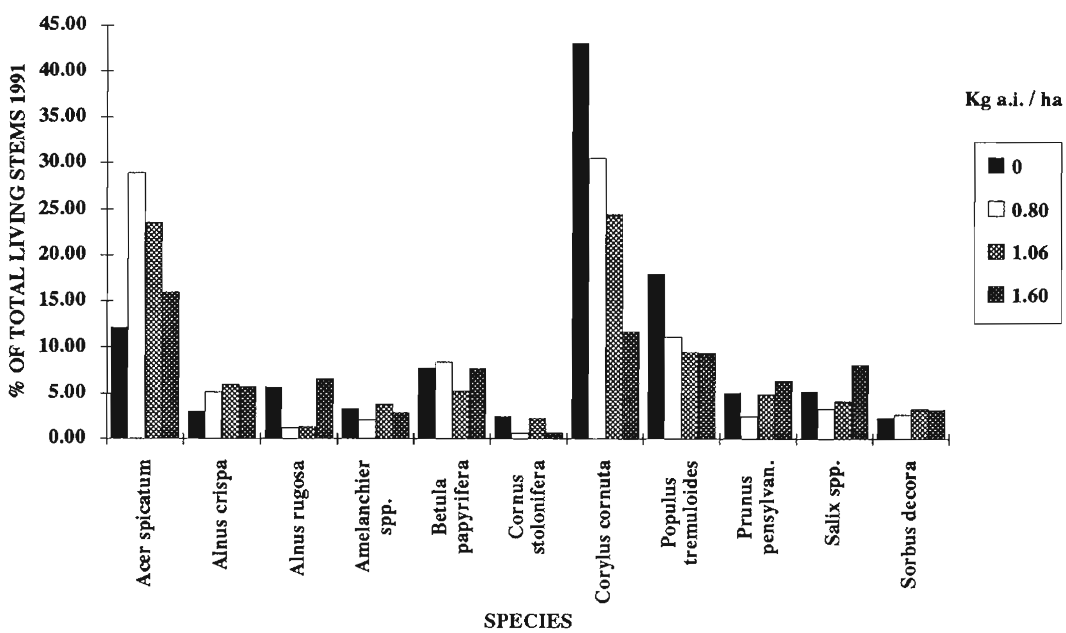

Fig. 2. Reduction in percentage of total living stems by species resulting from an aerial application of Vision® at 3 rates in fall, 1990.

application. Therefore, the habitat value for moose in treated areas is expected to increase again." In support of this statement, Newton *et al.* (1989) found that intensive forest management (including glyphosate use) to release crop trees improved browse availability 8 years after treatment. Lautenschlager (1990) using data from Newton *et al.* (1989) developed a model for browse availability after a release operation.

MANAGEMENT IMPLICATIONS

Application at a rate of 1.06 kg a.i. / ha of glyphosate when compared to the highest rate provided equivalent or superior control of herbaceous and hardwood competition. Ironically, the highest application rate combined with shielding effects of existing over-story vegetation and striping associated with aerial applications seems preferable to the higher rate, in terms of producing winter browse for moose. Until further studies document the growth response of crop trees the effectiveness of these treatments for conifer release remains unknown.

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