THE EFFICACY OF AERIAL HERBICIDE TRIALS

IN THE

MANITOBA MODEL FOREST AREA

Project # 94-3-08

Prepared By

SILVITECH Consulting
71 Millwood Meadow
Winnipeg MB
R2C 4W5

Executive Summary

The objective of this study is to determine the silvicultural and herbicidal efficacy of various aerial herbicide treatments based on an assessment of stocking, survival and growth of planted seedling stock and an assessment of vegetative competition levels within the study areas. These herbicide trials were initiated in 1979 by Abitibi-Price Inc., the Manitoba Department of Natural Resources and the Canadian Forest Service to evaluate the short-term herbicidal efficacy of three herbicides which were aerially applied at a variety of rates.

A review of information related to glyphosate, krenite and 2-4-D herbicides is presented along with background site descriptions including the original forest stand composition, site characteristics, harvesting methods and silvicultural treatments for each trial site. Only three of the six blocks treated in 1979 had sufficient skip areas which could act as control blocks for data comparison. Results of the silvicultural efficacy for total height, root collar diameter (rcd) and volume indicate that in all cases the average values for the white spruce and black spruce was greater on the treated sites than on the control sites ($p<0.01$). Differences in volume growth increases between treated and control blocks range from 61% to 679% for white spruce and 296% to 645% for black spruce. Average tree spacing did not vary between treated and control areas ($p= 0.87$).

The herbicidal efficacy on the dominant deciduous competition indicates that 88% to 95% of the crop trees within the treated blocks had attained a free-to-grow status while 67% to 93% of the crop trees in the control blocks were overtopped. Quantitative measurements of woody species control in the shrub layer indicate that generally the control or untreated sites are associated with fewer numbers of high density shrub species when compared to the treated sites which contain a greater number of shrub species at lower densities. Changes in percent cover for the herbaceous vegetation occurred in height class 2 (26 to 50 cm) and height class 3 (>50 cm). The general floristic composition of the herbaceous layer is very similar between control and treated blocks however there has been some change in abundance orders, the introduction of vetch spp. and an increase in grass spp. in the treated blocks.

The best overall results for glyphosate, in terms of silvicultural and herbicidal efficacy, appear to be met with application rates in the 2.8 L/ha to 5.8 L/ha range. Prescription of an application rate should be made after a review of the environmental conditions of the site in order to balance the benefits for volume increase, vegetation control and the provision of wildlife cover and browse. Higher rates should be considered if logging residuals are present after the harvest however a sites susceptibility to frost damage should also be a key consideration when prescribing a rate of application.

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The Efficacy of Aerial Herbicide Trials in the Manitoba Model Forest Area

1.0 Introduction

Forest vegetation management is carried out to reduce the survival and delay the growth of competing vegetation, thereby increasing the site resources (ie. light, water and nutrients) available to crop trees in order to ensure their survival and establishment. Effective use of herbicides for vegetation control requires that minimal amounts be applied at the proper time of the year to obtain maximum control of undesirable species without damaging the desirable tree species, wildlife browse or aesthetically desirable shrub species (Gratkowski 1975). Susceptibility of a plant species to a given herbicide is primarily influenced by mode of action of the herbicide, the rate of application, genetics of the target species, application time of year and local environmental conditions (Boyd et al. 1985).

Complete removal of a number of plant species from a vegetative community is not considered desirable for several reasons. Other species may invade the site and create serious competitive problems or may be more difficult to control than the original species (Vanden Born and Malik 1984). Sites without vegetation are also more subject to extremes in environmental conditions (MacKasey 1983).

The objective of this study is to determine the silvicultural and herbicidal efficacy of various aerial herbicide treatments based on an assessment of stocking, survival and growth of planted seedling stock and an assessment of vegetative competition levels within the study areas. These herbicide trials were initiated in 1979 by Abitibi-Price Inc., the Manitoba Department of Natural Resources and the Canadian Forest Service to evaluate the short-term herbicidal efficacy of three herbicides which were aerially applied at various rates.

2.0 Herbicide Review and Site History Descriptions

The following sections provide a review of information related to glyphosate, krenite and 2-4-D amine herbicides and some background site descriptions including the original forest stand composition, site characteristics, harvesting methods and silvicultural treatments for each trial site.

2.1 Glyphosate (Vision)

Glyphosate is a broad-spectrum, relatively non-selective, post-emergent herbicide that is effective on a wide range of annual and perennial plants (Sajdak 1982). In 1984 glyphosate was registered as a forest management herbicide in Canada. It was commonly referred to under the previous trade name Roundup which has recently been changed to Vision for forestry use. Glyphosate is a systemic herbicide which is absorbed through the foliage and other photosynthetically active portions of the plant and is translocated throughout the aerial and underground portions of the plant. This usually results in a failure of regrowth from underground propagation sites and subsequent deterioration of plant tissue (Sutton 1984).

Symptoms of glyphosate damage to vegetation are usually a gradual wilting and yellowing of foliage, which advances to complete browning. For most annuals this usually occurs within 2-4 days and for perennials after 7 to 10 days. Cold or cloudy weather at the time of treatment may slow the activity period (Sutton 1978). The long-term herbicidal effect of glyphosate on woody species does not reach a maximum until about 2 years after treatment (Vanden Born and Malik 1984).

Glyphosate is generally considered to be an excellent forestry herbicide. It is effective in controlling most woody species including trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*), beaked hazel (*Corylus cornuta*), mountain maple (*Acer spicatum*), pin cherry (*Prunus pensylvanica*), alder (*Alnus spp.*) and highbush cranberry (*Viburnum spp.*) (Balfour 1989, Butler & Fasteland 1987, Sutton 1978, Sutton 1984). It is poorly absorbed by conifers once buds have been set and new foliage has hardened off (Lund-Hoie 1980). Most research information indicates that glyphosate is safe and shortlived. Sprankle et al. (1975) studied the absorption of glyphosate on a clay loam and muck soil. Up to 56 kg/ha (25 times the recommended rate for conifer release) of the herbicide was rapidly inactivated. Complete and rapid degradation of glyphosate occurs in soil and water microbiologically and through chemical breakdown processes. Up to 90% of glyphosate was dissipated in two out of three soils in 12 weeks (Rueppel et al. 1977). Torstensson (1985) concludes that there is no reason to suppose that glyphosate may cause any unexpected damage to the soil or other environmental components after application. Henderson et al. (1988) indicated that no chemical residues could be detected ten months after application and no downward leaching occurred in a research trial located near Pine Falls, Manitoba. Glyphosate is considered non-toxic to mammals, birds, fish, insects and most bacteria (Franz 1978). This is also supported by Henderson et al. (1988) who noted that there appeared to be no indirect effects from glyphosate on songbirds, small mammals and ungulates.

Rate of application is a critical factor that influences herbicide efficacy for conifer release from vegetative competition. Conifers and competing vegetation are rate-sensitive to glyphosate (Alm 1981) and show varying degrees of response to glyphosate depending upon the rate of application and the specific vegetative species (Bell 1991). Rates of 3 to 6 L/ha (1.07 to 2.14 kg.ha respectively) are recommended for the control of trembling aspen (Monsanto 1987). Sutton (1984) found that 2.0 kg/ha of ground applied glyphosate resulted in 95% control of aspen three years after application and 1.0 kg/ha gave 50% control. However there is some evidence that low concentrations of glyphosate may result in a greater herbicidal effect than high concentrations because higher concentrations may kill plant tissue on contact before the herbicide can be translocated into other areas of the plant (Sutton 1978).

Timing is also an important factor for conifer release from hardwood competition. For most applications involving conifer release glyphosate should be applied late in the growing season, after bud-set on the conifers and before leaf fall by the competitive species (Sutton 1978, Sajdak 1982). According to Monsanto (1987) the time of glyphosate application is critical in crop damage terms because applications made during periods of rapid conifer growth may result in conifer tip and/or needle burn. Monsanto (1985) identified the final two weeks in August as being optimum for conifer release. Applied between August 8 and September 2, glyphosate provided more than 90%

reduction of aspen biomass at rates between 1.12 and 2.24 kg/ha however when applied on September 17, the same rates provided less than 50% reduction (Perala 1985).

The interaction between seasonal timing and application rates needed to optimize the performance of glyphosate is poorly documented (Perala 1985). Several other factors influence herbicide efficacy. Factors such as the formulation of the compound, climatic factors, spray drift and the physiological behaviour within the target plant are also important (Lund-Hoie 1980).

The first documented study on the use of glyphosate for vegetation control in coniferous plantations in the prairies was by Corns and Cole (1973). The efficacy and selectivity of glyphosate have been widely tested for forestry purposes in British Columbia and the eastern provinces of Canada over the last 14 years.

2.2 Fosamine Ammonium (Krenite)

Krenite, also known as fosamine ammonium, is a slow-acting systemic herbicide that is similar to glyphosate. Fosamine is highly water soluble and is rapidly adsorbed onto soil particles (WSSA 1983). It is applied during the 2 month period prior to autumn coloration and leaf fall. Fosamine ammonium is absorbed through the foliage, buds, and stems of woody vegetation with little or no effect until the following spring when susceptible deciduous plants fail to develop leaves and eventually die (Malik and Vanden Born 1986). Pines and herbaceous vegetation may show a response soon after application. Suppression of terminal bud growth is observed on moderately susceptible to resistant species. Field results have indicated that complete coverage of all plant parts of the woody species is necessary for effective control (WSSA 1983).
Very little to no leaching of fosamine was observed under actual field conditions or in soil column studies and the half-life of fosamine applied at recommended rates was about one week (Han 1979).

In Canada, fosamine ammonium was given temporary registration for forest management use in 1980 however this expired in 1982. It is currently not registered for forest management use in Canada and knowledge of it's efficacy and selectivity is very limited, especially in relation to the boreal forest region. In the United States, fosamine is registered for forest management use in site preparation and release and for maintenance of utility rights-of-way. When used for conifer plantation release in the southern U.S., fosamine has caused mortality, especially among southern pines. Fosamine has been increasingly used for site preparation in the Pacific northwest of the U.S. (Heinrichs 1982).

2.3 2,4-D Amine

2,4-D is produced in both the amine and ester formulations. Until 1984, 2,4-D ester was only one of two herbicides registered for forest management use in Canada. Currently the 2,4-D amine formulation is registered for forestry use with individual woody plant treatment through injection or stump application however it has not been registered for use in aerial or ground application methods.

2,4-D has varying effectiveness on species such as trembling aspen, birch, hazel, cherry and herbaceous broadleafed weeds. Trembling aspen is rated as susceptible to 2,4-D, but experience has shown that it is variable in response and often quite resistant (Anon. 1986). For example Basham (1982) found that after being sprayed with 1.4 kg/ha of 2,4-D, surviving aspen had reduced height and diameter growth, but within six years had resumed normal growth rates. Root suckering is also common after spraying 2,4-D and it may be necessary to spray more than once (Bell 1991). Steneker (1976) reports that 2,4-D applied to foliage from the air or ground during mid-July to mid-August will kill all above ground tree parts but will not prevent resuckering.

2,4-D is not effective on species such as maples, oaks, certain herbaceous broadleaves and grasses. Using a selective herbicide such as 2,4-D can create certain problems. For example brush can be replaced by raspberry or grass (Campbell 1981). However because of it's relatively low level of effectiveness, 2,4-D has possible value in improving wildlife habitat by encouraging sprouting of hardwoods within reach of browsing ungulates (Anon. 1981).

All plants exhibit seasonal changes in susceptibility to 2,4-D. Since 2,4-D tends to translocate with carbohydrates in the plant, sprays applied after leaf development in the late spring or early summer usually are more effective than sprays applied earlier or later (Miller 1978, Sajdak 1982). Sharma and Vanden Born (1970) reported that 2,4-D amine had maximum absorption in July. Susceptibility is usually low during dormancy in the late fall and winter, increases from time of bud-break throughout the active growing season, and decreases after shoot elongation has ceased (Gratkowski 1975).

2.4 Site History Descriptions

All of the trial sites are located along Sandy River Road within township 23 range 10 east and township 23 range 11 east in the Manitoba Model Forest area (Figure 1). These trials were initiated in 1979 to evaluate the short-term herbicidal efficacy of three different herbicides which were aerially applied at a variety of rates. No weather records or details about the spray equipment were documented at the time of the herbicide applications. The following provides some background information for each trial site:

Block 1 (Plantation 9-80)

This 14.7 ha site was selectively harvested during the summer of 1977 for white spruce (*Picea glauca*) using tree length cut and skid harvesting methods. The previous cover type was a mixedwood coniferous dominated stand of white spruce, trembling aspen and scattered balsam poplar. The site has a southern slope of less than 10%, a deep clay soil and a fresh moisture regime. Silvicultural site preparation records indicate that portions of this site received a 1978 scarification treatment with finned barrels. The site was aerially-sprayed with glyphosate or Roundup at the rate of 5.6 L/ha (0.5 gal./ac.) in August of 1979. On September 18, 1979 a follow-up visual survey indicated that the east end of the area showed excellent crown kill with moderate to good kill overall. Planting records indicate that the site was planted with black spruce 408 paperpot stock in August of 1980. In 1985, a small portion of this plantation located south of the Sandy River East Road received a touch up treatment with glyphosate however we could not determine the rate of application or specific locations from the silvicultural records.

A forest regeneration survey of the plantation conducted in 1991 indicates overall stocking levels of 59% black spruce (*Picea mariana*), 5% white spruce, 2% balsam poplar and 18% trembling aspen. The regeneration survey results also indicate overall stem densities of 1,977 for black spruce, 91 for white spruce, 23 for balsam poplar and 932 for trembling aspen. The white spruce on this site has originated from natural regeneration.

<u>Block 2 (Plantation 8-80)</u>

This 17.3 ha site was selectively harvested during the summer of 1976 for white spruce using tree length cut and skid harvesting methods to roadside. The previous cover type was a mixedwood coniferous dominated stand of white spruce, trembling aspen and scattered balsam fir (*Abies balsamea*), larch (*Larix laricina*), balsam poplar and white birch. The site has southern facing aspect with a variable slope of less than 10%, a deep clay soil and a fresh moisture regime. Silvicultural site preparation records indicate that portions of this site received a 1977 scarification treatment with finned barrels. Planting records indicate that the site was first planted with white spruce 313 paperpot stock in May of 1978 at a planting density of around 1,700 stems/ha. In 1978, selective areas of the plantation received a manual ground application of glyphosate at the rate of 1 oz./1 gal. of water with a backpack. The site was then aerially-sprayed with glyphosate or Roundup at the rate of 8.4 L/ha (0.75 gal./ac.) in August of 1979. Results from a September 18, 1994 follow-up survey indicated that this area received the best percentage of crown kill on the standing poplar which was accompanied by a good kill on the forest floor. In July 1980, unstocked portions of the northeast corner of this plantation received a refill of black spruce 408 paperpot stock.

A regeneration survey conducted in 1991 indicates overall stocking levels of 73% white spruce, 2% black spruce, 4% other conifer, 12% trembling aspen, 2% balsam poplar, and 2% white birch. The regeneration survey results also indicate overall stem densities of 1,449 for white spruce, 20 for black spruce, 102 for balsam poplar, 41 for white birch and 224 for trembling aspen.

<u>Block 3 (Plantation 7-80)</u>

This 48 ha site was selectively harvested during 1976 for white spruce using tree length cut and skid harvesting methods to roadside. The previous cover type was a mixedwood coniferous dominated stand of white spruce, trembling aspen and scattered balsam fir, balsam poplar and white birch. The site has an undulating topography, soils ranging from deep clay to gravel and boulder till and a variable moisture regime from fresh to moist. Silvicultural site preparation records indicate that 5 ha of the southern portion of this plantation received a 1977 scarification treatment with finned barrels. In 1978 portions of the plantation were disc trenched using a TTS (passive) disc trencher. Planting history indicates three different planting treatments. In 1978, 5 ha of the southern end of the plantation along Sandy River East Road was planted with white spruce plug stock at 1,000 stems/ha. In May 1979, a gross area of 48 ha was planted with white spruce 3+0 bareroot stock at 1,600 stems/ha. The site was then aerially sprayed with glyphosate at the rate of 2.8 L/ha (0.25 gal./ac.) in August of 1979. On September 18, 1979 a follow-up visual survey indicated that there was a good kill of all broadleaf vegetation and in the crowns of standing poplar but that many of the weed species seemed unaffected.

A regeneration survey in 1980 indicated overall conifer stocking of 29%. In July 1980, 21 ha of the plantation was replanted with black spruce 408 paperpot stock. In 1985 portions of the plantation received a touch-up with an aerial application of glyphosate. A regeneration survey conducted in 1991 indicates overall stocking levels of 63% black spruce, 5% white spruce, 17% balsam fir, 5% larch, 25% trembling aspen, 6% balsam polar, and 3% white birch. The regeneration survey results also indicate overall stem densities of 1,540 for black spruce, 48 for white spruce, 381 for balsam poplar, 95 for white birch, 111 for balsam poplar and 635 for trembling aspen.

<u>Block 4 (Plantation 6-78 & 8-78)</u>

This 7.2 ha site was clearcut during the summer of 1976 for white spruce using tree length cut and skid harvesting methods to roadside. The previous cover type was a coniferous stand of white spruce with minor amounts of trembling aspen and balsam fir. The site is flat, soils range from clay loam to sandy loam with a variable moisture regime from fresh to wet. Silvicultural site preparation records indicate that only the west end of this plantation received a 1977 scarification treatment with finned barrels. There was no site preparation in the east end of this plantation. In May 1978, the area was planted with white spruce 315 tubeling stock at 1,020 stems/ha in the western portion of the plantation and 1,000 stems/ha in the eastern portion of the plantation. In August 1978, a manual ground application of glyphosate at the rate of 1 oz./gal. of water was administered by a back-pack for spot application to reduce vegetative competition. The site was then

aerially-sprayed with krenite at the rate of 8.4 L/ha (0.75 gal./ac.) in August of 1979. On September 18, 1979 a follow-up visual survey indicated that this area showed little discoloration change. A regeneration survey in 1980 indicated that the western portion of this plantation had less than 20% softwood stocking and that the eastern portion had a clumpy distribution of balsam fir with white spruce planting stock randomly planted throughout resulting in many unplanted areas. Herbicide results from the 1980 survey for the east half of this plantation indicated that poplar kill on the mature trembling aspen was confined to the upper canopy. However 85% to 90% of the shrubs, willows and poplar suckers appear to be killed where the areas were open. No recent regeneration survey results for this area is available.

Block 8 (NSR Release)

This 12 ha site was selectively cut in 1970 using conventional cut & skid methods to select for the larger diameter white spruce in the stand. The previous cover type was a mixedwood coniferous dominated stand of white spruce, trembling aspen and balsam fir. The site is level with a clay loam soil that is moderate in depth and has a fresh moisture regime. After harvest, trembling aspen dominated the overstory stand composition with an understory of white spruce and balsam fir. The site received an aerial herbicide treatment of glyphosate at 2.8 L/ha. This release treatment was prescribed in order to kill the trembling aspen overstory component of the stand. On September 18, 1979 a follow-up visual survey indicated that there was evidence of good kill in most of the crowns of standing trembling aspen and in most of the broadleaf vegetation.

Block 12

This 10 ha site was a selective harvest for white spruce in 1976 using conventional cut & skid methods. The previous cover type was a mixedwood deciduous dominated stand of trembling aspen and white spruce. The site is level with a clay soil that is moderate in depth and has a fresh moisture regime. The site was aerially-sprayed with 2,4-D amine at the rate of 8.4 L/ha in August of 1979. Government records indicate that the area received a scarification treatment but was not planted.

3.0 Methodology

The objective of this study is to determine the silvicultural and herbicidal efficacy of various aerial herbicide treatments based on an assessment of stocking, survival and growth of planted seedling stock and an assessment of vegetative competition levels within the study areas. There were several constraints on how we measure and interpret efficacy of the herbiciding treatments for this study. These include:

i) The fact that this herbiciding trial was not set up as a controlled experimental design in 1979. There are some site differences between and within study blocks which include differences in moisture regime, soil types, and elevation which in turn will have some effect on growth and survival of the planted stock.

ii) The amount and distribution of the residual deciduous species retained on each block after the selective harvests varied considerably. Standing residuals will effect herbicide dispersal and interception during application.

iii) There was no documentation for the herbiciding treatments during the spray and a lack of site specific documentation for all the silvicultural treatments which varied greatly between these study blocks.

iv) Only three of the six blocks had skip areas of sufficient size to act as possible control blocks and two of the blocks had never received a planting treatment.

However we can assess the general herbicidal and silvicultural efficacy of the herbiciding treatments and relate any results to the original stand and site conditions, field observations, and data measurements where possible. The methods used to evaluate herbicide effectiveness concentrate on: i) compiling past information on original stand descriptions, site characteristics, harvesting methods and silvicultural records, ii) assessing growth, stocking and survival where possible, iii) assessing vegetation competition control, and iv) use of field observations to relate the historical information to the data collected in steps i, ii and iii.

Crop growth was evaluated by randomly selecting a minimum of 30 representative sample trees dispersed throughout each of the herbicided and non-herbicided (or skip) areas of the plantation if possible. The non-herbicided or skip areas were considered control plots and chosen so that they were similar to surrounding sprayed areas and were not skipped because of site factors such as terrain or residual stems for example. If no representative skip areas were found within the block than the assessment was restricted to the herbicided areas only. Measurements taken include total height (nearest cm), dbh (for future reference) and rcd (diameter at 10 cm from groundline to nearest mm). Representative sample trees include those trees which are not effected by non-competitive factors (eg. ungulate browsing). Stem volumes for individual trees was based on the formula of a right cone:

Stem Volume (cm^3)= 1/3 x pi x rcd^2 x ht

where:rcd = root collar diameter (cm)
ht = total stem height (cm)

Crop survival and stocking estimates were interpreted from average inter-tree spacing values by measuring the total linear distance to sample the 30 trees in each plot. In addition results of the 1991 forest regeneration surveys were recorded along with planting records and general site observations. Competition status for each crop tree in the herbicided and control plots was evaluated as either overtopped, threatened or free-to-grow. The average height, dbh and rcd was taken for the dominant competitive deciduous species. Quantitative measurements of competition for the herbicided and control plots were made through stem counts for the woody vegetation and through ocular estimates of percent cover for the herbaceous vegetation using millihectare plots distributed through the sample areas. The percent cover estimates were measured in three height layers representing low, medium and high herbaceous layers. The top five herbaceous species were also recorded in descending order of occurrence. An example of the forms used for the field data collection are presented in appendix 1.

4.0 Results

Fifteen year post-spray results of the 1979 herbicide trials are presented in two sections: i) silvicultural efficacy and ii) herbicidal efficacy. According to Sutton (1985) silvicultural efficacy is defined as the capacity of a herbicide to promote indirectly positive growth responses in crop tree while herbicidal efficacy is defined as the capacity of a herbicide to cause direct phytotoxic effects in non-crop vegetation.

4.1 Silvicultural Efficacy

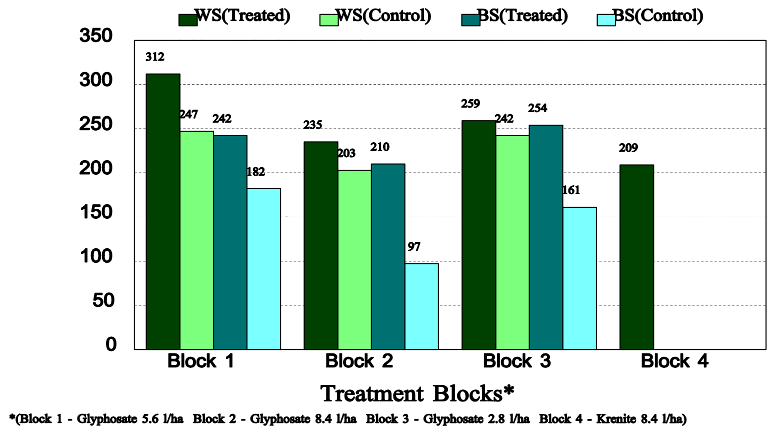
The field sampling results are presented in table 1. This table shows that only three of the six blocks treated in 1979 had sufficient skip areas which could act as control blocks for data comparison. No skip areas could be located within block 4 therefore we have no control data for comparison purpose. The remaining two blocks were selectively harvested for their softwood component but did not receive a planting treatment. No data was collected for these sites however some general field observations were recorded and will be discussed later in this report.

Table 1. Sampling size results of 1979 herbicide trials in Manitoba Model Forest area.

Block #	**Plantation #**	**Herbicide**	**Application Rate**	**No. of Lines Sampled**		**No. of Trees Sampled**	
				Treated	**Control**	**Treated**	**Control**
1	9-80	Glyphosate	5.6 L/ha	2	1	60	30
2	8-80	Glyphosate	8.4 L/ha	3	1	90	30
3	7-80	Glyphosate	2.8 L/ha	5	5	150	146
4	6-78 & 8-78	Krenite	8.4 L/ha	2	0	60	0
8	NSR Release	Glyphosate	2.8 L/ha	0	0	0	0
12	NSR Release	2,4-D amine	8.4 L/ha	0	0	0	0

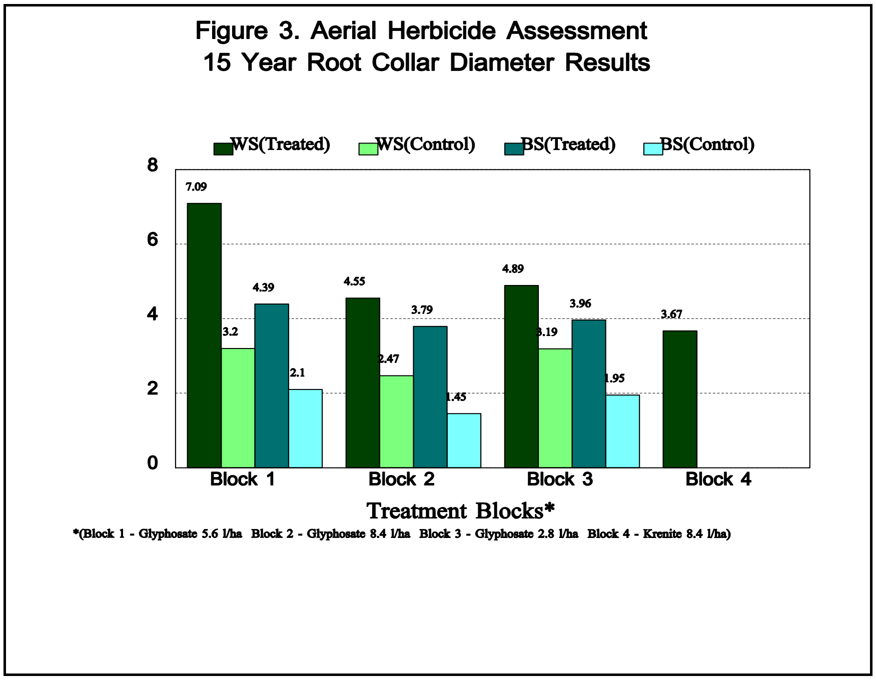
Results of the silvicultural efficacy of the herbicide treatments for white spruce and black spruce average total height can be seen in figure 2. These results indicate that

Figure 2. Aerial Herbicide Assessment 15 Year Height Results



in all cases the average total height of the white spruce and black spruce was greater on the treated sites than on the control sites. A comparison of height increases between white spruce and black spruce indicates that black spruce has the greatest increase for all blocks at 33% for block 1, 116% for block 2 and 58% for block 3. The increase for white spruce height was 26% for block 1, 16% for block 2 and 7% for block 3. The greatest average total height for white spruce and black spruce was 312 cm on block 1 and 254 cm on block 3 respectively.

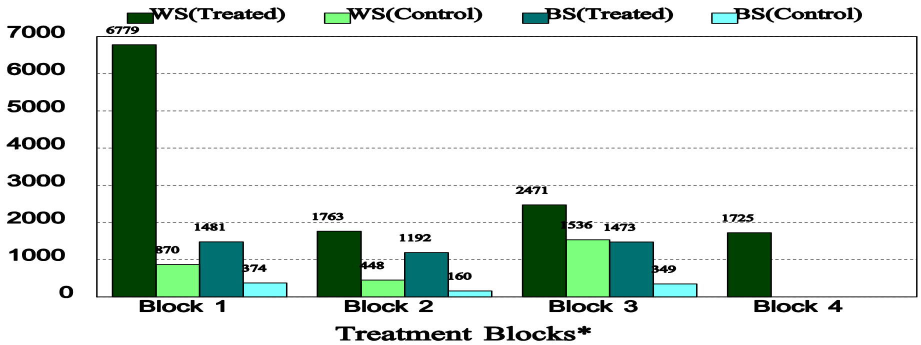
Results of the herbicide treatments on the average root collar diameter (rcd) can be seen in figure 3. The same trends observed with average total height are seen with average rcd. In all cases the average rcd for the white spruce and black spruce is



greater on the treated sites than on the control sites. Block 1 had the largest average rcd for both white spruce and black spruce at 7.09 cm and 4.39 cm respectively. Block 1 also had the largest increase in rcd for white spruce at 122% while block 2 had the largest increase in rcd for black spruce at 161%.

Results of the herbicide treatments for volume (cm^3) can be seen in figure 4. These results are also consistent with the trends seen with average total height and rcd. For all blocks the average volume was greater on the treated sites than on the control sites. The greatest increase in volume for white spruce was seen in block 1 at 679% and for black spruce in block 2 at 645%.

Figure 4. Aerial Herbicide Assessment
15 Year Volume Results



Block 1 - Glyphosate 5.6 l/ha Block 2 - Glyphosate 8.4 l/ha Block 3 - Glyphosate 2.8 l/ha Block 4 - Krenite 8.4 l/ha)

Table 2 summarizes the increases in average total height, rcd and volume for white spruce and black spruce between treated and control sites for all treatments blocks.

Table 2. Percent increases in Height, RCD and Volume for Treated versus Control

Treatment Block	**Tree Species**	**Average Growth Increase**		
		Height (%)	**RCD (%)**	**Volume (%)**
1	White Spruce	26	122	679
2	White Spruce	16	84	294
3	White Spruce	7	53	61
1	Black Spruce	33	109	296
2	Black Spruce	116	161	645
3	Black Spruce	58	103	322

Table 3 presents the average inter-tree spacing for the sample sites within each treatment block. Results show that there is not much variation in inter-tree spacing both among and between treatment blocks.

Table 3. Inter-Tree Spacing within each Treatment Block

Block No.	Treatment	Distance (m)
1	Control	0.87
1	Treated	0.92
2	Control	1.12
2	Treated	1.04
3	Control	1.33
3	Treated	1.27

Statistical analysis of the data sets were performed however there were some restrictions on what tests could be used because this herbicide trial was not set up as a controlled experimental design. The problem of deciding which statistical test to use for within-site analysis was confounded because of a lack of sample replication. Paired plot analysis could not be used because paired samples were not collected since there were not enough unsprayed areas in the plantations. With few control plots at each site simple t-tests were not feasible. A general ANOVA was not appropriate because of missing cells. In addition Block 4 could not be included in the analysis because no skip areas were encountered.

However it was decided to run a hybrid paired t-test for the within-site analysis where the ratio for each measurement (ie. height, rcd, volume) was calculated for the average treated plot over the average control plot for each block. These ratios were transformed to their square root to help stabilize the variance and the variance was pooled across all blocks. T-tests were then conducted to determine whether each ratio was significantly higher than 100%. The results indicate that in most cases the differences between total height, rcd and volume were highly significant, with the exception of white spruce height in blocks 1 and 2, and black spruce volume in block 1. The statistical tables generated from this analysis are presented in Appendix 2.

Summary statistics for all blocks were generated by comparing average height, rcd and volume values across all blocks between treated and control trees. It was found that the treated trees had significantly greater height, rcd and volume ($p<0.01$). Average tree spacing did not vary between treated and control areas ($p= 0.87$ - see table 3).

4.2 Herbicidal Efficacy

The degree of competition control attained by the herbiciding treatments on the dominant deciduous competition was evaluated by documenting the free-to-grow status of each crop tree in the herbicided and control plots and by recording an average height and dbh for the competition. These results are presented in table 4.

Table 4. Competition Status of Dominant Deciduous Species for each Block/Site

Block and Treatment	**Average Dominant Competition**			**Free to Grow Status**		
	Spp.	**Hgt (m)**	**Dbh (cm)**	**Overtopped (%)**	**Threatened (%)**	**Free-to-Grow (%)**
Blk 1/Treated	-	-	-	-	5	95
Blk 1/Control	Ta	11.7	10.0	93	7	-
Blk 2/Treated	-	-	-	7	4	89
Blk 2/Control	Ta	5.0	8.0	67	30	3
Blk 3/Treated	-	-	-	3	9	88
Blk 3/Control	Ta	8.0	6.5	85	12	3
Blk 4/ Treated	Ta	6.5	4.0	23	8	69

Quantitative measurements of woody species competition control in the shrub layer for the herbicided and control plots were made through stem counts for the woody vegetation. These results are presented in table 5 and show that the most common species on all sites were beaked hazel (*Corylus cornuta*), choke cherry (*Prunus virginiana*), prickly wild rose (*Rosa acicularis*), raspberry (*Rubus strigosus*) and Saskatoon (*Amelanchier alnifolia*).

Table 5. Shrub Species and Stem Densities/ha for Treated and Control Blocks.

Shrub Species	Block 1		Block 2		Block 3	
	Treated	Control	Treated	Control	Treated	Control
Balsam Poplar					417	333
Beaked Hazel	333	13,000	1,000	20,000+	250	18,583
Buckthorn					667	
Choke Cherry	5,333	500	1,429	2,000	3,250	833
Cranberry				1,500	417	1,167
Dogwood			1,857		1,500	6,250
Downy Arrow-wood	670	500	715		750	1,750
Gooseberry	3,000				667	834
Hawthorn			857			
Honeysuckle	670					
Pin Cherry						334
Prickly Wild Rose	1,667	10,500	4,286		1,833	6,833
Raspberry	3,000		2,429		5,083	833
Saskatoon	3,333	500	1,714	2,500	2,917	2,083
Snowberry			857			
Trembling Aspen						4,500
Willow	667				1,583	

The general trend after fifteen years seems to indicate that control or untreated sites are associated with fewer numbers of high density shrub species when compared to the treated sites which contain a greater number of shrub species at lower densities. The greatest degree of herbicidal control exhibited was seen with beaked hazel where control densities ranged from 13,000 to 20,000 stems/ha and treatment densities after fifteen years ranged from 250 to 1,000 stems/ha. The herbicide treatments also introduced or increased the presence of some species which were either not located in the control blocks or were present in low numbers. The stem densities of raspberry increased in the treated blocks. Raspberry seeds remain dormant in excess of 50 to 100 years (Whitney, 1982) and it is considered a seed bank species (Rowe, 1983). This increase is similar to that of other studies where raspberry has increased in abundance after glyphosate application (Kennedy and Jordan 1985, Balfour 1989). Another species which displayed a general increase after treatment was choke cherry which is considered to be shade-intolerant and primarily reproduces through seed (Vilkitis 1974).

Quantitative measurements of herbaceous competition control were made through ocular estimates of percent cover for the herbaceous vegetation using millihectare plots distributed through the sample areas. The percent cover estimates were measured in three height layers representing low, medium and high herbaceous layers. Results from table 6 indicate the changes in percent cover estimates for the herbaceous layers.

Table 6. Herbaceous Cover estimates (%) by Height Class

Height Class	Block 1		Block 2		Block 3	
	Treated	Control	Treated	Control	Treated	Control
1. <25cm	6	13	10	5	25	15
2. 26-50cm	38	35	80	20	40	30
3. >50cm	6	35	15	30	20	15

The greatest change occurred in height class 2 (26 to 50 cm) for block 2 where the herbaceous cover estimate increased by 60% for the treated area. The other change was in height class 3 (>50 cm) for blocks 1 and 2 where the average cover is much lower in the treated areas than in the control areas. It appears that there were minimal differences in percent cover for all height layers in block 3.

The top five herbaceous species were recorded in descending order of abundance. Results from table 7 indicate that after fifteen years the general floristic composition of the herbaceous layer is very similar between control and treated blocks however there has been some change in abundance orders. For the treated blocks the general abundance of grass spp. has increased and vetch spp. have been introduced as a new competitor.

Table 7. Top five herbaceous species listed in descending order of abundance.

Spp. Rank	**Block 1**		**Block 2**		**Block 3**	
	Treated	**Control**	**Treated**	**Control**	**Treated**	**Control**
1	Strawberry	Strawberry	Grass sp.	B.Sarsparilla	Strawberry	Strawberry
2	Fireweed	Mead. Rue	Strawberry	Lily sp.	Aster sp.	B.Sarsparilla
3	Grass sp.	Horsetail	Fireweed	Strawberry	Fireweed	Fireweed
4	Vetch sp.	Grass sp.	Vetch sp.	Grass sp.	Vetch sp.	Lily sp.

5	F.S. Seal	Aster sp.		Fireweed	Yarrow	Aster sp.

5.0 Discussion

It is difficult to make direct comparisons between the various herbicide application rates based on the field data because of the varied results from the herbicide treatment within each block. This is supported by the fact that skip or untreated areas were found in some of the blocks. Changes to the micro-environment of the site because of a herbicide treatment is dependant upon several factors other than the rate of application. This is especially obvious after reviewing the site history descriptions which indicated that after selective harvesting, the blocks contained mature deciduous residuals which varied in density and patch size throughout each block. These residuals played a role in aerial coverage of the herbicide during application because of canopy interception of the herbicide.

However we can discuss the general silvicultural and herbicidal efficacy of the herbiciding treatments based on average values between treated and control trees across all sites. Comparisons of the results from various herbicides and their application rates will be based on descriptions of the original stand and site conditions in relation to field observations. Please refer to the photographic series in appendix 3 for further detail throughout this discussion.

The results of the silvicultural efficacy of the herbiciding treatments indicate that in all cases, plot averages for height, diameter and volume for the treated trees were significantly greater than the untreated ($p<0.01$). Height was affected but not as much as diameter and when the two are combined, the differences in volume increase ranged from 61% to 679%. There was no evidence of an effect on survival between treated and control areas from the data.

The results of the herbicidal efficacy of the treatments shows that the dominant deciduous competition was reduced considerably as indicated by the free-to-grow status of the crop trees in the treated blocks which ranged from 88% to 95%. Measurements of woody species competition control in the shrub layer resulted in a higher number of shrub species at lower stem densities in the treated plots when compared to the control plots which were made up of fewer shrub species at much higher stem densities. The floristic composition of the herbaceous layers in the treated and control plots was relatively unchanged except for the order of abundance for individual species. Herbaceous cover generally increased for height class 2 (26 to 50 cm) and decreased for height class 3 (>50 cm) in the treated areas.

General field notes and observations of the blocks indicate that the largest amount of frost damage for all blocks was associated with block 2 which received the highest concentration of glyphosate at 8.4 L/ha. Ironically block 2 also showed the greatest volume gains for black spruce for all blocks at 645%. This is typical for black spruce which is a shade-intolerant species and grows best in full sunlight. This also demonstrates the extreme variation from the herbicide treatment due to the patchiness of the deciduous residuals left after the original selective harvest. There is no way to determine the actual concentration of the herbicide coverage for those trees which showed substantial volume increases (refer to photographs for block 2 in appendix 3).

Block 3, treated with glyphosate at 2.4 L/ha, generally showed the lowest increase in volumes for the crop trees. This block was associated with a large amount of wildlife browsing activity and contained the most diverse shrub layer of all treatments. Block 1 which was treated with glyphosate at 5.6 L/ha showed the best increase for white spruce rcd and volume growth when comparing treated and control plots. Treated trees in block 4, which was sprayed with Krenite at 8.4 L/ha, showed volume averages consistent with treated trees in block 2 (glyphosate 8.4 L/ha). However block 4 contained no control areas for silvicultural and herbicidal efficacy comparison.

Block 8 was a selective cut which was treated with glyphosate at 2.4 L/ha to kill the mature aspen in order to release and increase the growth of the understory conifer in the stand. Field observations and a review of the growth rings from some cross-sections of the conifer trees indicates that it was more likely that growth increases can be attributed to the selective harvest which occurred 9 years prior to the herbicide treatment. It is apparent however that the herbicide treatment was successful in terms of reducing the amount of trembling aspen within the stand.

We could not determine the exact location for block 12 which was treated with 2,4-D at 8.4 L/ha. A thorough walk through the general area, indicated by map and photo, failed to show any differences which would lead us to believe that this area had received a treatment. This area had not received any silvicultural treatments and minimal signs of previous harvesting activities could be found.

The best overall results for glyphosate, in terms of silvicultural and herbicidal efficacy, appear to be met with application rates in the 2.8 L/ha to 5.8 L/ha range. Prescription of an application rate should be made after a review of the environmental conditions of the site in order to balance the benefits for volume increase, vegetation control and the provision of wildlife cover and browse. Higher rates should be considered if logging residuals are present after the harvest however a sites susceptibility to frost damage should also be considered when making the herbicide prescription.

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