VEGETATION MANAGEMENT BY CHEMICAL AND MECHANICAL METHODS IN ASPEN (*Populus tremuloides*) -DOMINATED CLEARCUTS:

Vegetation response six years after treatment

1995

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ABSTRACT

The primary objectives of this study were to assess differences in vegetation composition, plant community structure, biodiversity, and conifer crop seedling growth as a result of different site preparation and conifer release treatments. The site preparation experiments (n = 900 plots) involved the use of 2 kg/ha and 4 kg/ha of hexazinone, Rome double disking, and disk trenching. Disk trenching followed by either the application of 2 kg/ha or 4 kg/ha of hexazinone, or by brushsawing, and Rome double disking were the treatments applied in the conifer release experiments (n = 600 plots). This analysis included pre-treatment data collected in 1986 and post-treatment data collected in 1988 and 1992-1994. Significant ($P < 0.05$) differences in the vegetation were found after several years of growth among the treatment plots and relative to the control plots. These differences consisted of reduced total plant cover, differences in species abundance, and fewer woody stems per hectare. All treatments had an effect on the native vegetation, but Rome double disking had the most substantial impact (e.g., >60 percent reduction in woody stems) of the site preparation treatments, while disk trenching followed by 4 kg/ha hexazinone and Rome double disking tended to be the most effective treatments for conifer release. The hexazinone treatments tended to have a greater number of species and higher levels of diversity than the controls or other treatments. Based on a combination of seedling height, vigor, and survival rate, lodgepole pine (*Pinus contorta*) growth was significantly ($P < 0.05$) better in the Rome double disking plots of both experiments. The best white spruce (*Picea glauca*) growth was promoted by the use of 4 kg/ha and 2 kg/ha of hexazinone in the site preparation and conifer release experiments, respectively. These treatments also greatly improved lodgepole pine stocking levels relative to the untreated vegetation. Various competition variables and indices were examined to identify parameters that were correlated with crop seedling height growth.

Key words: Site preparation, conifer release, vegetation management, hexazinone, Rome disk, disk trench, brushsawing, white spruce, lodgepole pine

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1.0 INTRODUCTION

Prior to the mid-1980's forestry activities in Alberta were primarily oriented towards the production of lumber and wood pulp for paper from white spruce (*Picea glauca* (Moench) Voss), Engelmann spruce (*Picea engelmannii* Parry *ex* Engelm.), lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.), and black spruce (*Picea mariana* (Mill.) BSP.).[1] These are common trees in the mountain and foothill zones along the west side of the province. White spruce is the primary commercial species in the mixedwood portion of the boreal forest. To facilitate the long-term sustainability of these softwood forests, loggers are required to meet minimum conifer stocking standards within a few years after cutting (Anonymous 1993). Restocking is usually accomplished by either hand planting with nursery stock or by minimizing the cutblock size which encourages natural regeneration. In addition, a variety of mechanical techniques have been employed for site preparation and planting to improve conifer seedling establishment and growth (Corns and Annas 1986, p. 213-215).

During the past ten years, however, most of the unallocated and unprotected deciduous forests in Alberta were leased to companies for aspen (*Populus tremuloides* Michx.) harvesting. Historically, these deciduous and mixedwood forests had been of little commercial value, except for their conifer component. Assuming a rotation age of 60 to 80 years (Bella and Yang 1991) and a productive land-base of 186,000 km^2 (Anonymous 1992a), annual cuts of deciduous and mixedwood forests could reach 2,300 to 3,100 km^2. The most common method of harvesting will probably be clearcutting of aspen dominated area. Many of these clearcuts will be planted to white spruce or lodgepole pine to ensure a future supply of softwood. The primary problem of establishing mixedwood stands is not a lack of adequate stocking but excessively high stem numbers of aspen and other woody species (e.g., 50,000 to 70,000 stems/ha), since aspen regenerates readily from root suckers on most sites. Because of these high stem densities, coniferous seedlings are often subjected to severe competition from faster growing trees and shrubs, and occasionally from taller native forbs and graminoid species during the early stages of seedling growth and stand establishment.

Clearcutting of aspen-dominated mixedwood forest stands can result in stocking problems, such as aspen densities which are too high and inadequate stocking of conifers. Forest companies are required to correct the stocking deficiencies. As a result, foresters may need to use mechanical and chemical forest management methods for site preparation and conifer release to control competing vegetation. Use of chemical methods in forestry has not been accepted by the public because of the large areas of forest that will be cut and the unknown long-terms effects of chemical herbicides and mechanical methods on native vegetation and wildlife.

To respond to the environmental concerns related to the use of chemical herbicides and mechanical methods to manage forest vegetation, a research and monitoring project was undertaken in 1985 by the Canadian Forest Service and Alberta Forest Service (Todd and Brace 1987; Sidhu and Feng 1991). This experimental study was designed to determine the impact of

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[1] Vascular plant nomenclature follows Moss (1983).

chemical and mechanical forest management methods on vegetation as well as the fate of herbicides and their residues in vegetation, soil, and small mammals. The initial environmental effects of these treatments have been measured and published (Feng et al. 1989a, 1989b; Penner 1990; Sidhu and Feng 1991, 1993; Sidhu et al. 1994; Sidhu 1994). The present study represents continued monitoring of these impacts, and analysis of vegetation composition and structure including biodiversity, seedling growth and associated competition indices. This report includes the results of field measurements in 1992 through 1994, and comparison of the results to the pre-treatment baseline established in 1986 and post-treatment data from 1988.

2.0 STUDY AREA

The two sites selected for study were located approximately 23 km (Cutblock 4007) and 30 km (Cutblock 4004) south of Grande Prairie in west-central Alberta, Canada (Figure 1). The specific study sites were located within clearcuts approximately 130 ha and 85 ha in size (Twardy and Dowgray 1985) that were logged in July and March of 1983, respectively. The general study area occurs within the Boreal South Cordilleran (SCb) Ecoclimatic region (Zoltai and Strong 1989) or the Lower Boreal-Cordilleran Ecoregion (Strong 1992) which is a climatic and biological transition zone between coniferous Cordilleran and deciduous Boreal forest biomes. Seral forests dominated by aspen with balsam poplar (*Populus balsamifera* L.), paper birch (*Betula papyrifera* Marsh.), white spruce, and lodgepole pine commonly occur on moderately well drained sites in this climatic zone.

Monthly temperatures and precipitation values that typify the study area probably are between meteorological values measured at the Grande Prairie Airport (Station 3072920) approximately 30 km north of the study area -- a Low Boreal Mixedwood Ecoregion site -- and Bald Mountain Lookout (Station 3070480) -- a Low Boreal-Cordilleran Ecoregion site -- which is located approximately 10 km south of the study area. This data suggests a 0.7° to 2.4°C and a 6 to 16 mm difference in monthly temperature and precipitation values between the two stations (Table 1). Monthly temperatures and precipitation values within the study area are probably 1°C lower and 10 mm greater, respectively, than those experienced at Grande Prairie. As a result, the study area may have a greater availability of moisture than at Grande Prairie due to decreased evapotranspiration rates and greater precipitation.

Both cutblocks occur within the Southern Alberta Uplands physiographic region (Pettapiece 1986) or ecodistrict (Strong 1992). This physiographic area consists of relatively flat-lying sedimentary bedrock that is higher in elevation than the adjacent Western Alberta Plain which occurs to the north and east, but lower than the more westerly Rocky Mountains or Foothills zones. Slopes in the two study areas were typically between three and five percent, but ranged up to nine percent. The surficial deposits were dominated by lacustro-tills. Gleyed Solonetzic Gray (Donnelly Series) and less amounts of Gleyed Dark Gray Luvisolic soils (Esher Series) were the typical soils (Twardy and Dowgray 1985). Surface horizons were silty clay to clay loam in texture, with clay in the subsurface horizons. Both sites were moderately well to imperfectly drained. Cutblock 4004 seemed to be somewhat wetter than 4007.

Aspen dominated the overstory canopy of both study sites prior to harvesting, although Cutblock 4007 was denser than 4004 and had a 20 percent cover of lodgepole pine. Overall canopy cover in Cutblock 4007 occurred within the 71 to 100 percent closure class with a height of 19 to 25 m. Canopy closure was up to 50 percent in Cutblock 4004. Forest stands at both sites originated about 1918.

Before harvesting, the cutblock vegetation most likely belonged to the aspen facies of the White Spruce/Mooseberry/Wild Sarsaparilla (LB5c) ecosystem described by Corns and Annas (1986), or its equivalent the Aspen-White Spruce-Lodgepole Pine/Low-bush Cranberry (11-D3.4) community-type described by Beckingham (1994). The understory vegetation was probably dominated by a mixture of *Viburnum edule* (mooseberry), *Rosa acicularis* (wild rose), *Linnaea*

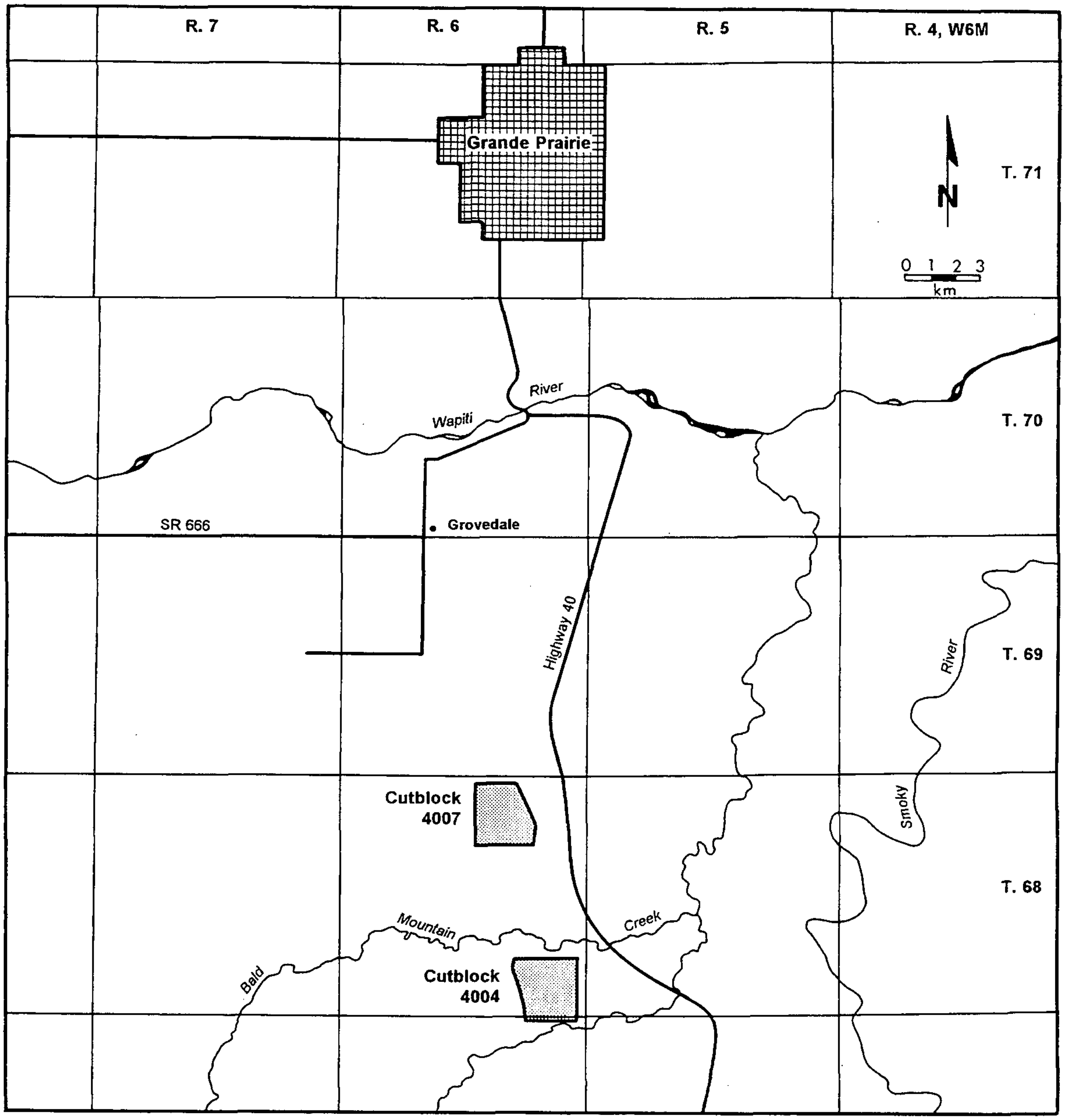


Figure 1. Location of Cutblocks 4004 and 4007 relative to Grande Prairie, Alberta.

borealis (twinflower), *Aralia nudicaulis* (wild sarsaparilla), *Calamagrostis canadensis* (northern reedgrass), and *Cornus canadensis* (bunchberry) with a small percent cover (average 10 percent) of forest bryophytes.

Table 1. Summary of monthly temperatures and precipitation based on 15 years of data from January 1979 to December 1993, inclusive (Anonymous 1980-1994).

Station	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
					Median Temperature (°C)							
Grande Prairie	-12.0	-10.3	-3.6	4.3	10.7	14.0	15.9	15.2	10.6	4.7	-4.9	-11.0
Bald Mountain	-	-	-	-	9.7	12.4	14.8	14.6	-	-	-	-
					Total Precipitation (mm)							
Grande Prairie	24	15	12	16	41	74	63	48	35	22	17	20
Bald Mountain	-	-	-	-	56	86	69	64	-	-	-	-

3.0 METHODS

This research project considers two components of vegetation management: Site Preparation and Conifer Release. In addition to the purposes and objectives of each study being different, they were also geographically separated and appeared to have somewhat different soil moisture regimes, and therefore are not directly comparable. A similar approach was used to design both studies and similar methods were employed for field sampling. The following sections summarize the experimental design, field sampling, and data analysis methods used in these studies.

3.1 Experimental Design

In the Site Preparation experiments, three 560 m x 180 m experimental blocks were laid out within an aspen forest clearcut (Cutblock 4007) in a nonrandomized complete block design approximately three years after harvesting (Figure 2). Each experimental block was divided into seven 80 m x 180 m treatment plots. The sequence of individual treatments was randomly determined within one block and then the same sequence was repeated in the other two blocks. Within the central portion of each treatment block, usually twenty 5 m x 5 m subplots were located along line transects at five metre intervals. The center of each subplot was marked with a 1.8 m long metal post, while the corners were marked with shorter wire pins to allow the re-location of individual subplots. The treatments selected for comparison included two herbicide applications (2 and 4 kg/ha of hexazinone), Rome double disking, and disk trenching as well as a control. A combination of chemical and mechanical treatments were applied to the remaining two plots, but these plots were not included in this analysis.

Hexazinone as the product PRONONE 10G was selected as the test chemical herbicide because it was certified to be free of contaminants such as dioxin and PCBs; it was available in granular form with an inert protective coating which minimized direct contact to applicators; it could be applied with minimal off-site drift; it did not depend on direct contact with foliage to be effective, since it could be absorbed by roots; it controls a broad spectrum of woody, forb and graminoid species; and it remains active in the soil for at least two growing seasons. Spreading of the herbicide was by aerial broadcasting with a helicopter. Sidhu and Feng (1991) should be consulted for additional details regarding the chemical application process.

In the Conifer Release experiments, the approach to block and plot layout was similar to that used in the Site Preparation experiments, but with only five treatment plots. Due to variation of site conditions, adequate space was not available in continuous segments within Cutblock 4004, therefore it was necessary to locate three treatment plots outside a systematic block layout (Figure 2). Included among the test treatments were a control, Rome double disking, and three disk trenched plots. The disk trenched plots were either treated with 2 or 4 kg/ha of hexazinone, or brushsawed. Treatment of these experiment blocks consisted of the following schedule:

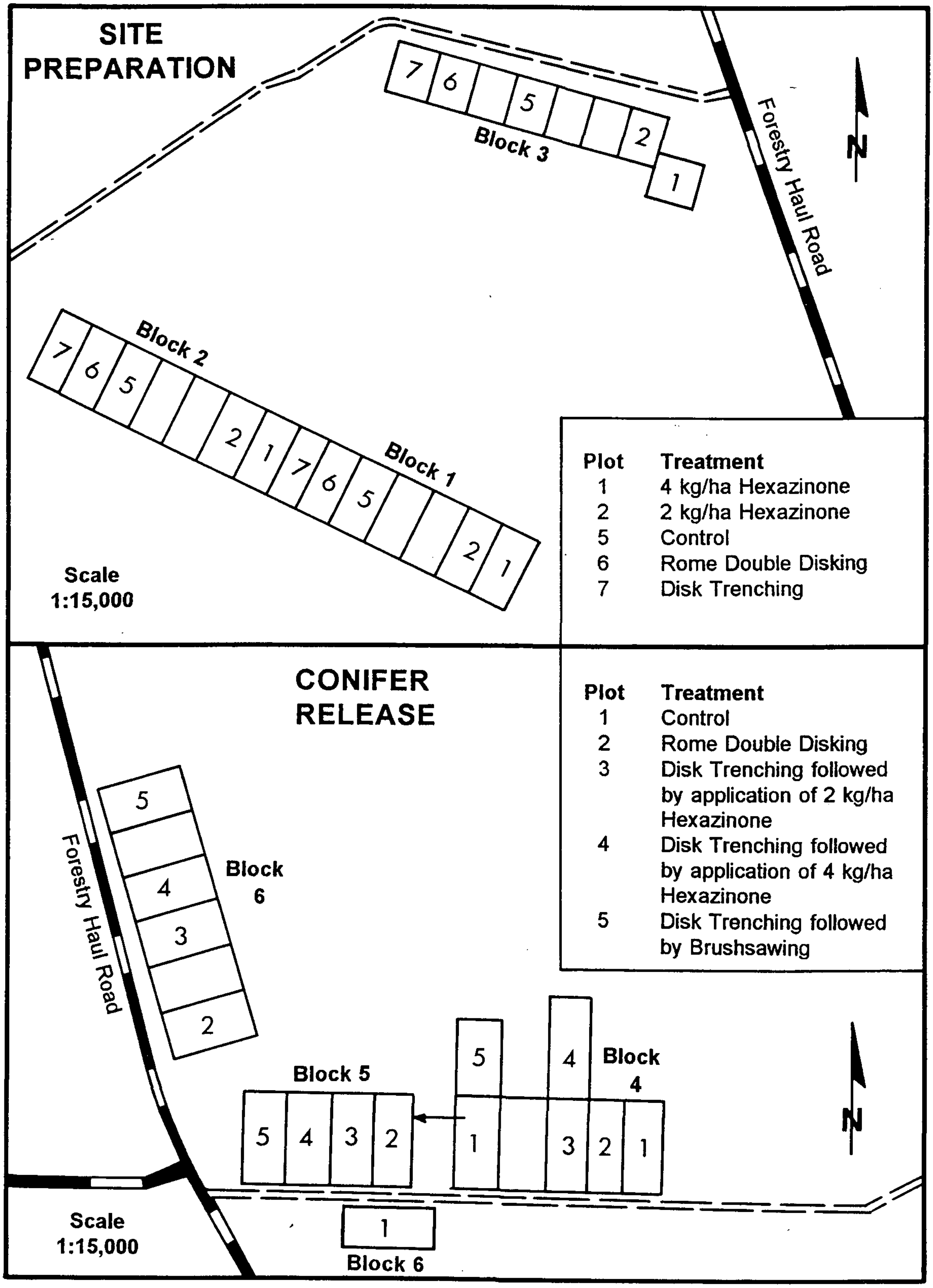


Figure 2. Schematic layout of blocks and treatment plots for the Site Preparation and Conifer Release experiments.

Site Preparation Experiment (Cutblock 4007)

Treatment	Date of Treatment
Control	No treatment
2 kg/ha hexazinone	28 August 1986
4 kg/ha hexazinone	28 August 1986
Rome double disking	12 - 18 May 1987
Disk trenching	12 - 15 May 1987

Conifer Release Experiment (Cutblock 4004)

Control	No treatment
Disk trenching followed by application of 2 kg/ha hexazinone	12 - 15 May 1987 with chemical application on 30 May 1989
Disk trenching followed by application of 4 kg/ha hexazinone	12 - 15 May 1987 with chemical application on 3 May 1989
Rome double disking	12 - 15 May 1987
Disk trenching followed by brushsawing	12 - 15 May 1987 with brush-sawing in mid-May to mid-June 1989

A conifer seedling was planted in each subplot quadrant during May 1987. Normally, a separate row of lodgepole pine and white spruce seedlings were planted parallel to each transect line. Seedlings were grown by the Alberta Forest Service and consisted of plug +1 white spruce (i.e., bare root stock) and Spencer-Lemaire container-grown lodgepole pine. Table 2 summarizes selected height and basal diameter parameters of these seedlings at the time of planting. The skewness and kurtosis measures suggest that both seedling height and basal diameter had normal distributions. The white spruce seedlings were taller and had larger basal diameters than the lodgepole pine seedlings (t-test, $P < 0.001$ level).

3.2 Vegetation Sampling

The frequency of woody stems, species composition, and percent cover were determined within the control and chemical treatment plots of Cutblock 4007 prior to treatment in 1986. The Rome double disking and disk trenching treatments were not assessed because their native vegetation was either fully or partially destroyed when treated. A full reassessment of the Site Preparation treatments was done in 1988 and again in 1992 and 1993. The Conifer Release experiment blocks were measured in 1993 and 1994.

Table 2. Characteristics of plant coniferous seedlings based on data collected by Todd and Brace (1987).

Seedling Height	Lodgepole Pine (mm)	White Spruce (mm)
Mean	150.4	171.5
Standard Deviation	40.9	40.5
Minimum	45.0	60.0
Maximum	285.0	305.0
Median	150.0	170.0
First Quartile	120.0	145.0
Third Quartile	180.0	195.0
Mode	130.0	180.0
Sample Skewness	0.30	0.27
Sample Kurtosis	-0.03	-0.00
Basal Diameter	(mm)	(mm)
Mean	2.9	4.2
Standard Deviation	0.6	0.9
Minimum	2.0	2.0
Maximum	6.0	6.0
Median	3.0	4.0
First Quartile	3.0	4.0
Third Quartile	3.0	5.0
Mode	3.0	4.0
Sample Skewness	0.19	0.03
Sample Kurtosis	1.09	-0.32
Sample Size	656	661

3.2.1 Stem Density

Woody plant stem density estimates were based on complete tallies of woody stems greater than 50 cm in height separated by species and three height classes: >50 to 150 cm, >150 to 300 cm, and >300 cm. These assessments were made in northeast and southwest quadrants (2.5 x 2.5 m) of the 5 m x 5 m subplots. The number of woody stems per hectare was determined by species. The total length of woody stems per hectare (i.e., Σ number of stems per species multiplied by their representative height) was determined on a quadrant basis and then converted to m/ha.

3.2.2 Vegetation Cover Analysis

The cover of individual species was estimated within a 1 m x 1 m quadrat located in the center of the northeast and southwest quadrants, or the center of quadrant space not occupied by the planted seedling. In addition to the ocular determination of cover for individual species within quadrats, the overall cover of woody plants >50 cm tall by height class, and growth-forms (i.e., shrubs, graminoids, forbs, and mosses) was also estimated.

To determine the reproducibility of ocular plant cover estimates, 35 quadrats (two microplots per treatment) were selected at random for resampling during the 1993 field season. These quadrats included data from both the Site Preparation and Conifer Release experimental blocks. To facilitate the relocation of individual quadrats, the corners of the sampling frame were marked prior to removal after the initial measurement, if randomly selected for re-analysis. After completing the field inventory of an entire treatment plot, the selected quadrats were re-sampled for composition and percent cover by species and height class without reference to the initial data. Resampling occurred within 18 to 24 hours of their initial measurement. The cover data from these two samplings were compared using Czekanowski's Index of Similarity. This index is also known as Sorensons's Index of Similarity but was originally proposed by Czekanowski in 1913 (Greig-Smith 1964). It was applied in this study as follows:

$$PS = \frac{\sum_{i=1}^{s} \text{minimum}(x_{i1}, x_{i2})}{\sum_{i=1}^{s} (x_{i1} + x_{i2})} \times 200$$

PS - Czekanowski's Index of Percent Similarity

x_{i1} - the cover value of the *i*th species in the initial or first time sample (i = 1,2,3 ... s)

x_{i2} - the cover value of the *i*th species in the second time sample (j = 1,2,3 ... s)

The results of this comparison showed an 87 percent similarity between the initial and the corresponding resampled cover data. Obviously, the ocular cover estimates are not 100 percent reproducible. The common sources of error associated with obtaining identical cover values aside from observer error were related to the: (i) disturbance of the vegetation during the initial sampling, since tall species were moved aside during the initial sampling to gain a better view of low-growing plants which could have influenced the perceived cover of the taller species in the subsequent analysis, and (ii) oversight of a very small number of species during the initial or repeated sampling and recording of others during the resampling. Missed species represented two percentage points of error in the similarity index. When missed species were excluded from the calculations, similarity was 89 percent. As a result, it was concluded that the estimation of cover among treatments was within acceptable limits of error for this type of work.

In addition to cover estimates, a qualitative vigor rating was assigned to each vascular plant species by strata and planted seedlings using the following scale:

0 Dead

1 Poor - Plants severely stunted, abnormally small leaves (severely browsed and lacking most of the foliage).

2 Fair - Plant shorter and smaller than normal compared to the control or what was typical of the species (browsed but with residual leaves and evidence of needle regrowth).

3 Subnormal - Some plants within the range of normal height and size growth but many of the specimens shorter and smaller than normal.

4 Normal - Most plants within the range of normal height and size growth.

5 Excellent - Most plants showing abnormally good growth as represented by greater than normal height, size, and leaf dimensions and coloration.

Vegetation sampling was split between two different field seasons for both the Site Preparation and Conifer Release experiment blocks. To determine if significant differences occurred in species cover values between the different sampling periods, cover data from 1992 and 1993 by treatments were analyzed using Mann-Whitney tests. No significant statistical difference ($P<0.05$) was found between the two different sampling periods; four species had trace occurrences. Therefore, vegetation data collected in sequential years were considered the same in terms of species cover values.

3.2.3 Seedling Growth and Vigor

Coniferous seedling heights and basal diameters were measured in all of the Site Preparation experimental blocks in June and September 1987, 1988, 1989, and July of 1992 and 1993. Seedlings in the Conifer Release treatments were measured in late July 1993 and 1994. A vigor rating was also given to each seedling measured in 1992 through 1994. Coniferous seedlings were measured within the same subplot quadrants where species cover was assessed when present during the 1987 to 1994 period.

Because of time limits, measurement of seedlings in Site Preparation blocks was split between 1992 (77 percent) and 1993 (23 percent). The 1993 heights were adjusted to 1992 values by subtracting the 1993 leader growth from the height of these seedlings. A similar procedure was followed for 20 percent of the seedlings from the Conifer Release experiment blocks which were measured in 1994.

In addition to seedling measurements, the following measures of competing woody vegetation were made with respect to crop seedlings in both the Site Preparation and Conifer Release experiment blocks during the July 1992 to August 1994 period:

1. distance from the seedling to nearest aspen within 180 cm;
2. basal diameter and height of nearest aspen;
3. distance from the seedling to tallest aspen within 180 cm;
4. basal diameter and height of tallest aspen;
5. distance from seedling to nearest woody shrub greater than 50 cm tall within 180 cm; and
6. basal diameter and height of nearest shrub.

No attempt was made to adjust seedling basal diameters or the height and basal diameter of competing species when field sampling occurred in two different years. No attempt was made to correct crop seedling basal diameter, since differences would probably have been a fraction of a millimeter which was more precise than the field measures (i.e., nearest millimeter). It was not considered necessary to adjust the competing species measurements, since changes in the conifer seedling and competing vegetation are presumably linked and reflective of each other.

3.3 Data Analysis

3.3.1 Statistical Description and Testing

The vegetation cover and seedling data were assessed for normality based on measures of skewness (range of acceptance -0.9 to 0.9) and kurtosis (-0.4 to 1.8) (Wetherill 1981). Since all the data were not normally distributed within a set, nonparametric statistical techniques for data analysis were utilized. Medians (or the 50th percentile) and first and third quartile (or 25th and 75th percentile, respectively) values were used as measures of central tendency.

Kruskal-Wallis tests (Sokal and Rohlf 1982, p. 431) were used to determine whether differences occurred among treatments:

$$\text{Kruskal-Wallis statistic (H)} = \left[12/(\Sigma n_i)\,(\Sigma n_i) * \Sigma(\Sigma R)_i^2/n_i\right] - (\Sigma n_i+1)$$

n_i = number of cases in *i*th group

ΣR = sum of the ranks in *i*th group

When significant statistical differences ($P < 0.05$) occurred within a set of treatments, nonparametric Scheffe' multiple range tests (Miller 1966, p. 166) were used to determine which treatments were different ($P < 0.05$):

Scheffe' test = $| \bar{R}_i - \bar{R}_{i'}| \leq \chi^2 * \sqrt{N(N+1)/12} * \sqrt{1/n_i + 1/n_{i'}}$

$\bar{R}_i$ = Mean rank of the *i*th group

χ^2 = Chi-square value (k-1) at a given probability

N = Total number of cases in compared groups

n_i = Number of cases in *i*th group

Goodness of Fit Chi-square and Contingency Table tests were used to determine whether differences occurred within frequency data. These analyses were based on the following formulas:

$$\text{Chi-square } (X^2) = \Sigma \frac{(O - E)^2}{E}$$

O = Observed value

E = Expected value (Goodness of Fit)

E = CR/N (Contingency Table Analysis)

C = Column total

R = Row total

N = Grand total of all data cells

Calculation of descriptive statistics; Kruskal-Wallis, Mann-Whitney, and Goodness of Fit Chi-square tests; Contingency Table Analysis; and correlation coefficients were performed with StatView 512+ computer programs (Anonymous 1986), while Scheffe' tests were performed manually.

3.3.2 Cluster Analysis

Clustering of quadrats from the Site Preparation and Conifer Release experimental blocks was based on SYSTAT programs (Anonymous 1992b). This analysis used all species with a frequency of more than three percent, including those differentiated on the basis of height. This restriction on included species was necessary due to limitations within the cluster analysis program. Dissimilarity/similarity differences were based on Euclidean distance measures, while the minimum variance (Ward) method was used for grouping. These methods were used because they often provide distinctive groups with minimal chaining. Clusters were recognized within the resulting dendrogram when a distinctive increase in grouping error occurred.

3.3.3 Diversity Measures

Simpson's Index and Shannon-Wiener's Index were used to assess vegetation diversity. Simpson's Index (Simpson 1949) was used in this study as follows:

$$\text{Simpson's Index } (\lambda) = \sum_{i=1}^{s} p_i^2 \quad \text{where } p_i = n_i / N$$

n_i = Percent cover of individual species (i = 1,2,3 ... s)
N = Total cover of all individual species

This index varies from 0 to 1 and gives the probability that two individual plants drawn at random would belong to the same species. If λ is low, community diversity is high, and if it is high the community diversity is low.

Shannon-Wiener's Index (Whittaker 1975, p. 95) is a measure of how equally abundant species are in a community :

$$\text{Shannon-Wiener's Index } (H') = -\sum_{i=1}^{s} p_i * \log p_i$$

$p_i = n_i / N$ (See Simpson's Index)

The index is maximum when all species are equally abundant and decreases towards zero if the relative abundance of species diverges away from evenness. This index is also known by the name Information Index (Whittaker 1975) and was derived independently by Shannon and Wiener (Magurran 1988, p. 34-35).

4.0 RESULTS

The study results are divided into three sections: 1) Site Preparation experiments; 2) Conifer Release Experiments; and 3) Crop Seedling Competition Analysis. Within the Site Preparation Experiments section an attempt is made to: (i) summarize the characteristics of the pre- and post-treatment vegetation, (ii) compare the effects of the various treatments on native vegetation, and (iii) compare the effectiveness of the treatments with respect to coniferous seedling growth. Analyses of the Conifer Release experiments are truncated relative to the Site Preparation analysis, since the pre-treatment and the first-year post-treatment data were not collected because of limited resources. Therefore, the section on Conifer Release experiments was limited to: (i) summarizing the characteristics of the 1993 post-treatment vegetation, (ii) comparing the effects of the various treatments on native vegetation, and (iii) comparing the effectiveness of the treatments with respect to coniferous seedling growth. The crop seedling competition analysis segment (Section 5.0) involves the summarization and modelling of various ecological parameters in an attempt to correlate different factors to coniferous seedling growth.

4.1 Site Preparation Experiments

4.1.1 Pre-treatment Vegetation Characteristics

In 1986, prior to treatment of the Site Preparation experimental blocks, an assessment of species composition and cover, and density of woody plant stems was conducted within control plots and chemical treatment plots (n = 540 quadrants 2.5 m x 2.5 m). Stem densities were also estimated in the Rome double disking treatment plots (n = 180 quadrants). The results of these surveys indicate that the vegetation in Cutblock 4007 was dominated by an A-stratum composed primarily of *Populus tremuloides* suckers with a median cover of 15 percent and a typical height of 90 cm. The number of suckers ranged from 43,609 to 51,897 stems/ha with an additional 1,058 *Populus* stems/ha that ranged from 160 to 165 cm tall (Table 3 and Photograph 1A). Mixed with the *Populus* stems were *Amelanchier alnifolia, Corylus cornuta, Prunus virginiana, Rosa acicularis, Salix* spp., *Shepherdia canadensis, Viburnum edule*, and other shrubs; but these species composed less than 20 percent of all woody stems greater than 50 cm tall. Total woody stem densities ranged from 52,789 to 63,440 stems/ha after three years of growth following clearcutting (Table 3). The total length of woody stems was 54,400 ± 7,500 m/ha.

The vegetation beneath the woody plant stratum was dominated by forbs which had an average cover of 55 percent. *Aster ciliolatus, Aster conspicuus, Epilobium angustifolium, Lathyrus ochroleucus, Spiraea betulifolia, Cornus canadensis*, and *Galium boreale* were among the most abundant species (individual cover values of 5 percent) with constancy values greater than 80 percent (Table 4). *Calamagrostis canadensis* was the most common graminoid with median cover values of five percent or less. Bryophytes had median cover values of five percent.

A total of 85 vascular plant species were found in the 1986 vegetation survey, but only 19 to 22 percent of these species had constancy values greater than 50 percent. Most species had less than ten percent constancy. Individual treatment plots contained from 66 to 77 species (Table 5). An

Table 3. Number of woody plant stems per hectare (typical height in cm) greater than 50 cm tall in Site Preparation experimental blocks by treatment. H values represent Kruskal-Wallis tests based on average stem densities (stems/m^2) within sampling quadrant (four group comparisons $P < 0.05 = 7.8$, $P < 0.01 = 11.3$, $P < 0.001 = 16.3$; five group comparison $P < 0.05 = 9.5$, $P < 0.01 = 13.3$, $P < 0.001 = 18.4$). Species within a given year followed by the same letter do not differ ($P < 0.05$) among different treatments according to nonparametric Scheffe' range tests.

	Year	Control	TREATMENT				H
			2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disk	Disk Trenching	
Strata C (>300 cm tall)							
Populus tremuloides	1986	0	0	0	0	-	-
	1988	107 (301)	370 (325)	0	0	0	-
	1992	5,052 (351)c	5,680 (373)c	2,142 (349)b	0a	2,418 (353)b	66
Salix spp.	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	18 (340)	9 (35)	0	0	0	-
Number of Stems per Hectare in "C" Stratum	1986	0	0	0	0	-	-
	1988	107	370	0	0	0	-
	1992	5,070c	5,689c	2,142b	0a	2,418b	66
Strata B (>150 to 300 cm tall)							
Alnus crispa	1986	0	0	0	0	-	-
	1988	62 (168)	18 (160)	0	0	0	-
	1992	45 (170)	44 (210)	0	0	53 (160)	-
Amelanchier alnifolia	1986	124 (165)	196 (179)	133 (169)	489 (186)	-	-
	1988	124 (172)	72 (169)	9 (165)	0	30 (168)	-
	1992	647 (171)	284 (174)	0	0	249 (178)	-
Betula papyrifera	1986	0	0	0	0	-	-
	1988	0	18 (176)	0	0	0	-
	1992	0	9 (270)	36 (250)	0	0	-
Corylus cornuta	1986	0	19 (183)	9 (165)	560 (212)	-	-
	1988	0	9 (200)	0	0	0	-
	1992	0	98 (175)	0	0	0	-
Pinus contorta	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	0	0	9(178)	9(167)	0	-
Populus tremuloides	1986	1,058 (163)	1,358 (166)	1,404 (170)	2,062 (187)	-	2
	1988	13,102 (193)c	15,900 (204)c	10,115(199)b	0a	7,517 (190)b	50
	1992	13,276 (237)c	10,578 (242)b	10,417 (223)b	462 (169)a	10,284 (225)b	354
Prunus pensylvanica	1986	0	9 (159)	0	0	-	-
	1988	0	0	0	0	0	-
	1992	0	9 (160)	18 (171)	0	0	-
Prunus virginiana	1986	0	0	0	18 (155)	-	-
	1988	0	9 (152)	0	0	0	-
	1992	0	0	0	0	0	-
Rosa acicularis	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	9 (186)	0	0	0	0	-

Table 3. Continued.

	Year	Control	TREATMENT 2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disk	Disk Trenching	H
Salix spp.	1986	0	0	0	160 (186)	-	-
	1988	151 (168)	207 (170)	26 (160)	0	40 (165)	-
	1992	0	213 (209)	98 (204)	516 (195)	551 (188)	-
Shepherdia canadensis	1986	0	19 (170)	0	0	-	-
	1988	0	0	0	0	0	-
	1992	0	0	0	0	0	-
Total Number of Stems per hectare in "B" Stratum	1986	1,182a	1,601a	1,546a	3,289a	-	11
	1988	13,439c	16,233c	10,150b	0a	7,587b	49
	1992	13,977c	11,235b	10,578b	987a	11,137bc	311
Stratum A (>50 to 150 cm tall)							
Alnus crispa	1986	213 (60)	0	0	124 (105)	-	-
	1988	142 (94)	72 (110)	0	0	0	-
	1992	108 (108)	18 (145)	27 (68)	151 (117)	44 (128)	-
Alnus tenuifolia	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	0	0	9 (55)	0	0	-
Amelanchier alnifolia	1986	5,520 (69)b	3,461 (73)a	8,711 (63)ab	7,858 (71)b	-	23
	1988	14,916 (75)d	6,133 (82)c	7,236 (67)b	80 (62)a	5,464 (75)c	204
	1992	12,692 (95)b	4,062 (89)a	7,671 (94)a	3,796 (64)a	8,658 (92)b	118
Betula papyrifera	1986	0	0	36 (65)	293 (83)	-	-
	1988	0	81 (125)	222 (78)	0	0	-
	1992	0	9 (51)	9 (140)	18 (56)	0	-
Cornus stolonifera	1986	0	0	0	0	-	-
	1988	44 (55)	18 (66)	44 (55)	0	0	-
	1992	0	178 (55)	204 (71)	0	80 (64)	-
Corylus cornuta	1986	53 (88)	902 (69)	258 (66)	3,449 (86)	-	-
	1988	0	3,743 (71)	2,764 (66)	0	523 (60)	-
	1992	126 (66)	5,236 (75)	7,742 (75)	71 (57)	1,484 (67)	-
Lonicera dioica	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	602 (58)	1,155 (64)	693 (72)	213 (55)	1,475 (66)	-
Lonicera involucrata	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	1,681 (61)	2,427 (64)	631 (62)	213 (61)	1,182 (59)	-
Picea glauca	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	36(55)	53(72)	53(96)	27(62)	36(101)	-
Pinus contorta	1986	0	0	0	0	-	-
	1988	0	0	0	0	0	-
	1992	0	36(118)	44(94)	27(139)	0	-
Populus balsamifera	1986	0	0	0	0	-	-
	1988	0	0	0	0	10 (65)	-
	1992	0	27 (58)	36 (67)	36 (65)	44 (82)	-
Populus tremuloides	1986	43,609 (90)	51,897 (92)	50,631 (92)	45,547 (97)	-	5
	1988	38,240 (97) d	30,456 (99)c	24,951 (100)b	1,689 (63)a	23,547 (92)c	410
	1992	5,707 (116)b	4,213 (119)a	5,289 (118)b	4,996 (86)b	5,618 (111)b	41
Prunus pensylvanica	1986	0	74 (65)	0	44 (84)	-	-
	1988	0	18 (57)	337 (71)	0	674 (79)	-
	1992	0	71 (125)	53 (90)	27 (70)	524 (106)	-

Table 3. Concluded.

	Year	Control	TREATMENT 2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disk	Disk Trenching	H
Prunus virginiana	1986 1988 1992	0 142 (69) 126 (77)	0 72 (80) 0	0 9 (65) 293 (72)	80 (66) 0 9 (56)	- 0 151 (78)	- - -
Prunus spp.	1986 1988 1992	0 0 0	0 0 0	196 (60) 0 0	0 0 0	- 0 0	- - -
Ribes lacustre	1986 1988 1992	0 0 54 (53)	0 0 0	0 0 36 (60)	0 0 0	- 0 27 (56)	- - -
Ribes oxyacanthoides	1986 1988 1992	9 (53) 0 54 (62)	9 (56) 45 (59) 684 (62)	0 26 (52) 151 (68)	9 (50) 0 18 (55)	- 50 (61) 427 (57)	- - -
Rosa acicularis	1986 1988 1992	444 (56) 2,756 (57)c 8,953 (61)d	930 (60) 3,878 (55)c 7,164 (65)bc	658 (56) 800 (58)b 4,781 (68)a	773 (77) 0a 4,027 (56)a	- 1,691 (57)c 8,160 (59)cd	- 53 100
Rubus idaeus	1986 1988 1992	0 0 0	0 0 0	0 0 0	0 0 80 (55)	- 0 71 (55)	- - -
Salix spp.	1986 1988 1992	1,662 (74) 2,018 (86)b 1,033 (106)a	1,321 (81) 478 (93)a 311 (113)a	1,324 (85) 98 (108)b 116 (105)a	1,333 (100) 293 (70)a 2,427 (76)b	- 1,258 (79)a 524 (114)a	<1 57 95
Shepherdia canadensis	1986 1988 1992	53 (61) 1,422 (57) 3,083 (65)	167 (80) 1,704 (64) 631 (74)	9 (51) 124 (57) 267 (62)	89 (87) 0 71 (56)	- 765 (62) 1,787 (70)	- - -
Spiraea betulifolia	1986 1988 1992	0 0 72 (55)	0 0 124 (56)	0 0 9 (59)	0 0 0	- 0 107 (53)	- - -
Symphoricarpos albus	1986 1988 1992	0 0 351 (54)	0 0 533 (61)	0 0 293 (53)	27 (55) 0 27 (58)	- 0 542 (54)	- - -
Viburnum edule	1986 1988 1992	44 (96) 222 (58) 404 (56)	124 (58) 226 (56) 933 (59)	71 (71) 0 613 (55)	27 (65) 0 0	- 10 (69) 231 (61)	- - -
Total Number of Stems per Hectare in "A" Stratum	1986 1988 1992	51,607 59,902 b 35,082d	58,891 46,915b 27,829bc	61,894 36,611b 28,976b	59,653 2,062a 16,207a	- 33,992b 31,136cd	6 78 138

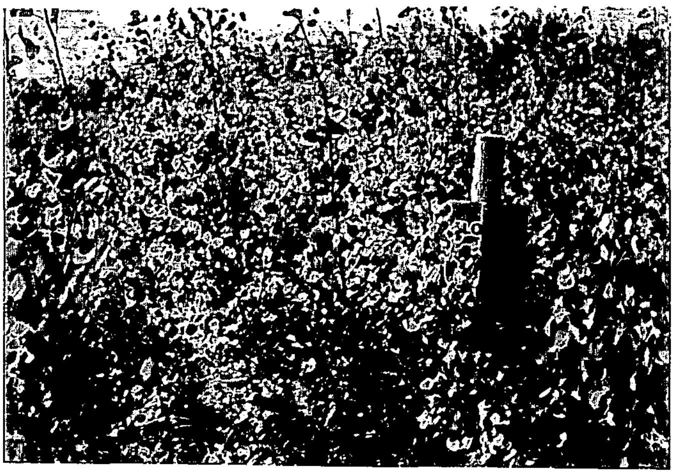
Summary Statistics							
Total Number of Stems per hectare	1986 1988 1992	52,789 73,448d 54,129d	60,492 63,351c 44,753bc	63,440 46,761b 41,696b	62,942 2,062a 17,194a	- 41,579b 44,691c	6 454 253
Total Stem Length (m/ha)	1986 1988 1992	46,763 79,128d 81,131d	55,602 76,803c 70,123c	56,167 53,026b 56,037b	61,491 1,310a 13,292a	- 43,388b 58,516bc	7 451 334
Net Change in m/ha	1992	+73%	+26%	0%	-78%	+6%	-
Number of Plots	1986 1988 1992	180 180 178	180 170 180	180 176 180	180 78 180	0 159 180	- - -

Photograph 1. Site Preparation Experiment - Control Plots.

Photograph 1A -

An example of the control plot and post-clearcut vegetation that occurred in the Site Preparation experimental blocks in July 1986 with mature mixedwood forest in the background. Clearcutting occurred in July 1983.

Photograph 1B - Control plot vegetation in July 1988. Note the height increase in *Populus tremuloides* relative to the 1986 condition using the marker post as a scale.



Photograph 1C - Control plot vegetation in July 1993. The *Populus tremuloides* trees are approximately 350 cm tall with an understory dominated by a mixture of graminoids and forbs. Increments on the scale are ten centimeters long.

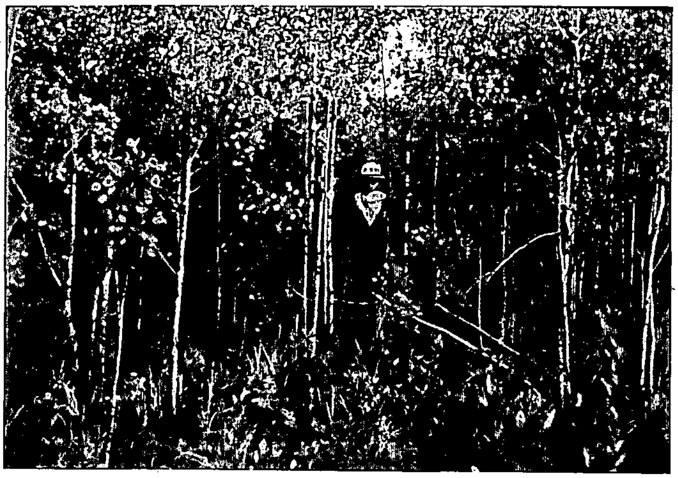


Table 4. Species composition and median (average) percent cover of vegetation in Site Preparation experimental blocks by treatment. Roman numerals indicate constancy classes (CC -- Class 0 - 0%; I - 1 to 10%; II - 11 to 20%; III - 21 to 30%; IV - 31 to 40%; V - 41 to 50%; VI - 51 to 60%; VII - 61 to 70%; VIII - 71 to 80%; IX - 81 to 90%; X - 91 to 100%); a "+" indicates a value <0.55; and H values represent the results of Kruskal-Wallis tests (three group comparisons P <0.05 = 6.0, P <0.01 = 9.2, P <0.001 = 13.8; five group comparisons P <0.05 = 9.5, P <0.01 = 13.3, P <0.001 = 18.4). Cover values within each species and year followed by the same letter do not differ (P <0.05) among different treatments according to nonparametric Scheffe' range tests. Z values represent a comparison of 1988 and 1992 cover values based on Mann-Whitney tests (P <0.05 = 1.96; P <0.01 = 2.58).

		Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		
	Year	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	H
Total "C" stratum (>300 cm tall)	1986	0	0	0	0	0	0	-[1]	-	-[1]	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	12(22)a	VI	10(23)a	VI	0(9)b	III	0c	0	0(5)b	III	186
	Z	15.13		11.02		6.87						
Total "B" stratum (>150 to 300 cm tall)	1986	0(1)	IV	0(1)	IV	0(1)	IV	-	-	-	-	1
	1988	5(5)a	X	5(6)b	VII	+(3)c	VI	-	-	-	-	43
	1992	20(25)a	IX	15(20)c	VII	20(24)b	VII	0(2)e	I	5(14)d	VII	210
	Z	13.35		4.97		7.66						
Total "A" stratum (>50 to 150 cm tall)	1986	15(18)	X	15(18)	X	15(17)	X	-	-	-	-	3
	1988	15(20)a	X	15(17)b	IX	5(11)c	IX	-	-	-	-	53
	1992	15(21)a	X	15(22)a	IX	15(21)b	VII	5(9)c	VIII	14(17)b	IX	70
	Z	23.11		1.07		2.91						
Total Graminoid cover	1986	5(9)a	X	5(5)b	X	5(5)b	X	-	-	-	-	21
	1988	5(5)a	X	+(2)b	VIII	+(1)b	VIII	-	-	-	-	205
	1992	20(24)b	X	5(10)e	VIII	8(12)d	IX	26(31)a	X	20(21)c	X	271
	Z	8.54		7.52		11.37						
Total Forb cover	1986	55(54)a	X	55(49)b	X	55(50)b	X	-	-	-	-	7
	1988	45(45)b	X	55(49)a	X	35(40)c	X	-	-	-	-	23
	1992	60(57)b	X	70(64)a	X	60(64)a	X	40(43)d	X	50(53)c	X	127
	Z	16.37		6.12		9.77						
Total Bryophyte cover	1986	5(7)	X	5(6)	IX	5(5)	IX	-	-	-	-	5
	1988	5(6)	X	5(9)	IX	5(6)	IX	-	-	-	-	3
	1992	0(1)e	III	+(3)d	IV	1(5)c	VII	5(10)b	VIII	8(14)a	IX	260
	Z	35.16		8.70		4.51						
Achillea millefolium	1986	0(+)	II	0(+)	II	0(+)	II	-	-	-	-	+
	1988	0(+)a	III	0(+)b	I	0(+)b	I	-	-	-	-	30
	1992	0(+)c	II	0(+)b	III	0(1)a	IV	0(+)b	III	0(+)d	II	27
Actaea rubra	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1992	0(+)	I	0(+)	I	0	0	0(+)	I	0(+)	I	4
Agropyron trachycaulum	1986	0(+)a	I	0(+)a	I	0(+)b	II	-	-	-	-	11
	1988	0(+)a	II	0(+)a	II	0(+)b	III	-	-	-	-	22
	1992	0(+)c	II	0(1)b	IV	+(3)a	IV	0(1)b	IV	0(+)d	I	123
Agrostis scabra	1986	0(+)	II	0(+)a	II	0(+)	II	-	-	-	-	+
	1988	0(+)	II	0(+)	II	0(+)	II	-	-	-	-	3
	1992	0(+)d	II	0(1)b	III	0(1)b	III	0(1)a	V	0(+)c	II	72

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Alnus crispa - B	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1992	0(+)	I	0(+)	I	0	0	0	0	0(+)	I	2
Alnus crispa - A	1986	0	0	0	0	0(+)	I	-	-	-	-	4
	1988	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1992	0(+)	I	0(+)	I	0	0	0(+)	I	0(+)	I	2
Alnus crispa	1986	0(+)a	I	0a	0	0(1)a	I	-	-	-	-	9
	1988	0	0	0(+)	I	0	0	-				2
	1992	0	0	0	0	0	0	0	0	0	0	0
Amelanchier alnifolia - B	1986	0	0	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)	I	0	0	0	0	-	-	-	-	2
	1992	0(+)a	I	0(+) ab	I	0(+)ab	I	0b	0	0(+)ab	I	11
Amelanchier alnifolia - A	1986	0(1)	III	0(1)	III	0(1)	III	-	-	-	-	2
	1988	0(2)a	IV	0(1)b	III	0(1)b	II	-	-	-	-	20
	1992	0(8)a	V	0(3)c	III	0(4)c	III	0(1)d	II	0(4)b	IV	47
Amelanchier alnifolia	1986	0(3)a	IV	0(2)a	III	0(3)b	V	-	-	-	-	9
	1988	0(2)a	V	0(2)b	III	0(1)b	III	-	-	-	-	16
	1992	0(1)b	III	0(+)cd	II	0(+)c	II	0(1)a	IV	0(1)c	II	39
Antennaria neglecta	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)	I	0	0	0	0	0	0	0	0	4
Apocynum androsaemifolium	1986	0(+)a	I	0(+)a	I	0(+)b	II	-	-	-	-	25
	1988	0(+)a	I	0(+)a	I	0(1)b	III	-	-	-	-	64
	1992	0(+)ab	I	0(+)a	I	0(2)c	III	0(+)b	I	0(+)ab	I	63
Arabis hirsuta	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0a	0	0a	0	0(+)a	I	-	-	-	-	33
	1992	0	0	0	0	+(0)	I	0	0	0	0	8
Arabis holboellii	1986	0a	0	0a	0	0(+)a	I	-	-	-	-	12
	1988	0	0	0	0	9(+)	I	-	-	-	-	4
	1992	0	0	0	0	0	0	0	0	0	0	0
Aralia nudicaulis	1986	5(4)	VII	5(4)	VII	+(3)	VI	-	-	-	-	5
	1988	5(3)	VII	5(4)	VII	5(4)	VII	-	-	-	-	+
	1992	2(4)c	VII	4(7)b	VII	4(9)a	VII	0(2)e	V	2(4)d	VI	51
Arctostaphylos uva-ursi	1986	0	0	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0	0	0(+)	I	0	0	-	-	-	-	2
	1992	+(0)	I	0(+)	I	0(+)	I	0	0	0(+)	I	4
Arnica cordifolia	1986	0(1)a	III	0(1)a	III	0(+)b	I	-	-	-	-	26
	1988	0(+)a	II	0(+)a	II	0(+)b	I	-	-	-	-	16
	1992	0(+)c	I	0(+)b	I	0(+)c	I	0(+)c	I	0(+)a	II	21
Arnica latifolia	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1992	0	0	0	0	0	0	0	0	0	0	0
Aster ciliolatus	1986	5(4)	VIII	5(4)	VIII	5(4)	IX	-	-	-	-	4
	1988	5(4)a	IX	+(3)b	VII	+(2)b	VIII	-	-	-	-	28
	1992	2(4)c	VII	4(9)b	VIII	5(9)a	IX	5(6)b	X	4(7)b	IX	47
Aster conspicuus	1986	5(7)a	X	5(5)b	IX	5(5)c	VIII	-	-	-	-	18
	1988	5(5)a	X	5(4)b	VII	5(3)b	VII	-	-	-	-	44
	1992	10(11)a	X	4(9)c	VII	2(4)d	VII	2(4)d	VIII	8(10)b	IX	130

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Beckmannia	1986	0(+)	I	0	0	0	0	-	-	-	-	2
syzigachne	1988	0(+)	I	0	0	0	0	-	-	-	-	2
	1992	0	0	0	0	0	0	0	0	0	0	0
Betula	1986	0	0	0	0	0	0	-	-	-	-	0
papyrifera - B	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0(+)	I	0	0	0	0	4
Betula	1986	0	0	0	0	0	0	-	-	-	-	0
papyrifera - A	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	1
	1992	0	0	0	0	0	0	0	0	0	0	0
Betula papyrifera	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1992	0	0	0	0	0	0	0	0	0	0	0
Bromus ciliatus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1992	0(+)d	II	0(1)b	III	0(2)a	V	0(+)c	II	0(+)e	I	91
Bromus inermis	1986	0(+)	II	0(+)	II	0(+)	II	-	-	-	-	2
	1988	0(+)a	III	0(+)b	I	0(+)a	III	-	-	-	-	17
	1992	0c	0	0(+)b	I	0(+)a	I	0c	0	0c	0	36
Calamagrostis	1986	5(5)a	IX	+(3)b	VIII	+(3)b	VIII	-	-	-	-	34
canadensis	1988	5(4)a	X	0(1)b	IV	0(+)c	II	-	-	-	-	290
	1992	15(19)b	IX	0(4)c	II	0(2)c	III	20(24)a	IX	15(16)b	X	404
Carex aenea	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0	0	0	0	0(+)	0	5
Carex brunnescens	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0(+)a	I	0(+)a	I	-	-	-	-	11
	1992	0(+)	I	0	0	0(+)	I	0	0	0	0	5
Carex deweyana	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0(+)	I	0(+)	I	0	0	3
Carex interior	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0	0	0	0	0	0	8
Carex macloviana	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0a	0	0(+)a	I	0a	0	-	-	-	-	6
	1992	0a	0	0(+)a	I	0a	0	0a	0	0a	0	16
Carex pachystachya	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	8
Carex praegracilis	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	2
Carex praticola	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0a	0	0a	0	-	-	-	-	6
	1992	0	0	0(+)	I	0(+)	I	0(+)	I	0(+)	I	4
Carex siccata	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0(+)	I	8

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Carex spp.	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	4
	1988	0(+)a	I	0(+)a	I	0(+)a	I	-	-	-	-	16
	1992	0(+)b	I	0(1)a	I	0(+)a	I	0(+)b	I	0(+)b	I	27
Castilleja miniata	1986	0(+)a	II	0(+)b	I	0(+)b	I	-	-	-	-	28
	1988	0(+)a	III	0(+)a	I	0(+)a	I	-	-	-	-	71
	1992	0(1)a	III	0(+)b	II	0(1)a	III	0(+)b	II	0(1)a	III	11
Cerastium arvense	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	4
	1992	0a	0	0(+)a	I	0(+)a	I	0a	0	0a	0	16
Chenopodium album	1986	0	0	0	0	0(+)	I	-	-	-	-	4
	1988	0a	0	0a	0	0(+)a	I	-	-	-	-	6
	1992	0	0	0	0	0	0	0	0	0	0	0
Cornus canadensis	1986	5(3)b	IX	5(4)a	X	+(2)c	VIII	-	-	-	-	28
	1988	5(3)a	IX	5(6)b	IX	5(6)b	IX	-	-	-	-	19
	1992	+(2)c	VII	3(6)a	IX	2(5)b	VIII	0(+)e	II	+(1)d	VI	237
Cornus stolonifera - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	5
Cornus stolonifera	1986	0	0	0	0	0(+)	I	-	-	-	-	4
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1992	0	0	0(+)	I	0(+)	I	0	0	0(+)	I	2
Corylus cornuta - A	1986	0a	0	0(+)a	I	0a		-	-	-	-	12
	1988	0a	0	0(+)a	I	0(+)a	I	-	-	-	-	14
	1992	0(+)b	I	0(3)a	II	0(4)a	II	0(+)b	I	0(1)b	I	42
Corydalis aurea	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0	0	0	0	0	0	0	0	0	0	0
Corylus cornuta	1986	0(+)a	I	0(1)b	II	0(+)a	I	-	-	-	-	25
	1988	0a	0	0(1)b	II	0(1)a	I	-	-	-	-	25
	1992	0(+)ab	I	0(+)a	I	0(+)a	I	0(+)ab	I	0(+)b	I	15
Crepis tectorum	1986	0(+)a	II	0(+)b	I	0(+)a	II	-	-	-	-	21
	1988	0(+)a	I	0(+)b	II	0(+)b	I	-	-	-	-	26
	1992	0	0	0	0	0(+)	I	0(+)	I	0	0	8
Cystopteris fragilis	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0a	0	0a	0	0(+)b	III	-	-	-	-	100
	1992	0	0	0	0	0	0	0	0	0	0	0
Deschampsia cespitosa	1986	.0	0	0(+)	I	0	0	-	-	-	-	2
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0	0	0
Disporum trachycarpum	1986	0(+)a	I	0(+)a	I	0(+)b	I	-	-	-	-	14
	1988	0(+)a	I	0(+)b	I	0(+)b	II	-	-	-	-	16
	1992	0(+)a	I	0(+)a	I	0(+)b	I	0(+)a	I	0(+)a	I	25
Elymus glaucus	1986	0(+)	I	0	0	0	0	-	-	-	-	2
	1988	0a	0	0a	0	0(+)a	I	-	-	-	-	12
	1992	0(+)	I	0	0	0(+)	I	0(+)	I	0	0	4
Elymus innovatus	1986	0(+)a	II	0(+)b	III	0(1)b	III	-	-	-	-	9
	1988	0(+)	III	0(+)	II	0(+)	II	-	-	-	-	2
	1992	0(+)a	I	0(+)a	I	0(+)a	I	0(1)b	II	0(1)a	I	13

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Epilobium angustifolium	1986	5(4)	X	5(4)	IX	5(4)	IX	-	-	-	-	1
	1988	5(4)a	IX	5(8)b	IX	5(8)b	VIII	-	-	-	-	25
	1992	6(8)d	IX	10(14)a	X	10(12)b	IX	7(9)c	X	5(7)e	X	52
Epilobium ciliatum	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0(+)b	II	0(1)b	III	-	-	-	-	42
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	5
Epilobium glaberrimum	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0	0	0
Equisetum arvense	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)	I	0	0	0(+)	I	-	-	-	-	2
	1992	0a	0	0(+)a	I	0a	0	0a	0	0a	0	16
Equisetum sylvaticum	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)a	II	0(+)a	I	0(+)a	II	-	-	-	-	11
	1992	0	0	0(+)	I	0(+)	I	0(+)	I	0(+)	I	6
Festuca rubra	1986	0(+)a	I	0(+)a	I	0a	0	-	-	-	-	7
	1988	0(+)	I	0	0	0	0	-	-	-	-	4
	1992	0	0	0	0	0	0	0	0	0	0	0
Festuca saximontana	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0(+)	I	4
Fragaria virginiana	1986	+(4)b	VII	5(4)a	VIII	+(3)c	VI	-	-	-	-	16
	1988	5(4)a	VII	0(+)b	I	0(+)b	I	-	-	-	-	221
	1992	2(6)a	VI	0(+)d	I	0(+)d	I	1(5)b	VI	0(3)c	V	221
Galeopsis tetrahit	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	3
	1992	0(+)a	I	0(+)a	I	0(+)b	I	0a	0	0(+)b	I	27
Galium boreale	1986	+(3)a	IX	+(2)b	VIII	+(2)a	IX	-	-	-	-	8
	1988	+(2)a	X	+(3)a	VIII	5(4)b	IX	-	-	-	-	23
	1992	1(2)c	IX	2(5)b	VIII	6(9)a	X	+(1)d	VII	2(3)b	IX	175
Gentianella amarella	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0a	0	0a	0	-	-	-	-	14
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	6
Geum aleppicum	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)	I	0	0	0	0	-	-	-	-	2
	1992	0	0	0	0	0	0	0	0	0	0	0
Geranium bicknellii	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	4
	1988	0(+)a	I	0(+)a	I	0(+)a	I	-	-	-	-	9
	1992	0	0	0	0	0	0	0(+)	I	0	0	4
Geranium richardsonii	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0(+)	I	0	0	4
Geum macrophyllum	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	1
	1992	0a	0	0(+)a	I	0(+)a	I	0a	0	0a	0	16
Galium triflorum	1986	0	0	0(+)	I	0(+)	I	-	-	-	-	5
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	3
	1992	0	0	0(+)	0	0(+)	0	0	0	0	0	8

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Halenia deflexa	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	2
	1988	0(+)	II	0(+)	I	0(+)	I	-	-	-	-	5
	1992	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	4
Heracleum lanatum - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0	0	0	0	0	0	0	0	0	0	0
Heracleum lanatum	1986	0	0	0(+)	I	0	0	-	-	-	-	2
	1988	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1992	0(+)	I	0(+)	I	0(+)	I	0	0	0(+)	I	0
Hieracium umbellatum	1986	0(+)	II	0(+)	II	0(+)	II	-	-	-	-	1
	1988	0(+)a	IV	0(+)b	I	0(+)b	I	-	-	-	-	38
	1992	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	5
Juncus balticus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0	0	-	-	-	-	2
	1992	0(+)	I	0	0	0	0	0(+)	I	0	0	5
Juncus vaseyi	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0	0	0	0	0(+)	I	3
Lathyrus ochroleucus	1986	5(4)a	X	5(5)a	X	5(4)b	X	-	-	-	-	7
	1988	+(1)a	VIII	+(1)b	VI	0(+)c	III	-	-	-	-	103
	1992	0(+)a	II	0(+)b	III	0(+)a	II	0(+)a	II	0(1)c	III	12
Linnaea borealis	1986	0(+)	III	0(+)	III	0(+)	III	-	-	-	-	2
	1988	0(+)a	III	0(+)b	I	0(+)b	I	-	-	-	-	68
	1992	0(+)a	II	0(+)c	I	0(+)b	I	0(+)cd	I	0(+)b	II	46
Lonicera dioica - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0(+)c	I	0(1)a	I	0(+)bc	I	0(+)c	I	0(+)ab	I	13
Lonicera dioica	1986	0(+)	I	0(1)	II	0(+)	II	-	-	-	-	4
	1988	0(+)a	I	0(1)a	II	0(+)a	I	-	-	-	-	11
	1992	0(1)b	I	0(1)a	II	0(+)b	I	0(+)c	I	0(1)a	II	24
Lonicera involucrata - A	1986	0	0	0	0	0	0	-	-	0	-	0
	1988	0(+)	I	0	0	0	0	-	-	-	-	2
	1992	0(1)bc	I	0(2)a	II	0(+)c	I	0(+)bc	I	0(+)b	I	29
Lonicera involucrata	1986	0(1)	II	0(1)	II	0(1)	I	-	-	-	-	5
	1988	0(1)a	II	0(1)a	III	0(+)b	I	-	-	-	-	24
	1992	0(1)a	II	0(1)a	II	0(+)b	I	0(+)b	I	0(1)a	II	21
Lycopodium clavatum	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0a	0	0a	0	-	-	-	-	6
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	3
Maianthemum canadense	1986	+(1)b	VI	+(1)a	VIII	+(1)c	VIII	-	-	-	-	22
	1988	+(1)a	VII	+(2)b	VIII	+(+)a	VII	-	-	-	-	12
	1992	0(1)c	V	1(2)a	VII	0(1)b	VI	0(+)e	II	0(+)d	IV	147
Mertensia paniculata	1986	0(1)	IV	0(1)	III	0(1)	IV	-	-	-	-	1
	1988	0(2)a	IV	0(+)b	II	0(+)b	I	-	-	-	-	80
	1992	0(1)a	IV	0(+)c	II	0(+)d	I	0(+)e	I	0(+)b	III	79
Mitella nuda	1986	0(+)a	I	0b	0	0(+)b	I	-	-	-	-	17
	1988	0a	0	0(+)a	I	0(+)a	I	-	-	-	-	15
	1992	0	0	0(+)	I	0(+)	I	0	0	0	0	5

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Moehringia lateriflora	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0a	0	0(+)a	I	0(+)a	I	0a	0	0a	0	17
Oryzopsis asperifolia	1986	0(1)a	IV	0(1)b	V	0(+)a	IV	-	-	-	-	11
	1988	0(1)a	V	0(+)b	II	0(+)b	II	-	-	-	-	61
	1992	0(3)b	II	0(1)c	I	0(2)b	II	0(2)b	II	0(3)a	III	26
Petasites palmatus	1986	0(1)a	II	0(1)b	IV	0(1)b	III	-	-	-	-	13
	1988	0(1)	II	0(+)	II	0(+)	I	-	-	-	-	4
	1992	0(+)b	II	0(+)b	II	0(+)b	II	0(1)b	II	0(1)a	III	29
Petasites sagittatus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0	0	-	-	-	-	4
	1992	0a	0	0(+)a	I	0a	0	0a	0	0a	0	16
Petasites vitifolius	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0(+)	I	0	0	0(+)	I	4
Phleum pratense	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	3
	1992	0(+)a	I	0a	0	0(+)	I	0a	0	0(+)a	I	16
Picea glauca - B [2]	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0(+)	I	0	0	0	0	4
Picea glauca - A [2]	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)b	I	0(+)	I	0(+)	I	0(1)a	I	1(1)a	I	28
Picea glauca [2]	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1988	0(+)a	I	0b	0	0(+)a	I	-	-	-	-	9
	1992	0(+)ab	I	0(+)ab	I	0(+)ab	I	0b	0	0(+)a	I	11
Picea mariana	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0	0	0
Pinus contorta - B [2]	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0b	0	0b	0	0(+)ab	I	0(1)a	I	0(+)ab	I	23
Pinus contorta - A [2]	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)c	I	0(+)c	I	0(+)bc	I	0(1)ab	I	0(1)a	I	26
Pinus contorta [2]	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	9
	1992	0(+)a	I	0b	0	0b	0	0b	0	0(+)	I	24
Poa palustris	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	3
	1992	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	7
Poa pratensis	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	2
	1988	0(+)	I	0(+)	I	0(+)	II	-	-	-	-	16
	1992	0a	0	0(+)a	I	0(+)a	I	0(+)a	I	0a	0	11
Populus balsamifera - B	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0	0	0(+)	I	4

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		HH
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Populus balsamifera - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0	0	0	0	0(+)	I	5
Populus balsamifera	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0b	0	0(+)a	I	0(+)ab	I	0(+)ab	I	0(+)b	I	12
Populus tremuloides - C	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	15(22)a	VI	10(23)a	VI	0(9)b	III	0d	0	0(6)c	III	187
Populus tremuloides - B	1986	0(1)	IV	0(1)	IV	0(1)	IV	-	-	-	-	1
	1988	5(5)a	IX	5(6)a	VII	+(3)b	VI	-	-	-	-	38
	1992	20(23)a	IX	10(18)c	VII	15(22)b	VII	0(1)e	I	4(11)d	VI	221
Populus tremuloides - A	1986	15(16)	X	15(17)	X	15(15)	X	-	-	-	-	3
	1988	15(16)a	X	15(14)b	IX	5(9)c	IX	-	-	-	-	48
	1992	2(5)b	VI	0(5)c	V	0(9)a	V	0(4)d	IV	1(5)b	VI	21
Populus tremuloides	1986	5(7)	X	5(7)	X	5(7)	X	-	-	-	-	+
	1988	5(4)a	X	5(3)b	IX	+(3)b	VIII	-	-	-	-	23
	1992	0(+)c	I	0(+)c	I	0(1)c	I	0(1)a	IV	0(+)b	II	73
Potentilla norvegica	1986	0(+)	I	0	0	0(+)	I	-	-	-	-	5
	1988	0a	0	0(+)a	I	0(+)a	I	-	-	-	-	10
	1992	0	0	0(+)	I	0(+)	I	0	0	0(+)	I	2
Prunus pensylvanica - B	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0(+)	I	0	0	0	0	0	0	8
Prunus pensylvanica - A	1986	0a	0	0a	0	0(+)a	I	-	-	-	-	6
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	5
	1992	0a	0	0(+)a	I	0(1)a	I	0a	0	0(+)	I	12
Prunus pensylvanica	1986	0a	0	0a	0	0(+)a	I	-	-	-	-	8
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	4
	1992	0	0	0	0	0(+)	I	0(+)	I	0(+)	I	5
Prunus virginiana - A	1986	0a	0	0a	0	0(+)a	0	-	-	-	-	8
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0(+)	I	0	0	0(+)	I	8
Prunus virginiana	1986	0a	0	0a	0	0(+)a	I	-	-	-	-	20
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0(+)	I	0	0	0(+)	I	0	0	0(+)	I	3
Pyrola asarifolia	1986	0(+)	III	0(+)	III	0(+)	II	-	-	-	-	4
	1988	0(+)a	III	0(+)b	II	0(+)b	I	-	-	-	-	38
	1992	0(+)a	II	0(+)b	I	0(+)b	I	0(+)b	I	0(+)b	I	41
Ranunculus abortivus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0(+)	I	-	-	-	-	1
	1992	0	0	0	0	0(+)	I	0	0	0	0	4
Ribes lacustre - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)	I	0	0	0(+)	I	0	0	0(+)	I	3
Ribes lacustre	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	I	0a	0	0(+)a	I	-	-	-	-	16
	1992	0(+)	I	0	0	0(+)	I	0(+)	I	0	0	8

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Ribes oxyacanthoides - A	1986	0	0	0(+)	I	0	0	-	-	-	-	4
	1988	0(+)	I	0	0	0(+)	I	-	-	-	-	7
	1992	0(+)a	I	0(+)b	I	0(+)a	I	0a	0	0(+)a	I	16
Ribes oxyacanthoides	1986	0(+)a	II	0(+)b	I	0(+)	I	-	-	-	-	13
	1988	0(+)a	II	0(+)ab	II	0(+)b	I	-	-	-	-	14
	1992	0(+)ab	I	0(+)a	I	0(+)bc	I	0c	0	0(+)b	I	18
Ribes triste	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1992	0	0	0	0	0	0	0	0	0(+)	I	4
Rosa acicularis - A	1986	0(+)	II	0(+)	I	0(+)	II	-	-	-	-	2
	1988	0(1)a	III	0(1)a	IX	0(+)b	II	-	-	-	-	23
	1992	2(5)a	VI	0(6)a	V	0(4)c	IV	0(2)d	III	0(4)b	V	37
Rosa acicularis	1986	5(6)	X	5(6)	X	5(7)	X	-	-	-	-	3
	1988	5(6)a	X	5(5)b	X	+(3)c	VIII	-	-	-	-	105
	1992	10(10)b	X	7(9)c	IX	1(4)d	VI	10(11)a	X	10(10)b	X	146
Rubus idaeus - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0	0	0(+)	I	0	0	4
Rubus idaeus	1986	0(+)	0	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	8
	1992	0(+)a	I	0(+)a	I	0(+)a	I	0(1)b	II	0(1)b	II	54
Rubus pubescens	1986	+(2)	VI	+(2)	VI	+(2)	VI	-	-	-	-	2
	1988	+(2)a	VII	0(1)b	III	0(+)c	I	-	-	-	-	154
	1992	0(2)a	V	0(1)c	II	0(+)d	I	0(1)b	IV	0(2)a	V	120
Salix spp. - B	1986	0	0	0	0	0(+)	I	-	-	-	-	2
	1988	0(+)a	I	0a	0	0a	0	-	-	-	-	10
	1992	0(1)a	I	0(1)ab	I	0(+)b	I	0(+)b	I	0(1)ab	I	10
Salix spp. - A	1986	0(1)	I	0(+)	I	0(+)	I	-	-	-	-	4
	1988	0(1)a	II	0(+)a	I	0(+)a	I	-	-	-	-	16
	1992	0(1)b	I	0(+)bc	I	0(+)c	I	0(1)a	II	0(+)bc	I	18
Salix spp.	1986	0(1)	I	0(+)	I	0(+)	I	-	-	-	-	1
	1988	0(+)a	I	0(+)a	I	0(+)a	I	-	-	-	-	28
	1992	0(+)a	I	0(+)a	I	0(+)a	I	0(+)c	II	0(+)b	I	73
Sanicula marilandica	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0	0	0	0	0(+)	I	0	0	0	0	4
Schizachne purpurascens	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	3
	1988	0(+)a	I	0a	0	0a	0	-	-	-	-	12
	1992	0(1)b	II	0(1)a	III	0(+)c	I	0(1)cd	I	0(+)d	I	43
Senecio pauperculus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0	0	-	-	-	-	4
	1992	0	0	0	0	0	0	0	0	0	0	0
Shepherdia canadensis - A	1986	0(+)	I	0(+)a	I	0(+)b	I	-	-	-	-	3
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	6
	1992	0(1)a	II	0(1)bc	I	0(+)c	I	0c	0	0(1)b	I	30
Shepherdia canadensis	1986	0(1)a	II	0(1)a	II	0(+)a	I	-	-	-	-	9
	1988	0(1)a	II	0(1)ab	II	0(+)b	I	-	-	-	-	20
	1992	0(1)a	II	0(1)ab	I	0(+)cd	I	0(+)d	I	0(+)bc	I	22

Table 4. Continued.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Smilacina racemosa	1986	0(1)a	III	0(+)b	II	0(1)a	III	-	-	-	-	9
	1988	0(1)a	III	0(+)ab	II	0(+)b	I	-	-	-	-	17
	1992	0(1)a	II	0(1)b	II	0(+)b	II	0(+)c	I	0(+)b	II	35
Smilacina stellata	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0(+)	I	0	0	-	-	-	-	2
	1992	0(+)a	I	0(+)b	I	0(+)ab	I	0(+)b	I	0(+)b	I	13
Solidago canadensis	1986	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	3
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	7
	1992	0(+)	I	0(+)	I	0(1)	I	0(+)	I	0(+)	I	8
Spiraea betulifolia - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0a	0	0(1)b	II	0(+)ab	I	-	-	-	-	39
	1992	0(+)a	I	0(+)a	I	0a	0	0a	0	0(+)a	I	11
Spiraea betulifolia	1986	5(4)b	IX	+(3)a	VIII	5(3)a	VII	-	-	-	-	12
	1988	5(4)a	IX	0(1)b	IV	0(+)c	II	-	-	-	-	215
	1992	3(4)a	VIII	0(1)d	IV	0(+)e	II	1(2)c	VII	2(4)	VII	219
Stellaria longifolia	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0(+)a	I	0(+)a	I	0(+)b	I	0a	0	0a	0	27
Symphoricarpos albus - A	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	9
Symphoricarpos albus	1986	0(2)	V	0(1)	IV	0(1)	V	-	-	-	-	3
	1988	+(2)a	VI	0(1)b	IV	0(1)b	IV	-	-	-	-	18
	1992	1(2)a	VI	0(2)c	IV	0(3)a	V	0(1)d	IV	0(2)b	V	23
Taraxacum ceratophorum	1986	0(+)	III	0(+)	II	0(+)	III	-	-	-	-	4
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)a	I	0(+)a	I	0(+)b	II	0(1)b	II	0(+)a	I	14
Taraxacum officinale	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0(+)a	III	0(+)a	III	0(1)b	IV	-	-	-	-	18
	1992	0(+)a	I	0(+)b	II	0(1)d	IV	0(1)e	V	0(+)c	III	84
Thalictrum occidentale	1986	0(+)a	I	0(+)a	I	0(2)b	IV	-	-	-	-	104
	1988	0(+)a	I	0(+)a	I	0(1)b	IV	-	-	-	-	74
	1992	0(1)a	I	0(+)a	I	0(2)c	IV	0(+)a	I	0(1)b	II	92
Trifolium repens	1986	0(+)	I	0	0	0	0	-	-	-	-	2
	1988	0	0	0	0	0	0	-	-	-	-	0
	1992	0(+)	I	0	0	0(+)	I	0(+)	I	0(+)	I	6
Vaccinium caespitosum	1986	0(+)a	III	0(2)a	IV	0(1)b	V	-	-	-	-	7
	1988	0(1)	IV	0(2)	III	0(1)	III	-	-	-	-	5
	1992	0(2)a	III	0(4)a	III	0(3)b	II	0(+)b	II	0(+)c	I	30
Vaccinium myrtilloides	1986	0a	0	0(+)a	I	0(+)a	I	-	-	-	-	10
	1988	0a	0	0(1)a	I	0(1)a	I	-	-	-	-	15
	1992	0(+)a	I	0(+)b	I	0(2)ab	I	0(+)ab	I	0(+)ab	I	10
Vaccinium myrtillus	1986	0	0	0	0	0	0	-	-	-	-	0
	1988	0	0	0	0	0(+)	I	-	-	-	-	2
	1992	0(+)a	I	0(+)a	I	0(1)a	I	0(+)b	I	0(+)a	I	11
Vaccinium vitis-idaea	1986	0(+)	I	0	0	0(+)	I	-	-	-	-	3
	1988	0(+)	I	0	0	0(+)	I	-	-	-	-	1
	1992	0	0	0	0	0(+)	I	0	0	0	0	4

Table 4. Concluded.

	Year	Control		2 kg/ha Hexazinone		4 kg/ha Hexazinone		Rome Double Disk		Disk Trenching		H
		Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Viburnum edule - A	1986	0	0	0(+)	I	0(+)	I	-	-	-	-	4
	1988	0(+)a	I	0(+)a	I	0a	0	-	-	-	-	11
	1992	0(+)a	I	0(+)a	II	0(+)a	I	0(+)b	I	0(+)b	I	21
Viburnum edule	1986	+(2)a	VI	+(2)b	VII	0(2)a	VI	-	-	-	-	9
	1988	+(2)	VI	0(2)	V	+(2)	VI	-	-	-	-	2
	1992	0(1)b	IV	0(1)b	IV	0(1)a	V	0(+)d	I	0(+)c	III	74
Vicia americana	1986	+(2)	IX	+(2)	IX	+(2)	VIII	-	-	-	-	5
	1988	+(1)a	VI	0(+)ab	V	0(+)b	IV	-	-	-	-	7
	1992	0(+)c	IV	0(+)d	III	0(1)a	V	0(+)d	IV	0(1)b	IV	17
Viola adunca	1986	0(+)a	I	0a	I	0(+)a	0	-	-	-	-	11
	1988	0(+)a	I	0(+)a	I	0(+)a	II	-	-	-	-	11
	1992	0a	0	0(+)a	I	0(+)b	I	0(+)a	I	0(+)a	I	36
Viola canadensis	1986	0(+)	I	0(+)	I	0	0	-	-	-	-	1
	1988	0(+)a	II	0(+)a	I	0(1)b	III	-	-	-	-	50
	1992	0(+)b	I	0(+)c	I	0(+)a	II	0(+)c	I	0c	I	58
Viola renifolia	1986	0	0	0	0	0(+)	I	-	-	-	-	1
	1988	0(+)	I	0(+)	I	0(+)	I	-	-	-	-	+
	1992	0	0	0(+)	I	0(+)	I	0(+)	I	0	0	9
Number of Samples	1986	180		180		180		0		0		
	1988	180		180		180		0		0		
	1992	178		180		180		180		180		

[1] Pre-treatment vegetation not sampled, but was considered very similar to the control plots and chemical treatment plots.

[2] Conifers other than the planted crop seedlings.

Table 5. Pre- (1986) and post-treatment (1988 and 1992) characteristics of the vegetation in the Site Preparation experimental blocks by treatment.

Treatment		Control	2 kg Hexaz-inone	4 kg Hexaz-inone	Rome Double Disking	Disk Trenching
TOTAL PERCENT COVER	1986	100	96	92	-	-
based on the summation of	1988	93	83	64	-	-
average cover values for	1992	163	156	147	94	124
individual taxa						
AVERAGE NUMBER OF TAXA	1986	20	20	19	-	-
PER QUADRANT based on 1 x 1 m	1988	22	17	16	-	-
plot for herbs and a 2.5 x 2.5 m	1992	18	16	16	14	17
plot for woody plants >50 cm tall						
SPECIES RICHNESS BY	1986	66	77	76	-	-
TREATMENTS (Total number	1988	76	82	87	-	-
of species)	1992	71	89	94	73	78
SPECIES RICHNESS AMONG	1986	61±7	68±8	57±3	-	-
TREATMENT BLOCKS (Mean	1988	61±7	68±8	57±3	-	-
number and standard deviation)	1992	63±3	64±3	52±5	53±2	61±8
SIMPSON'S INDEX (λ) [1]	1986	0.06	0.06	0.06	-	-
	1988	0.06	0.07	0.06	-	-
	1992	0.07	0.06	0.05	0.10	0.05
SHANNON-WIENER'S INDEX (H') [1]	1986	1.42	1.42	1.45	-	-
	1988	1.42	1.41	1.40	-	-
	1992	1.36	1.43	1.48	1.30	1.46
CZEKANOWSKI'S INDEX OF SIMILARITY [1] based on average cover values and includes taxonomic separations according to height (e.g., A-, B-, and C-stratum)						
Control	1986	-	90.4	86.7	-	-
2 kg Hexazinone		-	-	86.8	-	-
Control	1988	-	74.0	58.8	-	-
2 kg Hexazinone		-	-	77.3	-	-
Control	1992	-	73.7	59.0	58.0	77.0
2 kg Hexazinone		-	-	74.6	45.3	65.3
4 kg Hexazinone		-	-	-	42.2	54.6
Rome Double Disking		-	-	-	-	68.2
NUMBER OF PLOTS	1986	180	180	180	-	-
	1988	180	180	180	-	-
	1992	178	180	180	180	180

[1] For formula see Section 3.2.2 (Czekanowski's Index of Similarity) and Section 3.3.3 (Simpson's and Shannon-Wiener's Indices).

average of 19 to 20 species occurred within each sampled quadrant.

Among the three botanically surveyed treatment plots in 1986, statistically significant differences ($P < 0.05$ level) in percent cover values were found in 30 taxa (includes species in different height classes). However, only four species had constancy values greater than 30 percent and a substantial difference in median cover values. These species included *Calamagrostis canadensis* with greater cover in the control plots, *Cornus canadensis* with lower cover in the 4 kg/ha hexazinone treatment plot, and greater cover of *Fragaria virginiana* and lower cover of *Spiraea betulifolia* in the 2 kg/ha hexazinone treatment plots. These differences ranged from a minor occurrence (<0.55 percent) up to five percent cover (Table 4). A comparison of average percent cover values using Czekanowski's Index of Similarity revealed that an 86.7 to 90.4 percent similarity occurred among the three surveyed treatment plots (Table 5). Simpson's Index and the Shannon-Wiener's Index values were similar among the three surveyed plots. In relative terms, these indices suggest that cover was distributed among a variety of species, but somewhat concentrated within a subset of the total flora. Figure 3 suggests that in 1986, 90 percent of the total plant cover was concentrated in approximately 35 percent of the species, while 50 percent of the cover was concentrated in 10 percent of the flora. Perfect equatability in cover among all species would be represented by a straight line between the lower-left and upper-right corners of the diagram. Both control plots and the surveyed treatment plots had essentially the same cumulative cover curves as presented in Figure 3.

The compositional similarity, lack of substantial differences in individual species cover values, similarity in floristic characteristics, and similarity of woody stem densities suggests that the vegetation within the two surveyed treatment and control plots was quite similar in 1986. Therefore, it is assumed that the vegetation within the unsurveyed disk trenching and Rome double disking treatment plots was probably similar to the surveyed vegetation. Photograph 1A is an example of the pre-treatment vegetation within the Site Preparation blocks in 1986.

4.1.2 Post-treatment Vegetation

4.1.2.1 Control Plots

The general height of the *Populus tremuloides* canopy increased from approximately 90 cm in 1986 to 190 and 350 cm by 1988 and 1992, respectively (Photographs 1B and 1C). Tree species within the A- and B-stratum had a combined median cover of 35 percent (46 percent average). The total number of woody stems greater than 50 cm tall peaked in 1988 (73,448/ha) and declined to 54,129/ha by 1992. Most of the change in density occurred within the A-stratum (>50 to 150 cm). *Populus tremuloides* declined in density by 32,533 stems/ha, or 85 percent during the 1988 to 1992 period. *Amelanchier alnifolia* also showed a 15 percent decrease in density. However, the total length of woody stems continued to increase to a maximum of 81,131 m/ha in 1992 (Table 3). *Populus tremuloides* remained the dominant woody species based on the number of stems/ha, but showed a consistent decrease in its proportion of the total density (i.e., 1986 - 85 percent, 1988 - 70 percent, and 1992 - 44 percent). *Amelanchier alnifolia* followed by *Rosa acicularis* increased the most during the 1987 to 1992 period. Approximately

65 percent of all woody stems occurred within the A-stratum in 1992.

Table 4 summarizes the changes that occurred in the species abundance over the six year period following the initial baseline vegetation analysis based on surveys in 1988 and 1992. Changes in the vegetation included a substantial increase in graminoid cover, a moderate increase in forbs, and reduction in total bryophyte cover. The largest changes in cover were associated with increases from 5 to 10 percent in *Aster conspicuus*, 5 to 15 percent in *Calamagrostis canadensis*, and 5 to 10 percent in *Rosa acicularis*; and decreases from 5 to 2 percent in *Aralia nudicaulis*, *Aster ciliolatus* and *Fragaria virginiana*, 5 to <1 percent in *Cornus canadensis*, and 5 to 3 percent in *Spiraea betulifolia*. Photographs 1A, 1B, and 1C provide a visual comparison of stand growth within the control plots in 1986, 1988, and 1992.

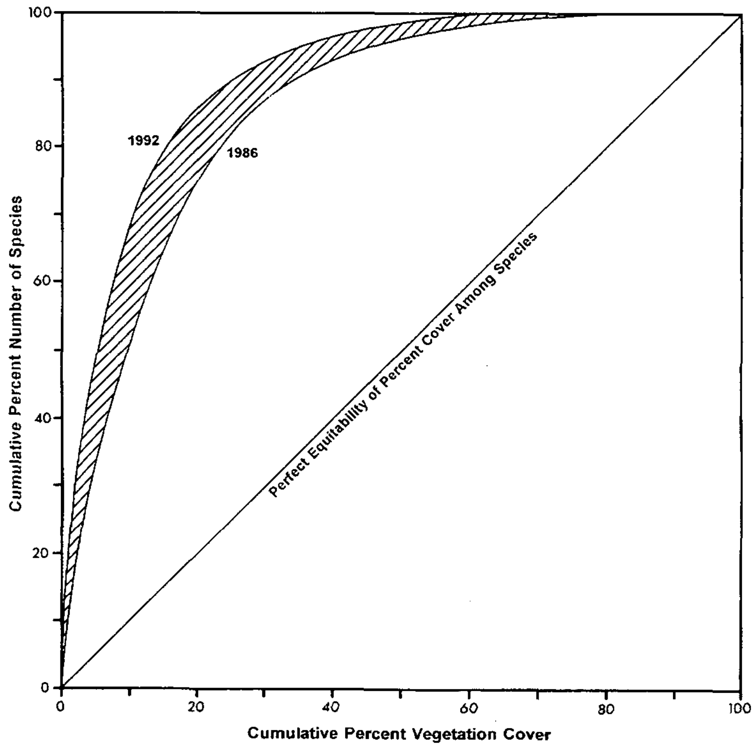


Figure 3. Relationship between cumulative percent cover and corresponding proportion of species in the Site Preparation control plots based on 1986 pre-treatment and 1992 post-treatment vegetation data. Species ranged according to increasing percent cover with cumulative cover representing a percentage of total species cover on the y-axis. The x-axis represents the cumulative percentage of plant species that occurred in the vegetation as a portion of the total flora.

The number of recorded species in the control plots was greater in the 1988 and 1992 vegetation surveys than the 1986 assessments (Table 5). However, the total number of species was low in the 1992 survey relative to the 1988 survey. This decline in species richness for the treatment was not a direct loss of five species, since 21 previously recorded taxa were not found and 16 new taxa were identified in 1992. Twelve species of the 71 found in the 1992 survey had constancy values greater than 50 percent: *Populus tremuloides*, *Rosa acicularis*, *Aster conspicuus*, *Calamagrostis canadensis*, *Epilobium angustifolium*, *Galium boreale*, *Spiraea betulifolia*, *Aralia nudicaulis*, *Aster ciliolatus*, *Cornus canadensis*, *Fragaria virginiana*, and *Symphoricarpos albus* (Table 4). These species represented approximately 80 percent of the total vegetation cover in 1992 (163 percent).

Relative to the 1986 vegetation survey, a greater degree of species dominance occurred in 1992 as shown on Figure 3. The shift to the left in the 1992 cumulative cover curve and the resulting gap (hatched area) is interpreted as an increased concentration of plant cover within a smaller proportion of the flora as the vegetation aged. Approximately 90 percent of all cover was concentrated within 25 percent of the flora in 1992 compared with 35 percent in 1986. Simpson's Index and Shannon-Wiener's Index values were essentially the same between 1986 and 1992 (Table 5).

In summary, this vegetation increased 250 cm in height, had a net increased woody stem density of 2.5 percent, and had a 73 percent increase in the total woody stem length during the 1986 to 1992 period.

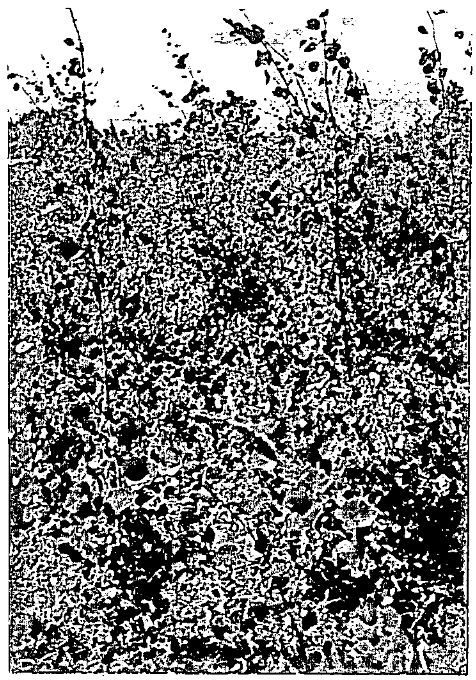
4.1.2.2 2 kg/ha Hexazinone Treatment Plots

A regenerating deciduous forest stand with a partially closed canopy (25 percent) and a general height of 370 cm dominated the physiognomy of the 2 kg/ha hexazinone treatment plots in 1992 (Photograph 2). In 1988, one year after treatment with hexazinone, the density (stems/ha) and length (m/ha) of total woody plant stems had increased above pre-treatment levels, but declined by 26 percent as of 1992 (Table 3). The largest declines in density occurred in *Populus tremuloides* (26,255 stems or a 56 percent decrease), *Amelanchier alnifolia*, and *Shepherdia canadensis*. Shrubs such as *Rosa acicularis* and *Corylus cornuta* increased in density to reduce the overall loss in density. Total stem densities in 1992 were 44,753 stems/ha, which represented 70,123 m of woody stems per hectare. Excluding *Populus tremuloides*, the most common woody plants in the 2 kg/ha hexazinone treatment plots were *Rosa acicularis*, *Corylus cornuta*, and *Amelanchier alnifolia*, respectively. Approximately 62 percent of all woody stems occurred within the A-stratum in 1992.

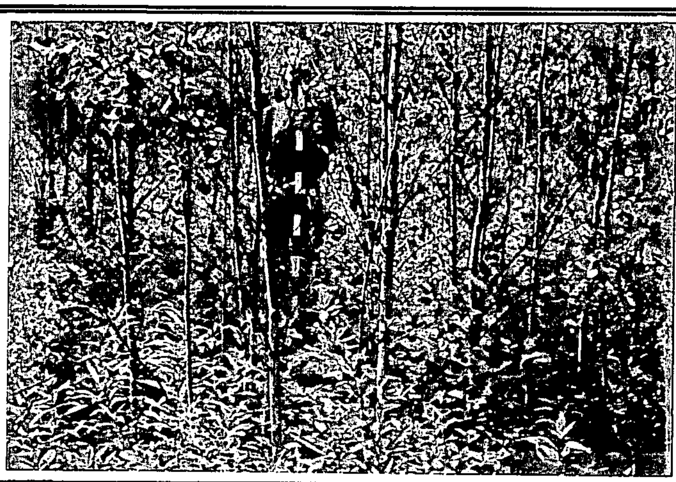
A shrub dominated A-stratum (>50 to 150 cm) and a mixed graminoid or forb stratum (<50 cm) occurred beneath the *Populus tremuloides* canopy. Forbs were the dominant growth-form in the herb stratum (Table 4). Treatment of the vegetation with 2 kg/ha of hexazinone initially reduced overall plant cover by 14 percent, but it recovered to levels comparable to the control plots by 1992 (Figure 4). This decrease appears to have been a general response by a variety of species which included *Fragaria virginiana* (percent change -4 percent), *Lathyrus ochroleucus* (-4 percent), *Populus tremuloides* in the A-stratum (-3 percent), *Calamagrostis canadensis* (-2

Photograph 2. Site Preparation Experiment - 2 kg/ha Hexazinone Plots.

Photograph 2A - Vegetation approximately two year (July 1988) after treatment with 2 kg/ha of hexazinone. Treatment occurred in August 1986.



Photograph 2B - Vegetation seven years (July 1993) after treatment with 2 kg/ha of hexazinone. The *Populus tremuloides* are approximately 350 to 370 cm tall. Note the high proportion of forbs in the understory vegetation. Increments on the scale are ten centimeters long.



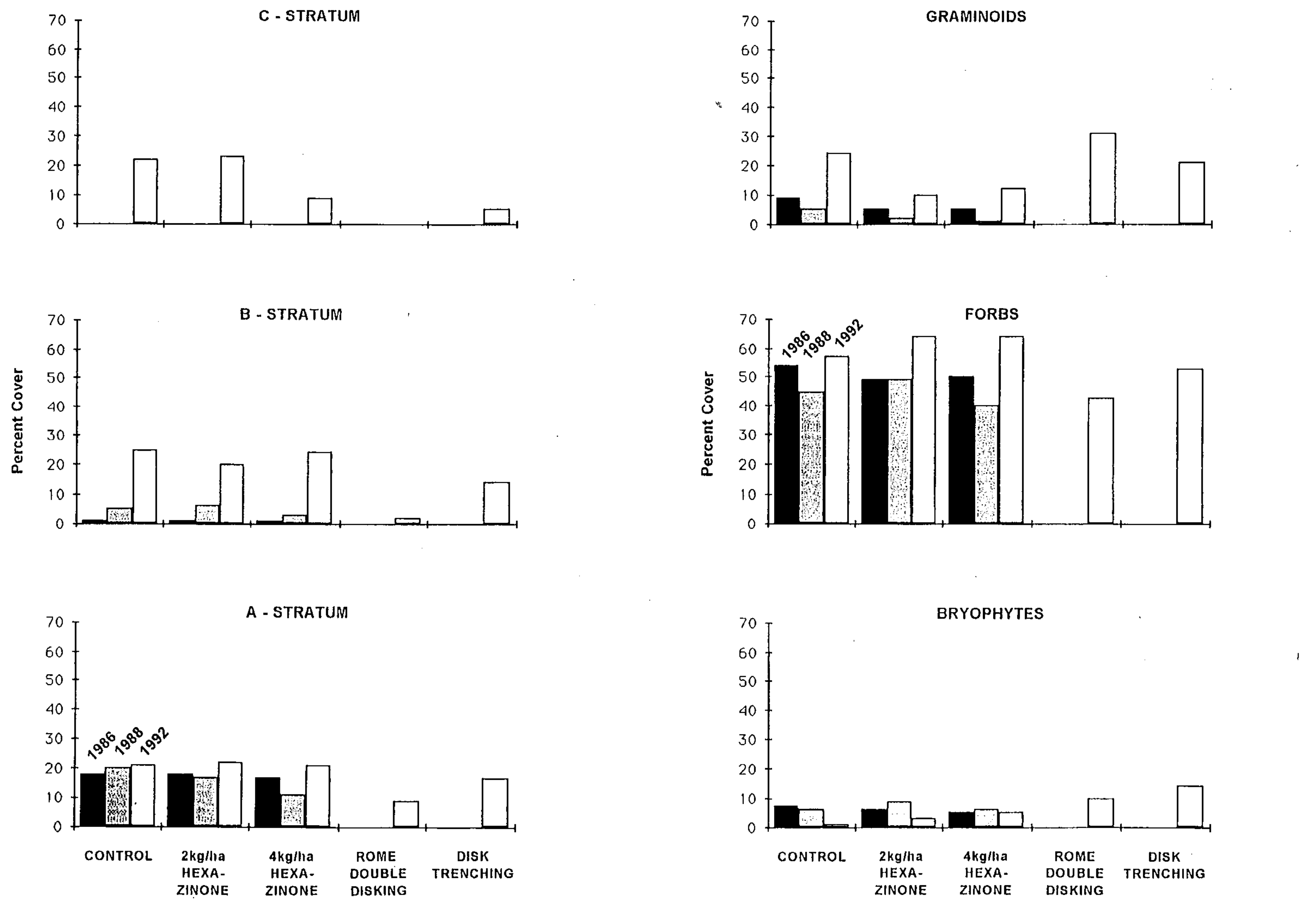


Figure 4. A comparison of total percent plant cover in Site Preparation blocks by treatment based on data from 1986, 1988, and 1992 vegetation surveys.

percent), and *Vicia americana* (-2 percent). A subsequent recovery was lead by *Populus tremuloides* (percent change +24 percent), *Rosa acicularis* (+9 percent), *Epilobium angustifolium* (+6 percent), *Aster ciliolatus* (+5 percent), *Aster conspicuus* (+5 percent), *Aralia nudicaulis* (+3 percent), and *Calamagrostis canadensis* (+3 percent). Six years after treatment the understory vegetation was dominated by *Epilobium angustifolium*, *Rosa acicularis*, *Aster ciliolatus*, *Aster conspicuus*, and *Aralia nudicaulis*. (Table 4).

The number of species in the treatment continuously increased from 77 species in the initial survey to 89 species in 1992, but the number of species per sampling quadrant decreased (Table 5). Simpson's Index and Shannon-Wiener's Index values were relatively constant during the 1986 to 1992 period. A shift in species cover concentration similar to that observed in the control plots also occurred (Figure 3). Following treatment, the degree of similarity with the vegetation in the control plots declined from 90 to 74 percent by 1992.

During the 1986 to 1992 growth period, this vegetation increased 280 cm in height, while total woody stem densities decreased 26 percent and total woody stem lengths increased 26 percent. *Populus tremuloides* had the largest decline in woody stem/ha.

4.1.2.3 4 kg/ha Hexazinone Treatment Plots

An aspen stand with an open canopy (20 percent) and a general height of 350 cm dominated the physiognomy of the 4 kg/ha hexazinone treatment plots in 1992. The understory vegetation included an A-stratum and a mixed forb and graminoid herb stratum. Forbs were the most dominant growth-form within the herb stratum based on percent cover (Photograph 3). The number of woody stems in this treatment plot have continuously decreased since 1986. For example, one year after treatment of the vegetation in 1987 with 4 kg/ha of hexazinone, total woody plant densities declined by 26 percent to 46,761 stems/ha. An additional decline in density of 11 percent occurred in the following five years (Table 3). However, the total length of woody stems remained about 55,000 m/ha throughout the period of study. *Populus tremuloides* was the dominant overstory species, since it represented approximately 96 percent of all stems that were greater than 150 cm tall. In the A-stratum, four species comprised 88 percent of all woody stems: *Amelanchier alnifolia*, *Corylus cornuta*, *Populus tremuloides*, and *Rosa acicularis*. These understory species have continuously increased in density since 1986, except *Populus* which has continuously decreased. Approximately 69 percent of all woody stems in the 4 kg/ha hexazinone treatment plot occurred within the A-stratum in 1992.

A general reduction in total plant cover (28 percent) occurred after the application of 4 kg/ha of hexazinone, but recovered to levels similar to the control plots by 1992 (Figure 4). In the A-stratum *Populus tremuloides* in the A-stratum (percent change -6 percent), *Rosa acicularis* (-4 percent), *Lathyrus ochroleucus* (-4 percent), *Fragaria virginiana* (-3 percent), *Rubus pubescens* (-2 percent), and *Vicia americana* (-2 percent) were among the species that showed the largest declines in cover. The post-treatment recovery was dominated by increased cover of *Populus tremuloides* in the B-stratum (+19 percent), *Aster ciliolatus* (+7 percent), *Galium boreale* (+5 percent), *Aralia nudicaulis* (+5 percent), *Epilobium angustifolium* (+4 percent), *Rosa acicularis* (+4 percent), *Agropyron trachycaulum* (+3 percent), and *Amelanchier alnifolia* (+3 percent).

Photograph 3. Site Preparation Experiment - 4 kg/ha Hexazinone Plots.

Photograph 3A - An example of the effects that a 4 kg/ha application of hexazinone had on regenerating *Populus tremuloides* vegetation one year after treatment (August 1987). Treatment occurred in August 1986.

Photograph 3B - Vegetation approximately three years after treatment with 4 kg/ha of hexazinone. Photograph taken in July 1989.

Photograph 3C - Seven years (1993) after treatment, the understory vegetation was dominated by forbs. Note the small size of the *Populus tremuloides* stems.

Although forbs had an overall cover of 60 percent, *Epilobium angustifolium* (median cover 10 percent), *Galium boreale* (6 percent), *Aster ciliolatus* (5 percent), and *Aralia nudicaulis* (4 percent) were the only species with a median cover of greater than three percent. The majority of other species had less than one percent cover in 1992. The increase in species numbers was in part due to recording most *Carex* species in 1992 as opposed to just the genus in 1986 and 1998.

Floristically, these treatment plots tended to have a greater number of species in the 1986 vegetation survey relative to the control plot and 2 kg/ha hexazinone plots (Table 5). This trend continued up to 1992 when 94 species were recorded. Despite the greater than normal number of species, the average number encountered in sampling quadrants and treatment blocks tended to be lower than in other treatments. The trend towards an increased concentration of foliar cover within few species as the vegetation aged (i.e., 1986 to 1992) was weak relative to the control plots. Nine of the 94 species in this treatment had constancy values greater than 50 percent. The most abundant of these higher constancy species were *Populus tremuloides* (based on C-, B-, and A-strata), *Epilobium angustifolium*, *Galium boreale*, *Aster ciliolatus*, and *Aralia nudicaulis*.

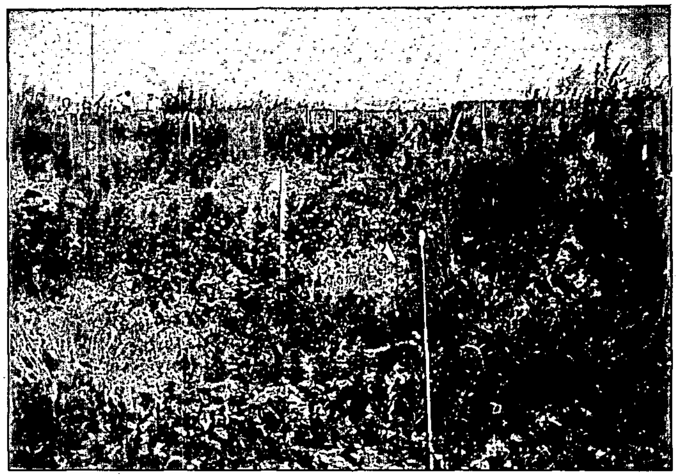
In summary, the overall height of this vegetation increased 260 cm between 1986 and 1992. The total number of woody stems decreased 34 percent, but total length of woody stems remained relatively constant.

4.1.2.4 Rome Double Disking Treatment Plots

Rome double disking completely destroyed the vegetation cover that developed on these plots between 1983 and 1986 following clearcut logging (Photograph 4A). Since double disking treatment, and after colonization and six years of growth, the vegetation was dominated by a mixed forb and graminoid herb stratum. These growth-forms represented approximately three quarters of the total vegetation cover which was approximately 94 percent (Figure 4). Woody plants greater than 50 cm tall composed less than ten percent of the total vegetation cover. The total number of woody stems/ha decreased from 62,942 in the pre-treatment vegetation to zero immediately after treatment (1987) and then increased to 2,062 and 17,194 in 1988 and 1992, respectively. Changes in the total length of woody stems (m/ha) showed trends similar to stem densities. Tree and shrub species were usually less than 100 cm tall with the composition dominated by *Populus tremuloides* (percent composition of all woody stems 31 percent), *Rosa acicularis* (28 percent), *Amelanchier alnifolia* (22 percent), and *Salix* spp. (14 percent). *Populus tremuloides* had established approximately 78 percent of its 1992 stem density within one year after treatment, although this represented less than ten percent of its pre-treatment density (Table 3). Other woody plants were slower to colonize the area with many having low densities (ca. <100 stems/ha) six years after treatment (Photograph 4C). Approximately 94 percent of all woody stems occurred within the A-stratum in 1992.

The vegetation cover of the Rome double disking plots was dominated by *Calamagrostis canadensis* (median cover 20 percent), *Rosa acicularis* (10 percent), *Epilobium angustifolium* (7 percent), *Aster ciliolatus* (5 percent), *Aster conspicuus* (2 percent), *Fragaria virginiana* (1 percent), and *Spiraea betulifolia* (1 percent) in the last survey. Other species in the vegetation

Photograph 4. Site Preparation Experiment - Rome Double Disking Plots.

Photograph 4A - The condition of the Rome double disking plots approximately two months after treatment in May 1987.	
Photograph 4B - About one years after treatment, the vegetation in the Rome Double disking plots was low-growing with only a scattered cover of woody plants. Photograph taken in August 1988.	
Photograph 4C - In July 1993 or approximately six years after treatment, the Rome double disking plots were dominated by a herb stratum with only a scattered cover of woody plants. The *Pinus contorta* were planted in May 1987. Increments on the scale are ten centimeters long.	

typically had only minor cover values (Table 4). The forb species within this vegetation tended to be smaller and less robust than their counterparts which occurred in stands with a C-stratum. Bryophytes had a five percent cover within the sampled plots. This vegetation had a 58 percent similarity to the control plots in 1992 (Table 5). Despite the moderate degree of botanical similarity between the Rome double disking and control plots, Rome double disking treatment plots were structurally and visually different.

Seventy-three vascular plant species were recorded in the Rome double disking treatment plots in 1992. Approximately eleven percent of these species had constancy values of more than 50 percent with four having constancies of greater than 80 percent. These species included *Epilobium angustifolium*, *Rosa acicularis*, *Calamagrostis canadensis*, and *Aster ciliolatus*. Approximately 90 percent of the total vegetation cover was concentrated within about 35 percent of the flora. On average, subplot quadrants (2.5 m x 2.5 m) contained 14 plant taxa compared to 18 in the control plots.

Herbaceous and woody plants less than 100 cm tall dominated this vegetation six years after treatment. The number of woody stems per hectare and their total lengths (m/ha) were very low.

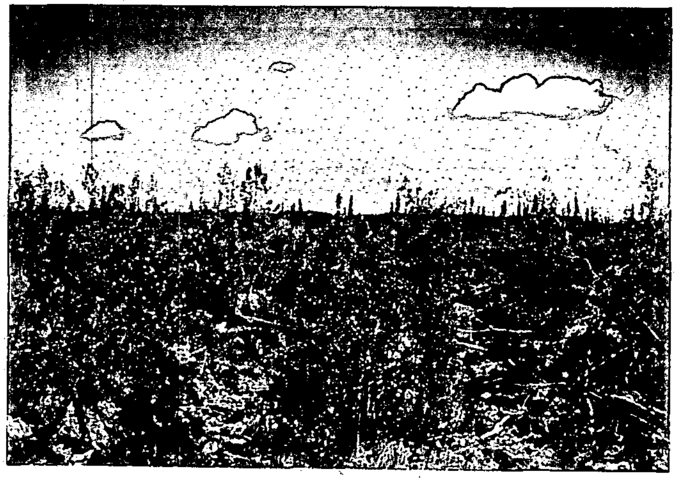
4.1.2.5 Disk Trenching Treatment Plots

The vegetation within the disk trenching treatment plots consisted of two distinctive components: the relatively undisturbed and developing forest vegetation, and the narrow linear disturbance zones which were created during site treatment. The composition and percent cover data presented in Table 4 primarily reflect conditions along the trenches since the 1 m x 1 m sampling quadrats were commonly located in the center of the 2.5 m x 2.5 m quadrants which were also centered on the trenches. Trenches tended to be approximately 50 cm wide and 15 cm deep with loose soil from the trench on one side. The C-stratum adjacent to the trench typically reached a height of 350 cm with a relatively continuous canopy (approximately 50 percent average cover), but within the trenching zone, woody plants greater than 150 cm had an average cover of 19 percent in 1992 (Photograph 5). Assuming the pre-treatment conditions in the disk trenching plots were similar to other treatment plots in the cutblock, stem densities declined about 30 percent following treatment with a minor increase (7 percent) during the subsequent five years of growth, while the length of stems increased by almost 35 percent to 58,516 m/ha. *Populus tremuloides* was the most common woody species in the C- and B-strata. *Amelanchier alnifolia*, *Rosa acicularis*, and *Populus tremuloides* comprised more than 70 percent of all stems in the A-stratum and 50 percent within these treatment plots (Table 3). Forbs with a high proportion of graminoids dominated the herb stratum during the 1992 survey (Figure 4). Bryophytes had a median cover of eight percent which was higher than the other treatments or the control plots.

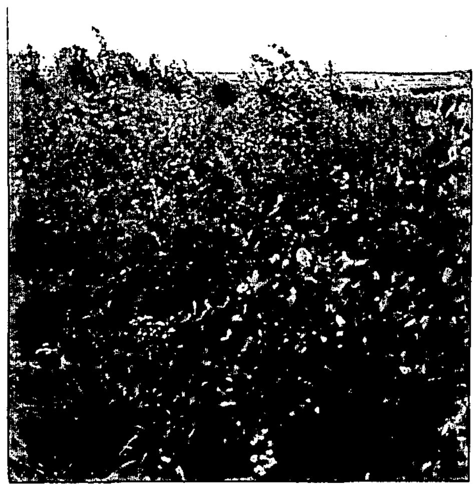
Within the trenched area in 1992, the ground cover was dominated by shrubs less than 50 cm tall and forbs. *Rosa acicularis* (median cover 10 percent), *Aster conspicuus* (8 percent), and *Epilobium angustifolium* (5 percent) were among the most common species. Mixed with the forbs was also a high proportion of *Calamagrostis canadensis* (15 percent cover). This vegetation had a 77 percent similarity with the control plots despite a lower percentage of overall cover and a high percentage of exposed mineral soils (Table 5). The majority of this difference in overall cover was related to a reduced *Populus tremuloides* cover.

Photograph 5. Site Preparation Experiment - Disk Trenching Plots.

Photograph 5A - Condition of the vegetation in June 1987 or approximately two months after disk trenching.



Photograph 5B - By August 1988, the vegetation had increased in both height and density.



Photograph 5C - Disk trenching created linear zones of disturbance which were still obvious in July 1993 or six years after treatment. *Populus tremuloides* were approximately 350 cm tall at this time. The blue flags indicate the location of a sampling quadrat. Increments on the scale are ten cm long.

Seventy-eight vascular plant species were found in this treatment along the trenched areas during the 1992 vegetation survey. Ten of these species had constancy values greater than 50 percent: *Calamagrostis canadensis*, *Rosa acicularis*, *Aster conspicuus*, *Populus tremuloides*, *Epilobium angustifolium*, *Aster ciliolatus*, *Aralia nudicaulis*, *Galium boreale*, *Spiraea betulifolia*, and *Cornus canadensis*. Approximately 90 percent of the total vegetation cover (124 percent) was concentrated in 30 percent of the flora. The cumulative cover curve for this treatment was similar to the 1992 control plots (Figure 3). Simpson's Index was slightly higher and Shannon-Wiener's Index was slightly lower than the values associated with the control plots. The average number of species per quadrant was 17 which was one species less than that found in the control plots.

This vegetation increased 250 cm in height between 1986 and 1992. The total number of woody stems decreased by approximate 25 percent but the total length of woody stems increased only six percent.

4.1.3 Comparison of Treatments

One difficulty with assessing the impact of different site preparation methods on native vegetation was separating the changes due to natural stand developmental processes from the effects of the treatment. This in part was accomplished by directly comparing the species composition of each treatment with the control plots. In addition, this approach assumes that the initial vegetation among all the treatment plots was essentially the same, which appears to be true with some exceptions (See Section 4.1.1). To determine where differences occurred among the treatments, Kruskal-Wallis tests were performed by plant growth-form and taxa. The results of these tests are given in Table 4.

The various site preparation treatments had an influence on all growth-form categories and 16 taxa which included 13 species (Table 6). Treatment with 2 kg of hexazinone per hectare appears to have had only a slight effect on the physiognomic and structural development of the vegetation, and little or no effect on total plant cover (Table 5). The density of woody stems one year after treatment (1988) was reduced by about 14 percent, and 17 percent in 1992 relative to the control plots (Table 6).[2] The length of woody stems (m/ha) showed a similar pattern of decline. This treatment reduced the cover of the B-stratum (mostly *Populus tremuloides*); somewhat reduced the abundance of *Populus tremuloides* in the A-stratum, *Rosa acicularis*, and *Symphoricarpos albus*; and significantly reduced the abundance of *Aster conspicuus* and *Fragaria virginiana*. The abundance of *Aralia nudicaulis*, *Aster ciliolatus*, *Cornus canadensis*, *Epilobium angustifolium*, *Galium boreale*, and *Maianthemum canadense* was increased relative to the control plots by 1992. The largest change was associated with *Epilobium angustifolium* which had an increased cover of about 65 percent (a change in median cover from 6 percent to 10 percent) in 1992 (Tables 4 and 6). Relatively large differences in the percent cover of *Calamagrostis*

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[2] Since most treatments had stem densities that were greater than the control plots, 1988 and 1992 densities were adjusted to allow direct comparison of treatment and control plots. Adjustments were based on a ratio between 1986 control and treatment plot densities. An average across all treatments was used for the 1986 disk trenching value.

Table 6. Qualitative synopsis of vegetation differences among Site Preparation methods relative to control plots. A "-", "+", and "0" represents a decrease, increase, and little or no difference in percent cover, respectively. The occurrence of multiple symbols indicates increasing degrees of difference. A "-" or "+" represents about 2 to 5 percentage points of change (e.g., a increase from 1 to 5 percent cover), a "--" or "++" about 10 percent, and "---" or "+++" about 15 percent). See Table 4 for absolute percent cover values within the treatment and control plots.

		2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching
Total C-stratum	1986	0	0		
	1988	0	0		
	1992	0	- -	- - -	- -
Total B-stratum	1986	0	0		
	1988	-	- -		
	1992	- -	-	- - -	- -
Total A-stratum	1986	0	0		
	1988	-	- -		
	1992	0	-	- - -	-
Total Graminoid cover	1986	-	-		
	1988	- -	- -		
	1992	- - -	- - -	+	-
Total Forb cover	1986	-	-		
	1988	+	-		
	1992	+	+	- -	-
Total Bryophyte cover	1986	0	0		
	1988	0	0		
	1992	+	+	+++	+++
Aralia nudicaulis	1986	0	0		
	1988	0	0		
	1992	+	+	-	-
Aster cilolatus	1986	0	0		
	1988	- -	- -		
	1992	+	+	+	+
Aster conspicuus	1986	-	-		
	1988	-	-		
	1992	- -	- - -	+	- -
Calamagrostis canadensis	1986	- -	- -		
	1988	- -	- -		
	1992	- - -	- - -	+	0
Cornus canadensis	1986	+	0		
	1988	+	+		
	1992	+	++	-	-
Epilobium angustifolium	1986	0	0		
	1988	+	+		
	1992	++	++	+	-

Table 6. Concluded.

		2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching
Fragaria virginiana	1986	++	-		
	1988	- - -	- - -		
	1992	- -	- -	-	- -
Galium boreale	1986	-	0		
	1988	0	++		
	1992	+	++	-	+
Maianthemum canadense	1986	+	-		
	1988	+	0		
	1992	+	+	-	-
Populus tremuloides - C	1986	0	0		
	1988	0	0		
	1992	0	- - -	- - -	- - -
Populus tremuloides - B	1986	0	0		
	1988	0	- -		
	1992	- -	-	- - -	- - -
Populus tremuloides - A	1986	0	0		
	1988	-	- -		
	1992	-	+	- -	0
Rosa acicularis - A	1986	0	0		
	1988	0	-		
	1992	0	-	-	-
Rosa acicularis	1986	0	0		
	1988	-	- -		
	1992	-	- -	+	0
Spiraea betulifolia	1986	- -	-		
	1988	- -	- -		
	1992	- -	- -	-	0
Symphoricarpos albus	1986	0	0		
	1988	-	-		
	1992	-	0	-	-
Number of woody stems/hectare	1986	+15%	+20%	+19%	
	1988	-14%	-36%	-97%	-43%
	1992	-17%	-23%	-68%	-17%
Number of *Populus tremuloides* stems/hectare	1986	+14%	+16%	+ 7%	
	1988	-10%	-32%	-97%	-47%
	1992	-15%	-26%	-77%	-24%
Total length of woody stems (m/ha)	1986	+19%	+20%	+31%	
	1988	- 3%	-33%	-98%	-45%
	1992	-14%	-31%	-84%	-28%
Total length of *Populus tremuloides* stems (m/ha)	1986	+17%	+19%	+17%	
	1988	+ 3%	-28%	-98%	-50%
	1992	- 7%	-34%	-91%	-32%

canadensis were also evident. The rate of species recruitment was greater (2.5x) within the 2 kg/ha hexazinone plots in 1992 than the control plots (i.e., a net increase of 12 species as opposed to 5 species between 1986 and 1992).

Treatment with 4 kg of hexazinone per hectare reduced the overall cover of tree and shrub species in the C-, B-, and A-strata with the greatest impact on the C-stratum as of 1992 (Table 6). *Populus tremuloides* was the most severely effected species. Most plants in the herb stratum responded similarly in both hexazinone treatment plots, except *Rosa acicularis* and *Spiraea betulifolia* which had greater cover reduction, and *Cornus canadensis* and *Galium boreale* which showed greater cover increases in the 4 kg/ha hexazinone treatment. The physiognomy of the vegetation continued to be within the realm of juvenile forest stands, but the C-stratum was more open and reduced in overall height compared to the control plots. Woody plants, mostly *Populus tremuloides*, in the 150 to 300 cm height class (B-stratum) formed the dominant component of the overstory. Woody plant stem densities were 36 and 23 percent lower than the control plots in 1988 and 1992, respectively (Table 3 and Figure 5). This treatment appears to have had only a slight effect on overall plant cover relative to the controls. Species richness was greatest within the 4 kg/ha hexazinone plots relative to the control and other treatments in 1992, but its initial value was also high, although not higher than the 2 kg/ha hexazinone plot. The net increase in species richness was three to four times greater than in the control plots (i.e., net increase of 18 versus 5 species between 1986 and 1992).

Rome double disking substantially reduced the overall cover of the C-, B-, and A-strata (mostly *Populus tremuloides*) and resulted in a significant reduction of forbs and an increase in graminoid cover as of 1992 (Photograph 4C). Within the herb layer, percent cover of *Aralia nudicaulis, Aster conspicuus, Cornus canadensis, Fragaria virginiana, Galium boreale, Maianthemum canadense, Spiraea betulifolia*, and *Symphoricarpos albus* decreased, while that of *Calamagrostis canadensis, Epilobium angustifolium, Rosa acicularis* and *Aster ciliolatus* increased. From a physiognomic perspective, Rome double disking converted forest vegetation into a herb community dominated by native species that are often associated with disturbed sites. The vertical structure of the vegetation was reduced from at least four strata (i.e., C-, B- A- and herb stratum) to a single layer less than 100 cm tall. Total vegetation cover was also reduced from an expected 160 percent (control plot) to 94 percent. The reduced vascular plant cover allowed an increase in bryophytes that colonize bare ground. Total woody stem densities and total length per hectare were 32 and 16 percent, respectively, of the values found within the control plots in 1992 (Figure 5). Woody plants occurred primarily in the lower portion of A-stratum and had a median cover of five percent. The number of plant species in the Rome double disking plots was comparable to the control plots (Table 5).

Disk trenching had its greatest impact immediately along the trench line where the native vegetation was destroyed (Photograph 5C). Trenching significantly reduced the cover of the C- and B-strata (mostly *Populus tremuloides*); decreased the overall cover of the A-stratum, graminoid and forb layers; and resulted in a significantly greater cover of bryophytes than was associated with the control plots. *Aralia nudicaulis, Aster conspicuus, Cornus canadensis, Epilobium angustifolium, Fragaria virginiana, Maianthemum canadense*, and *Symphoricarpos albus* were among the forb species with reduced cover (Table 6). Most of these species probably had cover values comparable to the control plots outside of the trench area. The physiognomy

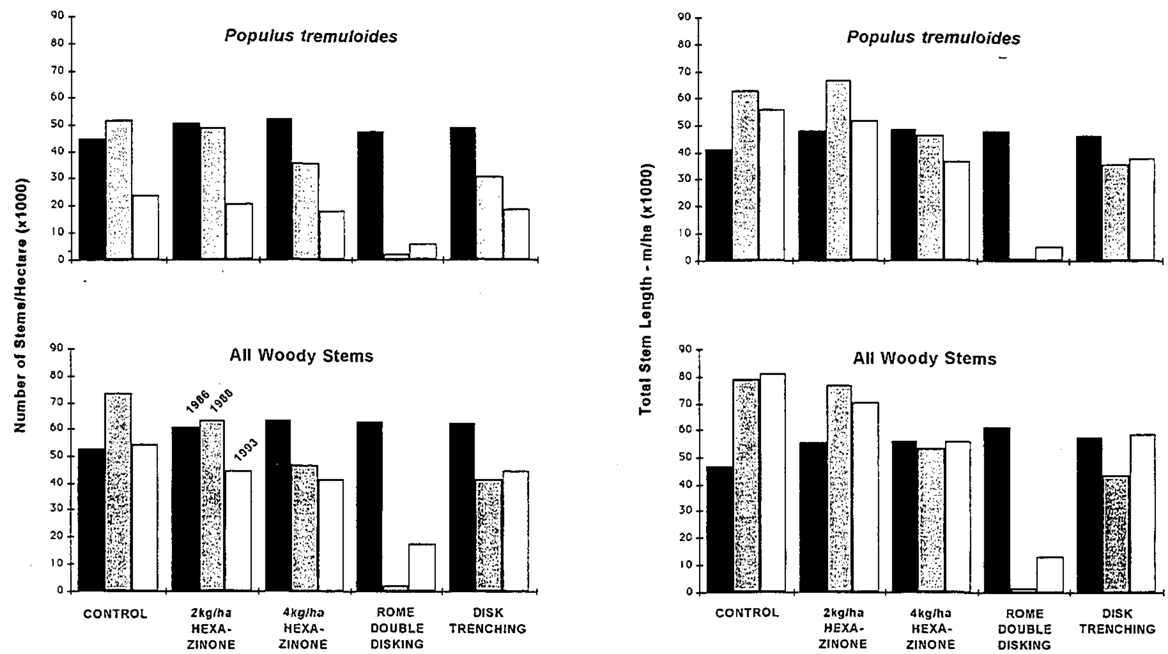


Figure 5. Total number of woody and *Populus tremuloides* stems (stems/ha) and their lengths (m/ha) in Site Preparation experiment blocks by treatment.

and structure of this vegetation was comparable to the control plots, except for the narrow linear disturbance strips that dissect the overstory canopy. The density of woody stems and overall plant cover along the trench area was less than in the control plots, while species richness was somewhat greater (Table 5).

To assess compositional variation within treatment, species cover data from individual 1992 sampling quadrats were compared and grouped using cluster analysis procedures. The results of the analysis are presented in Figure 6. The break in clustering was set at the level indicated on the dendrogram (i.e., dashed line), because it represented: (i) the general level where grouping error began to increase substantially relative to lower levels of clustering, (ii) a point when relatively distinct groups of clusters began to fuse, and (iii) a convenient number of groups for comparison.

Within the dendrogram (Figure 6) there occurred two broad types of vegetation plots. Each of these two broad groupings can be further subdivided into ten clusters. The left-branch and Clusters 1 through 3 of the diagram are dominated by plots that had a median cover of *Populus tremuloides* in the B- and/or C-stratum equal to or greater than 50 percent (Table 7). The understory vegetation in all three clusters was composed of an A-stratum of *Rosa acicularis* and a herb stratum dominated by *Aster conspicuus, Aster ciliolatus, Aralia nudicaulis, Epilobium*

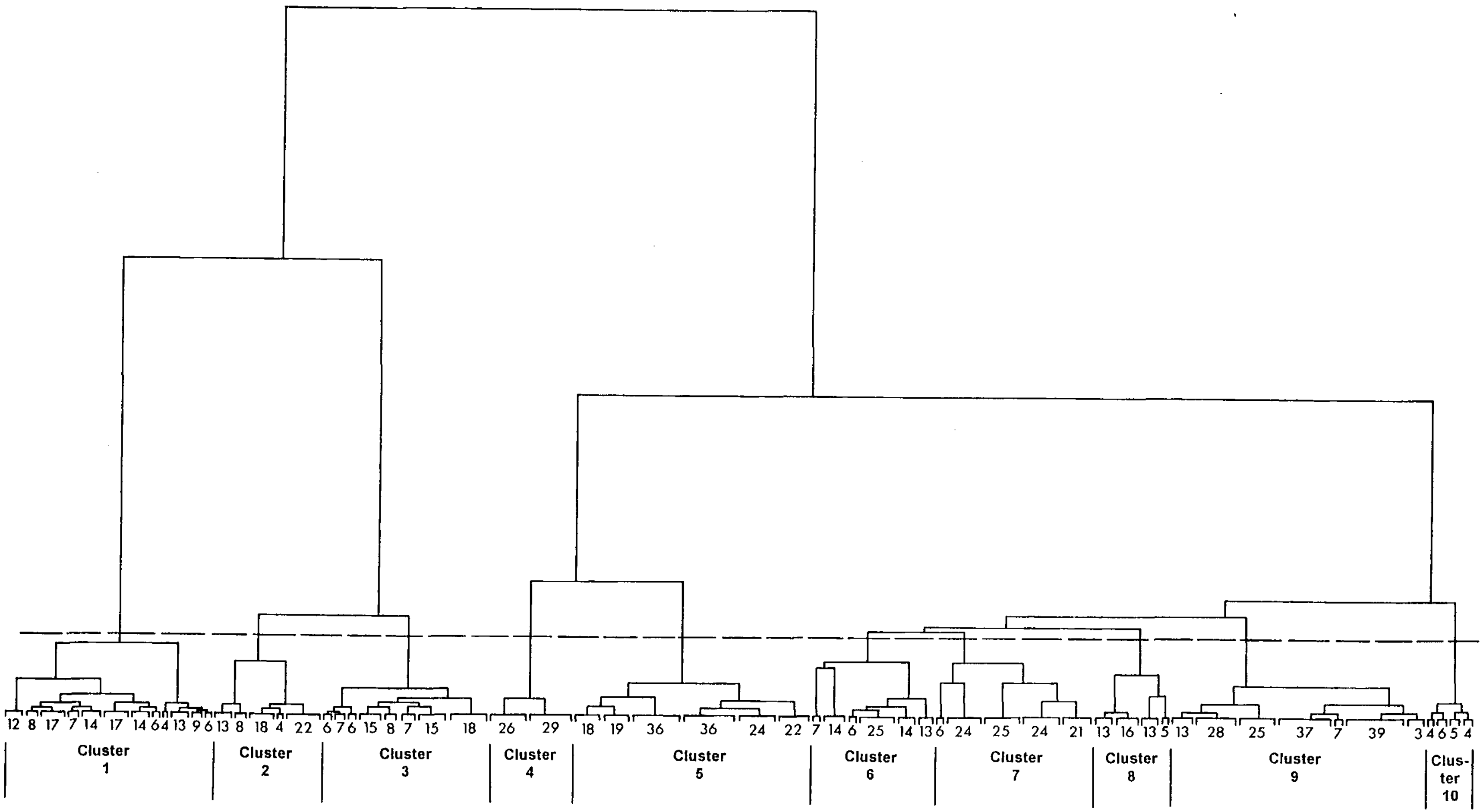


Figure 6. A cluster analysis dendrogram of vegetation plots from the Site Preparation experimental treatment blocks. The dashed line indicates the point where clustering was stopped, while the numbers along the bottom of the diagram identify how many quadrats occurred within subsets of the cluster. See Appendix I for listing of subplot quadrat membership by cluster.

Table 7. Median percent species composition of groups recognized within a cluster analysis of sampled quadrats from Site Preparation experimental treatment plots. H values represent Kruskal-Wallis tests to determine if differences occurred in cover values among the clusters. Only species with significantly different (P <0.05) H values and at least one median cover greater than zero among the clusters were included in the table. Shading indicates key diagnostic species in each cluster and within groups of similar clusters (e.g., Clusters 1, 2 and 3).

	Cluster										H
	1	2	3	4	5	6	7	8	9	10	
	C- AND B-STRATA (>150 cm tall)										
Populus tremuloides - C	0	70	40	0	0	0	0	0	0	0	565
Populus tremuloides - B	50	3	25	0	0	25	10	0	0	5	549
	A-STRATUM (>50 to 150 cm tall)										
Populus tremuloides - A	3	0	0	0	0	15	2	0	0	0	72
Amelanchier alnifolia - A	0	0	0	0	0	0	0	20	0	0	129
Rosa acicularis - A	2	4	5	0	0	0	0	10	0	0	107
Corylus cornuta - A	0	0	0	0	0	0	0	0	0	50	373
	HERB STRATUM (≤50 cm)										
Aralia nudicaulis	3	5	4	0	0	0	4	2	1	6	75
Aster ciliolatus	5	2	5	4	4	5	2	3	6	2	57
Aster conspicuus	6	12	6	5	2	4	10	3	3	+	95
Calamagrostis canadensis	0	1	0	50	24	0	10	4	+	0	384
Cornus canadensis	2	2	2	0	0	2	1	0	+	4	162
Epilobium angustifolium	10	10	10	12	5	10	5	10	8	5	77
Fragaria virginiana	0	0	0	+	2	0	2	0	0	0	113
Galium boreale	2	1	2	+	1	3	1	2	3	1	66
Maianthemum canadense	+	+	+	0	0	+	0	0	0	+	102
Oryzopsis asperifolia	0	0	0	0	0	0	5	0	0	0	180
Rosa acicularis	7	8	6	8	10	3	10	10	5	2	110
Spiraea betulifolia	0	1	+	0	+	0	3	1	0	0	80
Symphoricarpos albus	0	0	1	0	0	0	1	1	0	0	38
Number of Samples	127	66	85	55	157	79	100	47	163	19	898

angustifolium, and *Rosa acicularis*. While all three clusters had similar floristic and structural dominants, *Rosa acicularis* in the A-stratum was more abundant in Clusters 2 and 3 than 1, and *Aster conspicuus* had a greater amount of cover in Cluster 2 than 3. A total of 279 plots or 31 percent of the plots occurred within Clusters 1, 2, and 3. The vegetation in these clusters can be classified as follows:

Cluster 1 - *Populus tremuloides/Epibolium angustifolium* Type
Cluster 2 - *Populus tremuloides/Rosa acicularis-Aster conspicuus* Type
Cluster 3 - *Populus tremuloides/Rosa acicularis-Epilobium angustifolium* Type

The right-branch of the dendrogram was composed of clusters with no cover in the C-stratum and only a limited amount in the B-stratum (<30 percent). The A-stratum sometimes contained shrubs such as *Amelanchier alnifolia, Rosa acicularis*, and *Corylus cornuta*. The herb stratum includes a variety of forbs and low-growing shrubs, and sometimes elevated levels of *Calamagrostis canadensis* (Table 7). The vegetation within these clusters can be classified as follows:

Cluster 4 - *Epilobium angustifolium-Calamagrostis canadensis* Type
Cluster 5 - *Rosa acicularis-Calamagrostis canadensis* Type
Cluster 6 - Open-canopied *Populus tremuloides/Epilobium angustifolium* Type
Cluster 7 - Open-canopied *Populus tremuloides/Rosa acicularis-Calamagrostis canadensis* Type
Cluster 8 - Tall Shrub *Amelanchier alnifolia-Rosa acicularis* Type
Cluster 9 - *Rosa acicularis-Epilobium angustifolium* Type
Cluster 10 - *Corylus cornuta* Type

Clusters 4 and 5 occurred within a major sub-branch of the dendrogram probably because both were composed of plots that had a high cover of *Calamagrostis canadensis* relative to the other clusters. The differentiation of Clusters 6 through 9 on the dendrogram was less obvious than for the other groups (Figure 6). These clusters generally represent woody vegetation types that had C- and B-strata (i.e., 50 to 300 cm) with a mixed forb composition in the herb stratum. Cluster 10 was distinctive from the other groups, since it is dominated by *Corylus cornuta*. *Corylus* often forms dense circular clones that exclude most other species. As a result, the other species included in the vegetation composition of this cluster sometimes represent plants that occurred around the periphery of the clone. Among the 619 plots that formed the left-branch of the dendrogram, Clusters 5, 7 and 9 represented slightly more than two-thirds of this total (68 percent).

Populus tremuloides dominated the vegetation in Clusters 1 through 3 which were primarily composed of quadrats from the control plots, and 2 kg/ha and 4 kg/ha hexazinone vegetation treatments. Cluster 1 had a greater proportion of quadrats from the latter treatment (Table 8). Vegetation quadrats from the Rome double disking and disk trenching treatments primarily formed Clusters 4 and 5. Seventy-three percent of the quadrats that formed Open-canopied *Populus tremuloides/Epilobium angustifolium* vegetation type (Cluster 6) were found in hexazinone plots with a greater proportion in the 4 kg/ha treatment. In contrast, the Open-canopied *Populus tremuloides/Rosa acicularis-Calamagrostis canadensis* vegetation type of

Cluster 7 was concentrated (79 percent) in the control plots and disk trenching treatments. The Tall Shrub *Amelanchier alnifolia-Rosa acicularis* type was poorly represented (47 plots or 5 percent of sample) but occurred in all treatments and tended to be more abundant in the 4 kg/ha hexazinone and the disk trenching plots. The *Corylus cornuta* vegetation type of Cluster 10 tended to be associated mostly with the hexazinone treatment plots.

Table 8. Number of Site Preparation plots by treatment within each group from the cluster analysis. Clusters with a substantially higher than expected frequency of quadrats are highlighted. Assessment was based on Contingency Table Analysis (See Methods Section 3.3.1).

Treatment	Cluster										No. of Samples
	1	2	3	4	5	6	7	8	9	10	
Control	44	25	27	2	13	5	46	6	10	0	178
2 kg/ha Hexazinone	33	28	34	7	4	22	3	9	32	8	180
4 kg/ha Hexazinone	38	8	17	2	5	36	3	12	50	9	180
Rome Double Disking	0	0	0	36	82	4	15	4	39	0	180
Disk Trenching	12	5	7	8	53	12	33	16	32	2	180
No. of Samples	127	66	85	55	157	79	100	47	163	19	898

4.1.4 Crop Seedling Characteristics

Pinus contorta seedlings at planting had median heights of 14 to 16 cm but ranged from 11 to 19 cm (Figure 7). Seedling heights tended to be one and two centimeters taller in the Rome double disk and disk trenching plots than the control or hexazinone plots (Table 9). However, no significant differences occurred in the basal diameter or stem volume[3] of these seedlings.

[3] Stem volume calculations based on conical model, i.e., 1/3(basal area x height) (Husch et al. 1982, p. 101).

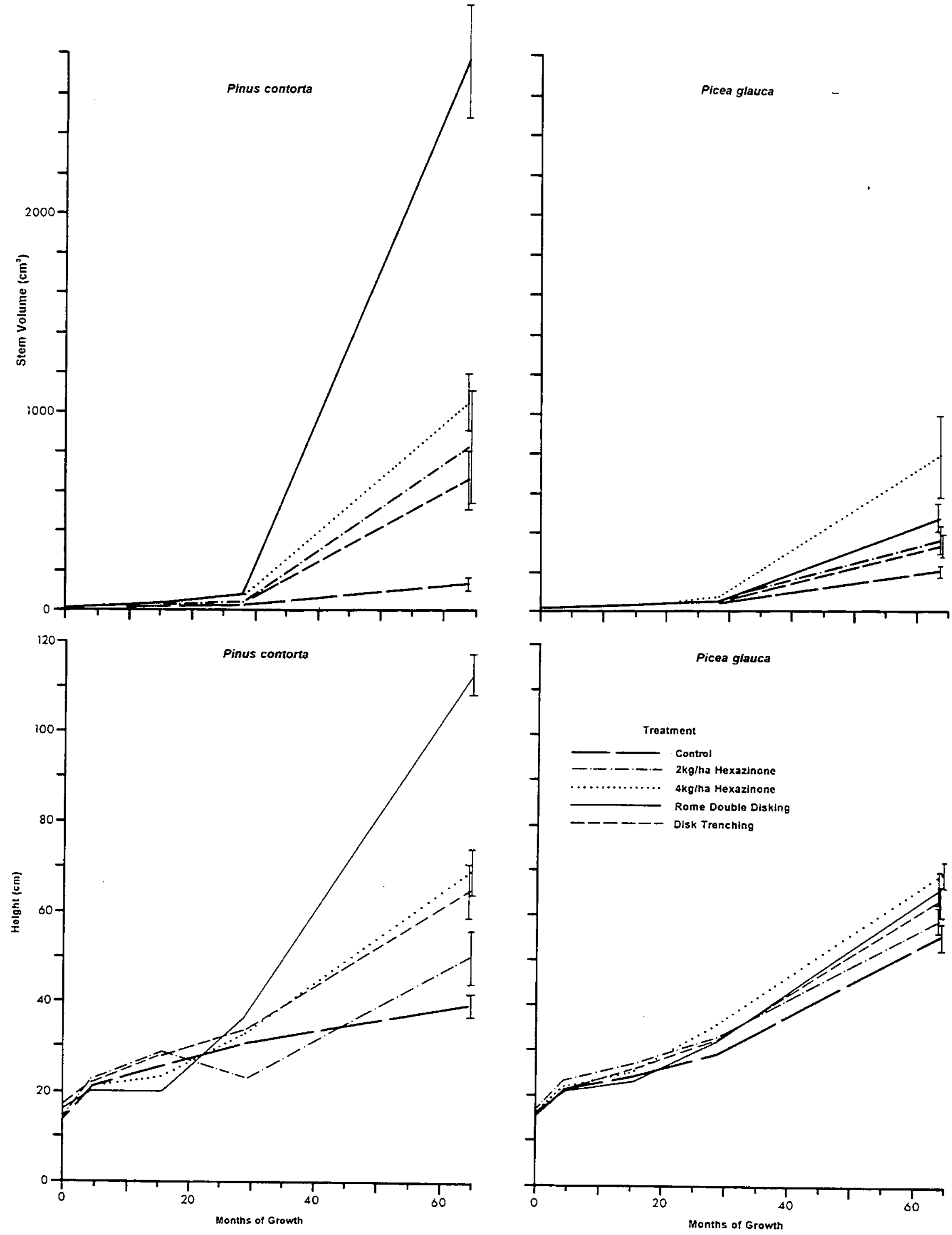


Figure 7. Average height, stem volume, and associated standard error of *Pinus contorta* and *Picea glauca* seedlings in Site Preparation treatments between 1986 and 1992. The dip in *Pinus* height within the 2 kg/ha hexazinone treatment at 28 months represents the impact of browsing during the winter of 1988/89.

Table 9. *Pinus contorta* seedling characteristics within the Site Preparation experimental treatment plots. Q1 and Q3 values represent first and third quartile values; H and X^2 values represent the results of Kruskal-Wallis ($P < 0.05 = 9.5$, $P < 0.01 = 13.8$) and Chi-square Goodness of Fit ($P < 0.05 = 7.8$, $P < 0.01 = 11.3$) tests. Values within a year that are followed by the same letter do not differ ($P < 0.05$) among the different treatments according to nonparametric Scheffe' tests.

	Year*	Months	Control	2 kg /ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disk	Disk Trenching	H	X^2
Median (Q1, Q3) Height (cm)	1987	0	14(11-18)a	14(11-17)ab	14(12-16)a	15(13-18)bc	16(13-19)c	24	-
	1987	4	20(18-24)ab	23(20-26)b	21(18-25)ab	20(18-24)a	23(20-25)ab	19	-
	1988	16	25(22-29)bc	30(24-34)c	20(16-32)ab	19(14-25)a	28(24-31)bc	46	-
	1989	28	33(25-38)b	20(14-27)a	30(20-48)b	39(25-48)b	36(25-42)b	41	-
	1992	64	36(27-53)a	35(18-71)ab	64(35-102)b	112(86-136)c	61(27-95)ab	100	-
Median (Q1,Q3) Basal Diameter (mm)	1987	0	3(3-3)	3(3-3)	3(3-3)	3(3-3)	3(3-3)	3	-
	1987	4	3(3-4)a	3(3-4)a	4(3-4)a	4(3-4)a	4(3-4)a	15	-
	1988	16	5(4-5)a	5(5-7)b	6(5-8)b	6(5-7)b	5(5-6)b	39	-
	1989	28	5(4-6)a	6(4-7)ab	8(6-10)cd	8(6-10)d	6(5-8)abc	57	-
	1992	64	9(7-11)a	9(7-20)ab	19(10-24)d	26(20-33)c	14(10-18)b	103	-
Median (Q1,Q3) Stem Volume (cm^3)	1987	0	3(2-4)	3(2-4)	3(3-4)	4(3-4)	4(2-5)	9	-
	1987	4	5(4-9)ab	7(5-11)ab	8(5-11)a	8(5-10)ab	8(5-10)b	10	-
	1988	16	14(10-19)a	20(15-33)b	20(11-51)b	14(9-28)ab	20(16-29)b	20	-
	1989	28	19(11-36)a	15(7-35)a	53(15-110)bc	65(31-126)c	35(17-55)ab	46	-
	1992	64	83(30-162)a	74(25-691)ab	505(120-1800)b	1676(875-3838)c	377(71-772)b	106	-
Median (Q1,Q3) Vigor Rating	1992	64	2(2-3)	2(1-4)	3(3-4)	4(4-5)	4(2-4)	-	133
Number of Live Seedlings/Number of Sampled Quadrants	1987	0	48/48	80/80	70/70	60/60	88/88	-	-
	1987	4	46/48	79/80	67/70	58/60	84/88	-	<1
	1988	16	45/48	78/80	67/70	58/60	82/88	-	<1
	1989	28	44/48	67/80	64/70	57/60	79/88	-	1
	1992	64	48/90	50/90	56/90	85/90	50/90	-	29
Survival Rate (%)	1987	0	100	100	100	100	100	-	-
	1987	4	96	99	96	97	95	-	-
	1988	16	94	97	96	97	93	-	-
	1989	28	92	84	91	95	90	-	-
	1992	64	53	56	62	94	56	-	-

* Crop seedlings data for 1987 to 1989 provided by P. Todd (Canadian Forest Service, Edmonton, Alberta).

During the first two years after treatment, median seedling height was greatest within the 2 kg/ha hexazinone plots, but dropped by ten centimeters in 1989 (Figure 7). Seedlings in the other plots increased in height by 8 to 20 cm with the greatest gain in the Rome double disking plots where seedlings had a median height of 39 cm. After 64 months of growth, *Pinus contorta* seedling growth was the poorest in the control plots. Seedlings were tallest and had the greatest stem volume in the Rome double disk plots. The differential in height growth was approximately 3:1 between the Rome double disk and control plots (Figure 7). Height growth among the other three treatments was similar, although it tended to be better in the 4 kg/ha hexazinone treatment plots but approximately half of the growth associated with the Rome double disk plots (Table 9). Stem volume, vigor ratings, and survival rates were also highest within the Rome double disk plots. Survival rates were about 50 to 60 percent after six years of growth (Figure 8), except for the Rome double disk plots (94 percent).

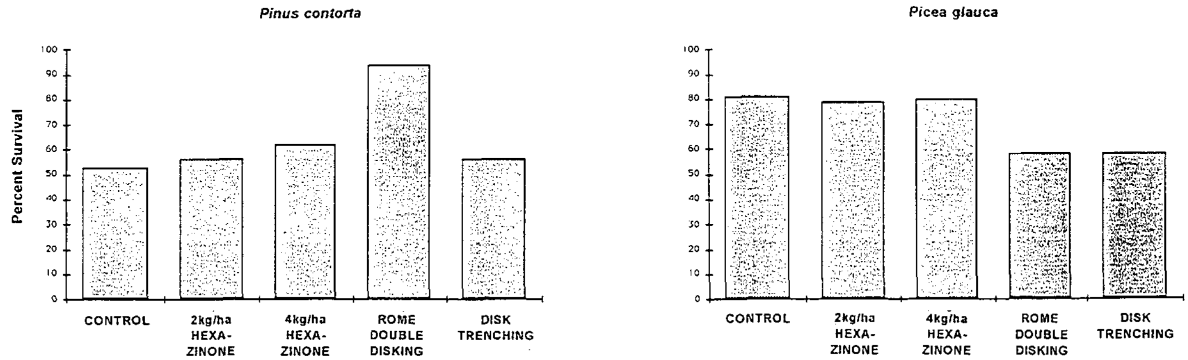


Figure 8. Comparison of *Pinus contorta* and *Picea glauca* seedling survival rates by treatment as of 1992 in the Site Preparation experiment blocks.

Picea glauca seedlings at the time of planting had a median height of 17 cm in all of the treatment plots and no significant difference occurred in the basal diameter or stem volume values (Table 10). No substantial differences in *Picea glauca* seedling height were found during the 1987 to 1989 period, except in the 2 kg/ha hexazinone plot where seedlings ranged from two to five centimeters taller than in the other plots. However, some differentiation in basal area and stem volume began to appear in 1989. After 64 months of growth, statistically different seedling heights occurred, although the range in median values was only 11 cm. The best growth was associated with the 4 kg/ha hexazinone plots, while the poorest occurred in the control plots. Associated with better height growth were larger basal diameter, stem volume, and vigor rating values. The reverse was true for seedlings in the control plots. Growth among the other treatments was considered comparable (Figure 7). Survival rates were approximately 20 percent

Table 10. *Picea glauca* seedling characteristics within Site Preparation experimental treatment plots. Q1 and Q2 values represent first and second quartile values; H and X^2 values represent the results of Kruskal-Wallis ($P < 0.05 = 9.5$, $P < 0.01 = 13.8$) and Chi-square Goodness of Fit ($P < 0.05 = 7.8$, $P < 0.01 = 11.3$) tests. Values within a year that are followed by the same letter do not differ ($P < 0.05$) among the different treatments according to nonparametric Scheffe' tests.

	Year*	Months	Control	2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disk	Disk Trenching	H	X^2
Median (Q1, Q3) Height (cm)	1987	0	17(13-20)	17(15-20)	17(14-19)	17(15-20)	17(15-20)	2	-
	1987	4	20(18-26)	23(20-28)	21(19-26)	22(18-25)	22(19-26)	6	-
	1988	16	24(20-30)a	28(24-32)b	26(20-31)a	23(20-28)a	25(20-30)a	12	-
	1989	28	30(23-34)	34(29-41)	36(25-44)	32(24-40)	33(26-39)	8	-
	1992	64	56(40-63)a	57(40-77)ab	63(49-85)b	62(48-88)ab	67(39-86)ab	14	-
Median (Q1,Q3) Basal Diameter (mm)	1987	0	4(4-5)	4(4-5)	4(4-5)	4(4-4)	4(4-5)	8	-
	1987	4	4(4-5)	5(4-5)	4(4-5)	4(4-5)	4(4-5)	4	-
	1988	16	6(5-6)	6(5-7)	6(5-7)	6(5-7)	6(5-7)	5	-
	1989	28	6(5-7)ab	7(6-8)b	6(6-8)ab	6(5-7)ab	5(5-7)a	15	-
	1992	64	10(8-12)a	11(8-15)ab	12(10-18)b	12(9-18)ab	13(9-14)ab	14	-
Median (Q1,Q3) Stem Volume (cm^3)	1987	0	8(5-11)	8(6-13)	7(5-10)	7(5-9)	7(5-13)	5	-
	1987	4	11(6-15)	13(8-18)	12(8-17)	10(7-16)	11(8-16)	5	-
	1988	16	20(13-29)	26(16-36)	26(12-37)	22(13-37)	19(13-34)	3	-
	1989	28	28(19-36)a	39(23-66)a	35(23-66)a	32(14-55)a	24(15-46)a	12	-
	1992	64	140(64-283)a	178(71-442)ab	232(132-817)b	186(118-716)ab	279(72-416)ab	15	-
Median (Q1,Q3) Vigor Rating	1992	64	3(2-3)	3(3-4)	3(3-4)	3(3-4)	4(3-4)	-	78
Number of Live Seedlings/Number of Sampled Quadrants	1987	0	50/50	80/80	71/71	60/60	90/90	-	-
	1987	4	48/50	74/80	69/71	56/60	86/90	-	<1
	1988	16	37/50	62/80	57/71	44/60	55/90	-	2
	1989	28	35/50	60/80	56/71	44/60	55/90	-	2
	1992	64	72/89	71/90	72/90	52/90	52/90	-	12
Survival Rate (%)	1987	0	100	100	100	100	100	-	-
	1987	4	96	92	97	93	96	-	-
	1988	16	74	78	80	73	61	-	-
	1989	28	70	76	79	73	61	-	-
	1992	64	81	79	80	58	58	-	-

* Crop seedlings data for 1987 to 1989 provided by P. Todd (Canadian Forest Service, Edmonton, Alberta).

higher in the control and hexazinone plots than the Rome double disk and disk trenching plots (Figure 8). These differences were found to be statistically significant ($P < 0.01$) based on a Chi-square Goodness of Fit test (Table 10).

An analysis of percent cover values resulted in the identification of five growth-forms and 26 taxa which differed according to relative *Pinus contorta* seedling heights (Table 11). Decreased vascular plant cover was associated with greater height growth, particularly in the C- and B-strata, while the reverse was true for bryophytes. Eleven vascular taxa showed a decrease in cover within increased seedling height, five increased in abundance, and the remaining ten species did not have a linear direction of change. Only *Aster conspicuus*, *Populus tremuloides*- C, and *Populus tremuloides* - B were associated with substantial differences in percent cover with all being negatively correlated with *Picea glauca* height.

A similar comparison using *Picea glauca* resulted in the recognition of two growth-forms and ten taxa that had different cover values when stratified according to relative seedling height categories (Table 12). Both growth-forms and four species showed a trend of decreased abundance with increased seedling height, while *Taraxacum ceratophorum* was the only species to show an increase in abundance. The strongest trends of difference were associated with the two *Populus tremuloides* taxa which are also included in the overall cover of the C- and B-stratum growth-form categories.

4.2 Conifer Release Experiments

4.2.1 Post-treatment Vegetation

4.2.1.1 Control Plots

When the control plots were established in 1986, the vegetation ranged in height from approximately 110 to 190 cm tall (Photograph 6A). *Populus tremuloides* was the dominant woody plant (i.e., 69 percent of all woody stems), although *Rosa acicularis* and *Salix* spp. were also abundant in the lower portion of the A-stratum (Table 13). The height of the overstory canopy increased to approximately 230 cm by 1988. In 1993, the vegetation within the control plots was dominated by five metre tall *Populus tremuloides* with a median canopy cover of approximately 60 percent (Table 14 and Photograph 6B) and a collective cover of all species of 194 percent (Table 15). The total number of woody stems per hectare in the control plots was 51,903 in 1986. This total decreased at a rate of approximately 1.0 to 1.5 percent per year up to 1993. The largest decrease in total density was due to a 50 percent reduction in the density of *Populus tremuloides* from 35,573 stem/ha in 1986 to 17,666 stem/ha in 1994. In contrast, the total amount of all woody stems increased from 58,394 m/ha in 1986 to 98,200 m/ha in 1993, or a net increase of 68 percent.

In 1993 an A-stratum dominated by *Rosa acicularis* with a median foliar cover of eight percent occurred below the C-stratum. Although *Rosa acicularis* was the most abundant, *Rosa* and *Salix* spp. represented more than 60 percent of the total number of stems that occurred within the A-

Table 11. Comparison of growth-form and species median (average) percent cover values according to relative *Pinus contorta* height categories (n = 288 seedlings) in Site Preparation experimental blocks based on 1992 data. H values represent the results of Kruskal-Wallis tests (P <0.05 = 7.8, P <0.01 = 11.3). Nonparametric Scheffe' range tests were used to differentiate groups (P <0.05). The trend category indicates the general relationship of forest species to the increase in seedling height (a "+", "-", and "~" represents an increase, decrease, and mixed change in percent cover, respectively). Trend was based on changes in the percent cover and Scheffe' tests; however, when no distinctive pattern occurred among the groups, trend was based on changes in average rank according to Kruskal-Wallis tests.

	Group 1 (<34 cm)	Group 2 (34 - 67 cm)	Group 3 (68 - 111 cm)	Group 4 (>111 cm)	H	Trend
Number of Seedlings	72	75	76	65		
Total C-stratum	0 (17)c	0 (14)bc	0 (5)ab	0 (+)a	40	-
Total B-stratum	20 (20)c	10 (17)bc	0 (9)ab	0 (8)a	30	-
Total A-stratum	13 (18)b	15 (22)b	11 (16)ab	6 (14)a	8	-
Total Forb Cover	60 (61)b	50 (53)ab	50 (54)ab	50 (50)a	13	-
Total Moss Cover	+ (7)a	0 (4)a	2 (7)ab	5 (9)b	19	+
Agrostis scabra	0 (+)a	0 (+)a	0 (+)a	0 (1)a	8	+
Apocynum androsaemifolium	0 (+)a	0 (+)a	0 (1)a	0 (1)a	10	~
Aralia nudicaulis	3 (7)b	0 (3)a	0 (3)a	1 (4)ab	23	~
Arnica cordifolia	0 (+)a	0 (+)a	0(+)a	0 a	10	-
Aster conspicuus	9 (10)b	4 (7)ab	4 (6)ab	3 (4)a	16	-
Bromus inermis	0a	0 (+)a	0(+)a	0a	9	~
Carex spp.	0 (+)a	0 (1)a	0 (+)a	0 (+)a	16	~
Cornus canadensis	+(4)b	0 (1)ab	0 (1)a	0 (2)a	17	-
Galium boreale	2 (4)b	2 (4)ab	2 (5)b	+ (3)a	14	~
Linnaea borealis	0 (+)a	0 (+)a	0 (+)a	0 (+)a	9	~
Lonicera dioica	0 (1)a	0 (+)a	0 (+)a	0 (+)a	11	~
Lonicera involucrata	0 (2)a	0 (+)a	0 (1)a	0a	9	-
Maianthemum canadense	+ (1)b	0 (1)ab	0 (+)a	0 (+)a	26	-
Populus tremuloides - C	0 (17)b	0 (16)b	0 (5)a	0a	46	-
Populus tremuloides - B	12 (18)c	2 (16)bc	0 (10)ab	0 (5)a	28	-
Populus tremuloides	0 (+)a	0 (+)a	0 (+)a	0(+)a	8	+
Ribes oxyacanthoides - A	0 (1)a	0 (+)a	0a	0a	9	-
Rosa acicularis - A	0 (4)ab	1 (6)b	0 (3)ab	0 (1)a	20	~
Rubus idaeus - A	0 (+)a	0 (+)a	0 (1)a	0 (1)a	14	+
Salix spp.	0 (+)a	0 (+)a	0 (+)a	0 (+)a	11	+
Schizachne purpurascens	0 (1)a	0 (+)a	0 (+)a	0 (+)a	8	-
Stellaria longifolia	0 (+)a	0(1)a	0 (+)a	0a	8	~
Symphoricarpos albus	0 (+)a	0(+)a	0 (+)a	0a	11	-
Taraxacum officinale	0 (+)a	0(+)ab	0 (1)b	0 (1)b	27	+
Thalictrum occidentale	0 (1)a	0 (1)a	0 (1)a	0 (+)a	15	~
Viburnum edule	0 (1)a	0 (1)a	0 (+)a	0 (+)a	12	-

stratum. Forbs and shrubs less than 50 cm tall composed 80 percent of the overall cover in the herb stratum. The dominant herbs included *Calamagrostis canadensis* (median cover 15 percent), *Rosa acicularis* (10 percent), *Epilobium angustifolium* (8 percent), *Aster conspicuus* (6 percent), *Fragaria virginiana* (4 percent) and *Vicia americana* (3 percent). Several other boreal species were also common (e.g., *Aster ciliolatus, Galium boreale, Lathyrus ochroleucus, Petasites palmatus*, and *Rubus pubescens*) (Table 14 and Photograph 2).

Sixty-nine vascular plant species were found within the three control plots in 1993. An average of 50 species occurred in each control plot (Table 15). Both of these values are lower than those found in the pre-treatment vegetation of the Site Preparation experimental blocks (Table 5). On average, 18 taxa occurred within each individual sampling quadrant which included differentiation of species according to height classes. Simpson's and Shannon-Wiener's Index values suggest the vegetation did not have a high degree of dominance concentration among its member species at present, and cover was distributed among a large number of species; however, 90 percent of the total species cover was concentrated within 30 percent of the flora.

Table 12. Comparison of growth-form and species median (average) percent cover values according to relative *Picea glauca* height categories (n = 318 seedlings) in Site Preparation experimental blocks based on 1992 data. H values represent the results of Kruskal-Wallis tests ($P < 0.05 = 7.8$, $P < 0.01 = 11.3$). Nonparametric Scheffe' range tests were used to differentiate groups ($P < 0.05$). The trend category indicates the general relationship of forest species to the increase in seedling height (a "+", "-", and "~" represents an increase, decrease, and mixed change in percent cover, respectively). Trend was based on changes in the percent cover and Scheffe' tests; however, when no distinctive pattern occurred among the groups, trend was based on changes in average rank according to Kruskal-Wallis tests.

	Group 1 (<42 cm)	Group 2 (42 - 59 cm)	Group 3 (60 - 77 cm)	Group 4 (>77 cm)	H	Trend
Total Number of Seedlings	75	80	88	75		
Total "C"Stratum	0 (17)b	0 (15)ab	0 (9)ab	0 (5)a	17	-
Total "B" Stratum	10 (23)b	20 (20)ab	10 (19)ab	0 (13)a	10	-
Cornus canadensis	2 (4)a	2 (5)a	1 (2)a	0 (4)a	9	-
Fragaria virginiana	0 (3)a	0 (4)a	0 (3)a	0 (1)a	9	~
Lonicera dioica	0 (+)a	0 (+)a	0 (+)a	0 (+)a	8	~
Populus tremuloides - C	0 (18)a	0 (13)a	0 (10)a	0 (5)b	16	-
Populus tremuloides - B	10 (22)a	15 (20)a	7 (14)a	0 (12)a	10	-
Pyrola asarifolia	0 (+)a	0 (+)a	0 (+)a	0a	9	~
Rubus idaeus	0 (+)a	0 (+)a	0 (+)a	0 (1)a	9	~
Schizachne purpurascens	0 (+)a	0 (1)a	0 (1)a	0 (+)a	12	~
Taraxacum ceratophorum	0 (+)a	0 (+)a	0 (+)a	0 (1)a	10	+
Viburnum edule	0 (1)a	0 (1)a	0 (+)a	0 (+)a	9	-

Photograph 6. Conifer Release Experiment - Control Plots.

Photograph 6A - An example of the pre-treatment and control vegetation of the Conifer Release experimental treatment plots in July 1986 with mature mixedwood forest in the background. Clearcutting occurred in March 1983.

Photograph 6B - The control plot vegetation was approx-imately five meters tall with a well developed shrub and herb understory in July 1993. Increments on scale are ten centimeters long.

Table 13. Number of woody plant stems per hectare (typical height in cm) greater than 50 cm tall in Conifer Release experimental blocks by treatment. H values represent Kruskal-Wallis tests based on average stem densities (stems/m^2) within sampling quadrant (four group comparisons $P < 0.05 = 7.8$, $P < 0.01 = 11.3$, $P < 0.001 = 16.3$; five group comparisons $P < 0.05 = 9.5$, $P < 0.01 = 13.3$, $P < 0.001 = 18.4$). Species within a given year followed by the same letter do not differ ($P < 0.05$) among different treatments according to nonparametric Scheffe' range tests.

	Year	Control	TREATMENT				H
			Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	
Stratum C (>300 cm tall)							
Alnus tenuifolia	1986	0	0	0	0	0	-[1]
	1988	0	0	80 (301)	0	0	-
	1993	0	0	213 (329)	0	0	-
Betula papyrifera	1986	0	0	0	13 (620)	27 (700)	-
	1988	14 (500)	13 (308)	0	0	0	-
	1993	187 (410)	40 (330)	107 (330)	0	14 (310)	-
Populus balsamifera	1986	0	0	0	13 (450)	14 (700)	-
	1988	0	0	0	0	122 (360)	-
	1993	0	13 (340)	0	13 (320)	0	-
Populus tremuloides	1986	0	13 (675)	13 (750)	0	27 (925)	-
	1988	895 (321)	1,398 (350)	1,620 (345)	0	1,397 (380)	-
	1993	10,360 (505)c	1,880 (475)b	626 (410)a	733 (347)ab	190 (328)	342
Salix spp.	1986	0	39 (800)	93 (397)	27 (565)	0	-
	1988	0	175 (350)	220 (325)	0	0	-
	1993	907 (347)	480 (349)	400 (359)	53 (332)	0	-
Total Number of Stems per Hectare in "C" Stratum	1986	0	52	106	53	68	-
	1988	909	1,586	1,920	0	1,519	-
	1993	11,454c	2,413b	1,346ab	799ab	204a	326
Stratum B (>150 to 300 cm tall)							
Alnus crispa	1986	0	131 (232)	0	480 (178)	0	-
	1988	0	40 (165)	100 (178)	0	0	-
	1993	0	80 (160)	0	27 (159)	41 (210)	-
Alnus tenuifolia	1986	0	26 (151)	133 (230)	0	0	-
	1988	0	0	120 (163)	0	0	-
	1993	0	0	40 (263)	0	0	-
Amelanchier alnifolia	1986	0	39 (177)	133 (161)	267 (180)	14 (160)	-
	1988	0	0	100 (168)	0	0	-
	1993	427 (184)	27 (165)	27 (155)	13 (153)	0	-
Betula papyrifera	1986	160 (163)	420 (167)	413 (175)	253 (191)	475 (174)	-
	1988	298 (191)	336 (187)	600 (192)	0	271 (196)	-
	1993	67 (222)	240 (196)	53 (203)	0	434 (211)	
Cornus stolonifera	1986	0	0	40 (156)	0	0	-
	1988	0	0	40 (157)	0	0	-
	1993	13 (158)	0	0	0	0	-

Table 13. Continued.

	Year	Control	TREATMENT				H
			Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	
Populus balsamifera	1986 1988 1993	0 0 13(158)	761(191) 309(203) 133(187)	387(202) 200(200) 0	1,347(193) 0 307(201)	664(189) 705(196) 434(186)	- - -
Populus tremuloides	1986 1988 1993	9,840 (191)a 14,876 (233)c 5,213 (244)c	16,748 (210)c 9,351 (227)b 3,133 (220)b	13,720(212)abc 5,826 (239)b 1,320 (220)a	14,626 (212)bc 26 (166)a 3,973 (215)b	11,091 (207)ab 7,525 (231)b 3,932 (196)b	29 273 94
Prunus pensylvanica	1986 1988 1993	13 (100) 0 40 (190)	0 0 0	0 0 0	53 (106) 0 0	0 0 0	- - -
Prunus virginiana	1986 1988 1993	0 14(168) 0	0 0 0	0 0 0	0 0 0	0 0 0	- - -
Rosa acicularis	1986 1988 1993	0 0 0	0 0 0	13 (181) 0 0	13 (151) 0 0	0 0 0	- - -
Salix spp.	1986 1988 1993	1,360 (172)a 2,142 (201)ab 2,640 (205)b	1,377 (205)a 1,398 (179)abc 1,347 (207)a	3,173 (234)a 3,460 (199)bc 880 (213)a	2,987 (200)a 80 (180)a 2,507 (210)ab	3,593 (174)a 5,383 (187)c 6,441 (172)b	24 62 49
Shepherdia canadensis	1986 1988 1993	0 0 0	0 0 0	0 0 0	27 (176) 0 0	27 (185) 0 0	- - -
Viburnum edule	1986 1988 1993	13 (160) 0 0	0 0 0	27 (169) 0 0	67 (156) 0 0	0 0 0	- - -
Total Number of Stems per Hectare in "B" Stratum	1986 1988 1993	11,386a 17,330b 8,413c	19,502b 11,434b 4,960b	18,039b 10,446b 2,320a	20,120b 106a 6,827b	15,864b 13,884b 11,282c	31 262 114

Stratum A (>50 cm tall)							
Alnus crispa	1986 1988 1993	0 0 0	708 (96) 121 (99) 93 (91)	13 (121) 360 (85) 0	1,627 (98) 140 (71) 67 (108)	0 14 (113) 0	- - -
Alnus tenuifolia	1986 1988 1993	0 0 0	184 (97) 0 0	80 (91) 60 (60) 40 (85)	0 0 0	0 0 0	- - -
Amelanchier alnifolia	1986 1988 1993	1,000 (72)a 1,369 (75)ab 2,040 (93)a	1,836 (73)a 1,412 (78)ab 1,280 (93)a	2,587 (79)a 2,600 (79)b 413 (96)a	3,453 (82)a 120 (56)a 1,653 (82)a	1,397 (70)a 1,139 (78)ab 1,708 (79)a	11 32 18
Betula glandulosa	1986 1988 1993	40 (82) 0 0	0 0 0	0 0 13 (60)	0 0 0	0 0 0	- - -
Betula papyrifera	1986 1988 1993	440 (93) 217 (116) 120 (109)	630 (101) 457 (97) 120 (102)	560 (99) 600 (116) 200 (83)	240 (103) 20 (51) 93 (155)	719 (99) 353 (111) 203 (130)	- - -
Cornus stolonifera	1986 1988 1993	653 (66)a 827 (65)a 1,307 (82)a	1,993 (68)a 1,600 (67)ab 2,520 (74)a	5,440 (77)a 6,660 (77)b 2,786 (70)a	5,067 (70)a 20 (51)a 667 (72)a	1,993 (71)a 1,925 (64)ab 2,346 (73)a	21 70 18

Table 13. Continued.

	Year	Control	TREATMENT: Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H
Lonicera dioica	1986	280 (60)	0	0	0	0	-
	1988	0	0	0	0	0	-
	1993	373 (81)	653 (64)	387 (66)	333 (64)	583 (64)	-
Lonicera involucrata	1986	120 (55)	0	0	13 (54)	0	-
	1988	0	13 (53)	0	0	0	-
	1993	787 (68)a	2,093 (63)a	2,426 (60)a	640 (57)a	1,288 (57)a	21
Populus balsamifera	1986	213 (67)a	1,128 (102)ab	533 (98)ab	2,120 (102)ab	3,458 (98)b	47
	1988	258 (101)a	363 (85)ab	60 (130)a	300 (61)a	1,654 (93)b	76
	1993	53 (118)	93 (111)	0	253 (100)	949 (110)	-
Populus tremuloides	1986	25,733 (103)ab	27,725 (102)b	22,187 (102)ab	21,120 (105)a	22,522 (103)a	20
	1988	14,807 (105)b	14,871 (96)b	20,300 (99)b	5,620 (62)a	16,475 (96)b	173
	1993	2,093 (108)ab	3,120 (101)b	1,253 (107)a	5,480 (97)c	7,105 (103)c	173
Prunus pensylvanica	1986	40 (67)	26 (55)	0	0	0	-
	1988	0	0	0	0	0	-
	1993	53 (80)	0	0	0	0	-
Prunus virginiana	1986	53 (79)	13 (55)	0	0	27 (52)	-
	1988	41 (66)	13 (72)	0	0	14 (50)	-
	1993	200 (100)	27 (88)	0	0	41 (57)	-
Ribes lacustre	1986	53 (70)	66 (53)	53 (58)	0	0	-
	1988	0	40 (55)	360 (83)	0	0	-
	1993	0	0	13 (64)	13 (52)	0	-
Ribes oxyacanthoides	1986	373 (61)	813 (61)	1,747 (68)	1,427 (60)	1,275 (63)	-
	1988	732 (63)	484 (62)	840 (69)	0	949 (60)	-
	1993	440 (62)a	2,387 (62)a	2,759 (60)a	533 (57)a	1,139 (60)a	32
Ribes triste	1986	0	0	160 (63)	0	0	-
	1988	0	13 (55)	20 (77)	0	0	-
	1993	0	0	760 (56)	0	14 (52)	-
Rosa acicularis	1986	6,280 (60)	5,167 (61)	5,480 (65)	7,800 (65)	4,380 (60)	8
	1988	6,902 (61)bc	3,832 (61)b	6,920 (67)c	100 (56)a	6,969 (63)c	193
	1993	12,040 (68)c	8,039 (63)b	3,053 (77)a	5,640 (61)b	6,129 (60)b	121
Rubus idaeus	1986	13 (67)	184 (67)	280 (55)	107 (62)	41 (57)	-
	1988	41 (64)	13 (65)	560 (67)	0	41 (53)	-
	1993	0	0	120 (59)	0	0	-
Salix spp.	1986	4,453 (92)a	3,620 (97)a	6,773 (102)ab	6,600 (113)ab	18,251 (106)b	20
	1988	5,980 (92)b	5,015 (94)b	6,320 (96)b	4,640 (85)a	18,237 (105)c	98
	1993	5,520 (98)bc	4,466 (100)ab	2,934 (95)a	6,120 (96)c	20,705 (114)d	104
Shepherdia canadensis	1986	333 (59)	459 (63)	693 (64)	987 (80)	380 (67)	-
	1988	380 (62)	713 (77)	660 (86)	0	800 (68)	-
	1993	1,947 (80)	320 (81)	253 (64)	227 (76)	963 (70)	-
Spiraea betulifolia	1986	0	0	0	13 (50)	0	-
	1988	0	0	0	0	0	-
	1993	0	0	0	0	0	-
Symphoricarpos albus	1986	13 (50)	0	40 (54)	93 (53)	27 (51)	-
	1988	0	0	0	0	0	-
	1993	107 (57)	360 (53)	693 (57)	13 (61)	54 (53)	-
Viburnum edule	1986	427 (66)a	2,282 (70)ab	3,520 (69)ab	4,560 (75)b	1,451 (69)ab	29
	1988	461 (58)b	861 (60)b	1,200 (65)b	0a	732 (63)c	98
	1993	1,253 (68)b	1,627 (64)ab	1,280 (69)ab	120 (56)a	203 (63)a	53

Table 13. Concluded.

	Year	Control	TREATMENT				H
			Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	
Total Number of Stems per Hectare in "A" Stratum	1986 1988 1993	40,517a 32,015b 28,333c	46,834ab 29,821 b 27,198bc	50,146ab 47,520c 19,383a	55,227b 10,960a 21,852ab	55,921b 49,302c 43,430d	20 250 122
Summary Statistics							
Total Number of Stems per Hectare	1986 1988 1993	51,903a 50,254bc 48,200c	66,388b 42,841b [2] 34,571b	68,291ab 59,886c [2] 23,049a	75,400 b [2] 10,066a 29,478ab	71,853b 64,705c [2] 54,916c	30 263 168
Total Stem Length (m/ha)	1986 1988 1993	58,394a 71,493bc 98,200d	83,953b 56,944b [2] 42,267b	84,068b 78,042bc [2] 24,608a	92,229b [2] 8,083a 35,587ab	85,816b 80,155c [2] 62,997c	33 261 240
Net in m/ha	1993	+68%	-49%	-71%	-61%	-26%	-
Number of Plots	1986 1988 1993	120 118 120	122 119 120	120 80 120	120 120 120	118 118 118	- - -

[1] Treatments not compared because of low stem frequencies.
[2] Lines in the table cells separate pre- and post-treatment periods.

Table 14. Species composition and median (average) percent cover of vegetation in Conifer Release experimental blocks by treatment. Roman numerals indicate constancy classes (CC -- Class 0 - 0%; I - 1 to 10%; II - 11 to 20%; III - 21 to 30%; IV - 31 to 40%; V - 41 to 50%; VI - 51 to 60%; VII - 61 to 70%; VIII - 71 to 80%; IX - 81 to 90%; X - 91 to 100%); a "+" indicates a value <0.55; and H values represent the results of Kruskal-Wallis tests (P <0.05 = 9.5; P <0.01 = 13.3; P <0.001 = 18.4). Cover values within each species followed by the same letter do not differ (P <0.05 level) among treatments according to nonparametric Scheffe' range tests.

	Control		Disk Trenching and 2 kg/ha Hexazinone		Disk Trenching and 4 kg/ha Hexazinone		Rome Double Disking		Disk Trenching followed by Brushsawing		H
	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Total "C" stratum	67(59)a	X	0(15)b	I	0(6)c	II	0(6)bc	II	0(+)c	I	313
Total "B" stratum	10(14)a	VII	10(14)a	IV	0(8)b	IV	0(14)a	V	10(15)a	VI	14
Total "A" stratum	19(20)a	X	10(14)b	IX	5(10)b	VII	12(14)b	IX	23(25)a	X	79
Total Graminoid cover	15(20)a	X	5(7)b	X	15(17)a	X	15(19)a	X	15(19)a	X	110
Total Forb cover	60(62)a	X	60(57)ab	X	55(55)b	X	60(62)a	X	50(52)b	X	34
Total Bryophyte cover	0(3)a	IV	30(35)a	X	5(14)bc	IX	3(9)c	VII	15(24)b	X	180
Achillea millefolium	0(+)a	III	0(1)b	V	+(1)b	VI	1(1)b	VII	+(0)a	IV	45
Achillea sibirica	0(+)a	I	0(+)a	I	0a	0	0(+)a	II	0(+)a	I	13
Actaea rubra	0(+)	II	0(+)	II	0(+)	II	0(+)	I	0(+)	II	9
Agropyron trachycaulum	0(+)a	II	1(2)b	III	4(7)c	VIII	+(1)b	VI	0(+)a	III	194
Agrostis scabra	0(+)a	I	0(+)b	V	0(1)b	V	0(+)a	III	0(+)a	II	94
Alnus crispa - A	0	0	0(+)	I	0	0	0	0	0	0	4
Alnus crispa	0	0	0(+)	I	0	0	0	0	0	0	4
Alnus tenuifolia - C	0	0	0	0	0(1)	I	0	0	0	0	8
Alnus tenuifolia - B	0	0	0	0	0(+)	I	0	0	0	0	8
Alnus tenuifolia	0	0	0	0	0(+)	I	0	0	0	0	4
Amelanchier alnifolia - B	0(1)	I	0(+)	I	0	0	0(+)	I	0	0	6
Amelanchier alnifolia - A	0(1)	II	0(+)	I	0(+)	I	0(1)	I	0(1)	I	6
Amelanchier alnifolia	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	6
Arabis hirsuta	0	0	0	0	0	0	0(+)	I	0	0	4
Aralia nudicaulis	0(2)a	IV	0(1)a	IV	0(2)a	IV	0(1)b	IV	0(1)ab	IV	20
Arctostaphylos uva-ursi	0(+)	I	0	0	0	0	0	0	0	0	4
Arnica cordifolia	0(+)	I	0	0	0(+)	I	0(+)	I	0(+)	I	2
Aster ciliolatus	2(4)a	VIII	3(4)a	VIII	1(3)b	VI	3(5)a	VIII	2(3)a	VIII	19
Aster conspicuus	6(7)a	VII	1(4)b	VI	0(1)c	III	1(3)b	VI	2(3)b	VI	83
Betula glandulosa - A	0	0	0	0	0(+)	I	0	0	0	0	4
Betula papyrifera - C	0(1)a	I	0a	0	0(+)a	I	0a	0	0(+)a	I	16
Betula papyrifera - B	0	0	0(1)	I	0(+)	I	0(+)	I	0(1)	I	8
Betula papyrifera - A	0	0	0(+)	I	0(+)	I	0(+)	I	0(+)	I	3
Betula papyrifera	0(+)	I	0(+)	I	0(+)	I	0	0	0(+)	I	4
Bromus ciliatus	0(+)a	II	+(1)b	VI	2(5)c	VIII	+(1)b	VI	0(+)a	III	200

Table 14. Continued.

	Control		Disk Trenching and 2 kg/ha Hexazinone		Disk Trenching and 4 kg/ha Hexazinone		Rome Double Disking		Disk Trenching followed by Brushsawing		H
	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Bromus inermis	0	0	0	0	0	0	0(+)	I	0(+)	I	5
Calamagrostis canadensis	15(18)a	X	1(3)b	VI	0(2)b	III	14(16)a	II	15(17)a	X	304
Carex aenea	0(+)	I	0	0	0(+)	I	0	0	0(+)	I	2
Carex brunnescens	0a	0	0a	0	0(+)a	II	0a	0	0a	0	40
Carex macloviana	0a	0	0a	0	0(+)a	I	0a	0	0a	0	12
Carex praticola	0	0	0	0	0(+)	I	0	0	0	0	8
Carex spp.	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	7
Castilleja miniata	0(+)a	II	0(I)a	III	0(2)b	V	0(+)a	II	0(1)ab	III	45
Cerastium arvense	0a	0	0(+)a	I	0a	0	0a	0	0(+)a	I	23
Cornus canadensis	0(1)bc	V	2(3)a	VII	1(2)ab	VI	0(+)d	II	0(+)cd	III	112
Cornus stolonifera - A	0(1)	I	0(1)	I	0(1)	II	0(1)	I	0(1)	II	5
Cornus stolonifera	0(+)	I	0(1)	I	0(+)	II	0(+)	I	0(+)	I	4
Corylus cornuta	0(+)	I	0(+)	I	0	0	0	0	0	0	3
Crepis tectorum	0a	0	0(+)a	I	0(+)a	IV	0a	0	0a	0	19
Disporum trachycarpum	0(+)	I	0(+)	I	0	0	0(+)	I	0	0	6
Elymus innovatus	0(1)a	I	0a	0	0a	0	0(+)a	I	0(1)a	I	13
Epilobium angustifolium	8(8)bc	VIII	10(11)b	X	4(5)d	VIII	13(14)a	II	5(6)cd	IX	119
Epilobium ciliatum	0a	0	0(+)a	I	0(+)a	II	0a	0	0(+)a	I	23
Equisetum arvense	0a	0	0(+)a	I	0a	0	0a	0	0a	0	12
Equisetum sylvaticum	0(+)a	I	0(I)ab	IV	+(1)a	VI	0(+)c	I	0(+)bc	II	112
Festuca rubra	0	0	0	0	0(+)	I	0	0	0(+)	I	5
Fragaria virginiana	4(6)b	VII	1(2)c	VI	0(1)d	IV	10(13)a	X	7(9)ab	X	235
Galeopsis tetrahit	0a	0	0(+)a	I	0(+)a	I	0(+)a	I	0a	0	12
Galium boreale	2(2)b	IX	4(6)a	IX	10(12)a	IX	2(2)b	IX	1(2)b	VIII	111
Galium triflorum	0(+)a	I	0(+)a	I	0(+)a	II	0(+)a	I	0(+)a	I	16
Gentianella amarella	0a	0	0a	0	0(+)a	II	0(+)a	I	0(+)a	I	21
Geum aleppicum	0	0	0	0	0(+)	I	0	0	0	0	5
Geum macrophyllum	0(+)a	I	0(+)a	II	0(+)a	III	0(+)a	I	0(+)a	I	36
Halenia deflexa	0a	0	0a	0	0(+)a	I	0a	0	0a	0	12
Heracleum lanatum - A	0(+)	I	0	0	0	0	0(+)	I	0(+)	I	2
Heracleum lanatum	0(+)	I	0(+)	I	0	0	0(+)	I	0(+)	I	7
Hieracium umbellatum	0(+)a	II	0(+)a	II	0a	0	0(+)a	II	0(+)a	II	19
Hordeum jubatum	0	0	0	0	0(+)	I	0	0	0	0	4
Juncus balticus	0a	0	0a	0	0(+)a	0	0a	0	0(+)a	I	12
Juncus vaseyi	0	0	0	0	0	0	0(+)	I	0	0	4
Lathyrus ochroleucus	2(2)b	VII	1(2)ab	VI	1(2)ab	I	0(1)a	IV	1(2)b	VII	29
Ledum groenlandicum	0	0	+(0)	I	0	0	0	0	0	0	4

Table 14. Continued.

	Control		Disk Trenching and 2 kg/ha Hexazinone		Disk Trenching and 4 kg/ha Hexazinone		Rome Double Disking		Disk Trenching followed by Brushsawing		H
	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Linnaea borealis	0(1)a	IV	0(+)ab	II	0(+)b	I	0(+)b	I	0(1)ab	II	70
Lonicera dioica - A	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	2
Lonicera dioica	0(1)	II	0(+)	I	0(+)	II	0(+)	I	0(+)	II	5
Lonicera involucrata - A	0(+)a	I	0(1)a	I	0(1)a	II	0(+)a	I	0(+)a	I	14
Lonicera involucrata	0(2)	II	0(2)	I	0(1)	II	0(1)	II	0(2)	II	6
Maianthemum canadense	0(+)ab	III	0(1)a	IV	0(1)abc	III	0(+)c	I	0(+)bc	II	52
Melilotus officinalis	0	0	0	0	0(+)	I	0	0	0	0	8
Mertensia paniculata	1(3)a	VII	1(2)ab	VI	0(1)a	IV	1(2)ab	VI	1(2)a	VII	29
Mitella nuda	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	5
Moehringia lateriflora	0a	0	0(+)a	I	0(1)a	II	0a	0	0a	0	68
Oryzopsis asperifolia	0(+)a	I	0a	0	0a	0	0(+)a	I	0(+)a	I	11
Petasites palmatus	2(4)a	VII	2(4)a	VII	0(1)b	III	4(4)a	VIII	1(3)a	VI	80
Petasites vitifolius	0(+)a	I	0a	0	0(+)a	I	0a	0	0(+)a	I	20
Phleum pratense	0a	0	0(+)a	I	0(+)a	I	0(+)a	I	0(+)a	I	13
Poa palustris	0(+)a	I	0(+)a	II	0(1)a	II	0(+)a	I	0(+)a	I	34
Populus balsamifera - C	0	0	0(+)	I	0	0	0(+)	I	0	0	8
Populus balsamifera - B	0(+)a	I	0(+)a	I	0a	0	0(1)a	I	0(1)a	I	13
Populus balsamifera - A	0a	0	0(+)a	I	0a	0	0(+)a	I	0(1)a	II	31
Populus balsamifera	0(+)	I	0(+)	I	0	0	0	0	0(+)	I	6
Populus tremuloides - C	60(56)a	X	0(12)b	IV	0(4)c	II	0(4)c	II	0(+)c	I	323
Populus tremuloides - B	0(9)a	V	0(9)a	V	0(3)b	II	0(8)ab	IV	0(7)ab	IV	27
Populus tremuloides - A	0(2)a	III	0(3)ab	IV	0(2)a	III	0(5)bc	V	5(9)c	VII	71
Populus tremuloides	0(+)a	I	0(+)a	II	0(+)a	I	0(+)a	I	0(1)a	III	30
Potentilla norvegica	0a	0	0(+)a	I	0(+)a	II	0(+)a	I	0(+)a	I	29
Prunus pensylvanica - B	0(+)	I	0	0	0	0	0	0	0	0	8
Prunus pensylvanica - A	0(+)	I	0	0	0	0	0	0	0	0	4
Prunus virginiana - B	0(+)	I	0	0	0	0	0	0	0	0	4
Prunus virginiana - A	0(+)	I	0	0	0	0	0	0	0(+)	I	5
Prunus virginiana	0	0	0(+)	I	0	0	0	0	0(+)	I	3
Pyrola asarifolia	0(+)a	II	0(+)a	II	0(+)a	I	0(+)a	I	0(+)a	I	24
Ribes lacustre - A	0a	0	0a	0	0a	0	0(+)a	I	0a	0	4
Ribes lacustre	0	0	0(+)	I	0	0	0(+)	I	0	0	5
Ribes oxyacanthoides - A	0(+)a	II	0(+)a	I	0(1)a	II	0(+)a	I	0(+)a	I	10
Ribes oxyacanthoides	0(+)	I	0(1)	III	0(1)	III	0(1)	II	0(1)	III	8
Ribes triste - A	0	0	0	0	0(+)	I	0	0	0	0	8
Rosa acicularis - A	8(10)a	VI	0(3)b	V	0(1)b	III	0(2)b	IV	0(2)b	IV	99
Rosa acicularis	10(11)a	X	8(9)a	IX	1(3)b	VII	8(8)a	X	7(8)a	X	106

Table 14. Continued.

	Control		Disk Trenching and 2 kg/ha Hexazinone		Disk Trenching and 4 kg/ha Hexazinone		Rome Double Disking		Disk Trenching followed by Brushsawing		H
	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	Percent Cover	CC	
Rubus idaeus	0(1)a	III	0(+)a	II	0(1)a	II	0(1)a	IV	0(1)a	II	21
Rubus pubescens	2(3)ab	VII	1(2)b	VI	0(1)c	IV	2(3)ab	VIII	3(4)a	VIII	78
Salix spp. - C	0(4)a	I	0(2)a	I	0(1)a	I	0(2)a	I	0a	0	15
Salix spp. - B	0(3)a	I	0(2)a	I	0(2)a	I	0(1)a	I	0(6)a	II	13
Salix spp. - A	0(4)a	IV	0(2)a	III	0(2)a	II	0(4)a	III	4(11)b	VI	59
Salix spp.	0(1)a	II	0(+)a	I	0(+)a	II	0(+)a	III	0(1)a	IV	19
Sanicula marilandica	0(+)	I	0(+)	I	0	0	0	0	0(+)	I	3
Schizachne purpurascens	0	0	0(+)	I	0	0	0	0	0(+)	I	9
Senecio pauperculus	0	0	0	0	0(+)	I	0	0	0	0	4
Shepherdia canadensis - A	0(1)a	I	0(+)a	I	0	0	0(+)a	I	0(+)a	I	10
Shepherdia canadensis	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	3
Smilacina racemosa	0(+)	I	0(+)	I	0	0	0(+)	I	0(+)	I	3
Smilacina stellata	0(+)	I	0	0	0(+)	I	0(+)	I	0(+)	I	1
Solidago canadensis	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0(+)	I	6
Sonchus spp.	0	0	0	0	0(+)	I	0	0	0	0	4
Spiraea betulifolia	0(1)a	III	0(+)a	I	0a	0	0(+)a	I	0(+)a	II	40
Symphoricarpos albus - A	0(+)	I	0(+)	I	0(+)	I	0(+)	I	0	0	6
Symphoricarpos albus	+(2)a	VI	+(3)a	VI	1(4)b	VI	0(1)a	V	0(1)a	IV	88
Taraxacum ceratophorum	0(+)a	I	0(1)cd	V	0(1)d	III	0(1)bc	V	0(+)ab	III	106
Taraxacum officinale	0(+)a	I	0(1)b	V	1(3)b	VI	0(+)a	II	0(+)a	I	179
Thalictrum occidentale	0(+)a	I	0(+)a	I	0(+)b	I	0(+)a	I	0(+)a	I	222
Trifolium repens	0(+)a	I	0(1)ab	III	0(7)c	IV	0(1)bc	IV	0(1)abc	III	55
Vaccinium caespitosum	0(+)	I	0	0	0	0	0	0	0	0	4
Vaccinium myrtilloides	0	0	0(+)	I	0	0	0	0	0	0	4
Vaccinium vitis-idaea	0	0	0(+)	I	0	0	0	0	0	0	4
Viburnum edule - A	0(+)a	I	0(1)a	II	0(+)a	I	0a	0	0a	0	23
Viburnum edule	0(2)a	IV	0(1)a	IV	0(1)a	III	0(+)b	II	0(+)b	II	41
Vicia americana	3(4)b	VIII	1(2)a	VIII	2(3)ab	VIII	3(4)b	IX	3(4)b	IX	26
Viola adunca	0	0	0(+)	I	0	0	0	0	0	0	4
Viola canadensis	0(+)a	I	0a	0	0a	0	0(+)a	I	0(+)a	I	27
Viola renifolia	0(+)a	I	0(+)a	I	0(+)a	I	0a	0	0a	0	22
Number of Samples	120		120		120		120		118		

Table 15. Characteristics of the vegetation in the Conifer Release experimental blocks by treatment based on 1993/4 inventory data.

Treatment	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing
TOTAL PERCENT COVER based on the summation of average cover values for individual taxa	194	126	115	127	127
AVERAGE NUMBER OF TAXA PER PLOT based on a 1 x 1 m plot for herbs and a 2.5 x 2.5 m plot for woody plants >50 cm tall	18	21	18	18	19
SPECIES RICHNESS BY TREATMENTS (Total number of species)	69	75	74	69	74
SPECIES RICHNESS AMONG TREATMENT BLOCKS (Mean number and standard deviation)	50±8	61±2	59±1	54±3	56±2
SIMPSON'S INDEX (λ)[1]	0.11	0.04	0.04	0.06	0.05
SHANNON-WIENER'S INDEX (H')[1]	2.00	1.87	1.79	1.70	1.75
CZEKANOWSKI'S INDEX OF SIMILARITY[1] based on average cover values and includes taxonomic separations according to height (e.g., A, B, and C stratum)					
Control	-	61.8	34.6	61.5	60.4
Disk Trenching and 2 kg/ha Hexazinone	-	-	55.9	68.8	59.7
Disk Trenching and 4 kg/ha Hexazinone	-	-	-	44.6	40.8
Rome Double Disking	-	-	-	-	77.0
NUMBER OF PLOTS	120	120	120	120	118

[1] For formula see Sections 3.2.2 (Czekanowski's Index of Similarity) and Section 3.3.3 (Simpson's and Shannon-Wiener's Indices).

Only stem density data were collected at the time of plot establishment due to a lack of resources. Therefore, botanical changes that may have occurred within or between control and treatment plots prior to 1993 cannot be evaluated. In general, the vegetation was similar to the Site Preparation experiment blocks.

In summary, the control plot vegetation was dominated by five meter tall *Populus tremuloides* trees with an A-stratum composed of *Rosa acicularis*. The understory vegetation was composed of a mixture of herbs and low-growing shrubs.

4.2.1.2 Disk Trenching and 2 kg/ha Hexazinone Plots

This plot was initially disk trenched in May 1987 and then treated with 2 kg/ha of hexazinone approximately two years later in May 1989. The vegetation was dominated by a B- and open-canopied C-stratum in 1993 (Photograph 7B). *Populus tremuloides* was most common in the B-stratum (150 to 300 cm) with a density of 3,133 stem/ha, but an additional 1,880 stems reached a typical height of 475 cm. Overall plant cover within both the B- and C-strata was ten percent (Table 14).

Of the 27,198 stems/ha that occurred within the A-stratum, *Rosa acicularis*, *Salix* spp, and *Populus tremuloides* composed the majority (i.e., 57 percent). In 1986, 66,388 woody plant stems greater than 50 cm tall occurred in this treatment plot. Density decreased by 35 percent within three years and decreased by an additional 13 percent by 1993 following the application of 2 kg/ha of hexazinone for a net density of 34,571 stems/ha in 1993. The pattern and degree of change was similar for the total length of woody stems in the treatment. The largest losses in stem numbers following chemical treatment occurred in *Populus tremuloides* in the B- and A-strata (i.e., 17,969 stems/ha), while large increases occurred in the A-stratum among shrubs such as *Lonicera involucrata* (increased from 13 to 2,093 stems/ha between 1988 and 1993 or 161x increase), *Ribes oxyacanthoides* (5x), *Rosa acicularis* (2x), and *Viburnum edule* (2x) (Table 13).

Forbs and shrubs less than 50 cm tall dominated the herb stratum with 92 percent of its overall cover (Table 14). *Epilobium angustifolium* (median cover 10 percent), *Rosa acicularis* (8 percent), *Galium boreale* (4 percent), and *Aster ciliolatus* (3 percent) were among the most common species. In addition, approximately 30 percent of the ground surface was covered with bryophytes. Total species cover was 126 percent with the majority of cover represented by plants less than 150 cm tall.

A total of 75 vascular plant species were found within this treatment in 1993, but only 61 species occurred in each of the three replicate treatment plots. An average of 21 taxa were normally encountered in individual quadrants. Percent cover was relatively evenly distributed among the species that occurred in the vegetation based on Simpson's and Shannon-Wiener's Index values (Table 15). A comparison of plant taxa cover values suggests that approximately 90 percent of the total vegetation cover was concentrated within 40 percent of the flora.

In 1993, this vegetation was composed of a 150 to 300 cm tall very open-growing *Populus tremuloides* stand with a well developed herb stratum.

Photograph 7. Conifer Release Experiment - Disk Trenching and 2 kg/ha Hexazinone Plots.

Photograph 7A - Vegetation conditions in July 1989 or approximately two months (May 1989) after treatment with 2 kg/ha of hexazinone. These plots were disk trenched in May 1987.

Photograph 7B - In July 1993 or approximately four years after chemical treatment with 2 kg/ha of hexazinone, the vegetation contained patches of woody vegetation and open areas dominated by herbs. Increments on scale are ten centimeters long.

4.2.1.3 Disk Trenching and 4 kg/ha Hexazinone Plots

The vegetation within this treatment in 1993 was dominated by a very open-growing (median cover 5 percent) A-stratum with a moderately well developed herb stratum. Although trees greater than 300 cm in height occurred within the plots (Table 14 and Photograph 8), these represented remnant strips of untreated vegetation that were apparently missed when the 4 kg/ha of hexazinone was applied in 1988. *Populus tremuloides* in the C- and B-strata (i.e., >150 cm) had a combined density of 1,946 stems/ha, or eight percent of the number of stems/ha. The A-stratum was dominated by *Salix* spp. and *Populus tremuloides* which had a typical height between 95 and 110 cm. *Rosa acicularis, Cornus stolonifera, Ribes oxyacanthoides*, and *Viburnum edule* were also common but reached a general height of only 77, 70, 60, and 69 cm, respectively. These four species represented half of all shrubs that occurred in the A-stratum. Total stem densities decreased between 1986 and 1988 from 68,291 to 59,886 per hectare (12 percent). Four years after treatment with 4 kg/ha of hexazinone, total stem densities were reduced by an additional 61 percent relative to 1988 levels (Table 13). The total length of woody stems showed a similar pattern and level of decrease between the 1986 and 1993 period. Treatment with 4 kg/ha of hexazinone reduced the density of woody plants in the C- and B-strata, primarily *Populus tremuloides*; however, it also had a substantial negative impact on the frequency of shrubs in the A-stratum, except for *Lonicera involucrata, Ribes oxyacanthoides, Ribes triste*, and *Viburnum edule* which increased their numbers (Table 13).

The herb stratum was dominated by forbs with graminoids composing only about one-fifth of its overall cover. *Epilobium angustifolium* (median cover 4 percent) and *Galium boreale* (10 percent) were the most abundant herbs in this vegetation, although other species such as *Vicia americana, Taraxacum officinale, Symphoricarpos albus,* and *Cornus canadensis* were also common. *Agropyron trachycaulum* and *Bromus ciliatus* were the dominant graminoids in the disk trenched plots treated with 4 kg/ha hexazinone.

Seventy-four species were found among the three treatment plots in 1993. An average of 59 species occurred in individual treatment plots. Approximately 18 taxa were normally encountered in each subplot quadrant during sampling. Percent cover was relatively evenly distributed among the species that occurred in the vegetation based on Simpson's and Shannon-Wiener's Indices (Table 15). A comparison of plant taxa cover values suggests that approximately 90 percent of the total vegetation cover was concentrated within 40 percent of the flora.

This vegetation was dominated by open-growing A-stratum composed primarily of *Populus tremuloides* and *Salix* spp., although a scattered cover of taller *Populus tremuloides* trees also occurred. These taller trees were apparently missed during chemical treatment.

Photograph 8. Conifer Release Experiment - Disk Trenching and 4 kg/ha Hexazinone Plots.

Photograph 8A - Vegetation conditions in July 1989 or approximately two months (May 1989) after treatment with 4 kg/ha of hexazinone. These plots were also disk trenched in May 1987.	

Photograph 8B - In July 1994 or five years after treatment with 4 kg/ha of hexazinone, the vegetation contains clumps of woody vegetation and patches dominated by herbs. Increments on the scale are ten centimeters long.	

4.2.1.4 Rome Double Disking Plots

The vegetation within the Rome double disking plots in 1993 or six years after treatment consisted of open-growing B-stratum dominated by shrubs with a moderately well developed herb stratum (Photograph 9). *Populus tremuloides* and *Salix* spp. with a combined density of 6,480 stem/ha composed approximately 95 percent of the woody plants found in the B-stratum of this vegetation (Table 13), but this represents a foliar cover of only 10 to 15 percent. The A-stratum was dominated by *Salix* spp. (6,120 stems/ha), *Rosa acicularis* (5,640 stems/ha), and *Populus tremuloides* (5,480 stems/ha). Rome double disking destroyed most of the woody plant stems that occurred in these treatment plots. One year after disking, however, approximately 11,080 woody stems occurred per hectare with 29,478 per hectare after six years of growth (Figure 9). This latter value represented less than 40 percent of the total density that occurred in these plots prior to treatment. Similar reduction was evident in the total length of woody stems (Table 13 and Figure 9). The majority of woody stems were *Populus tremuloides*.

The herb stratum was dominated by *Calamagrostis canadensis* (median cover 14 percent), *Epilobium angustifolium* (13 percent), *Fragaria virginiana* (10 percent), *Rosa acicularis* (8 percent), *Petasites palmatus* (4 percent), *Vicia americana* (3 percent), and *Aster ciliolatus* (3 percent). The two most abundant of these species had constancy values of less than 20 percent, which suggests their distribution was patchy but of high cover where they occurred. Total species cover within this treatment was approximately 127 percent (Table 15).

Sixty-nine species were found in the three replicate plots that formed this treatment in 1993. An average of 54 species occurred in individual treatment plots. During sampling approximately 18 taxa were normally encountered in each subplot quadrant. Percent cover was relatively evenly distributed among the species that occurred in the vegetation based on Simpson's and Shannon-Wiener's Index values (Table 15). A comparison of plant taxa cover values suggests that approximately 90 percent of the total vegetation cover was concentrated within 30 percent of the flora.

In 1993, the vegetation in this treatment consisted of an open-growing B stratum dominated by a combination of *Populus tremuloides* and *Salix* spp. The herb stratum was composed of a mixture of graminoids, forbs, and low-growing shrubs.

4.2.1.5 Disk Trenching Followed by Brushsawing Plots

The vegetation on these treatment plots consisted of an open-growing B-stratum with a moderately well developed herb stratum (Photograph 10). The B-stratum was primarily formed by *Salix* spp. and secondarily by *Populus tremuloides* which composed approximately 92 percent of all the woody stems (Table 13). The A-stratum was dominated by the same species, although they represented only two-thirds of the total number of stems. *Rosa acicularis* was also a notable species in this stratum with 6,129 stem/ha. Shrubs within the A-stratum had an overall cover of approximately 23 percent and a constancy of more than 90 percent. Approximately 10 percent shrub cover occurred in the B-stratum but its frequency of occurrence was only 50 to 60 percent. In 1986, 71,853 woody stems occurred per hectare in this treatment. This density decreased by

Photograph 9. Conifer Release Experiment - Rome Double Disking Plots.

Photograph 9A - Approximately one year after Rome double disking in May 1987, the plant cover in this treatment plot was limited with a high proportion of exposed soil. This photograph was taken in July 1988.	

Photograph 9B - In July 1993 or approximately six years after Rome double disking, the vegetation in this treatment plot consisted of scattered woody plants with a moderately well developed herb stratum . The *Pinus contorta* were planted in May 1987. Increments on the scale are ten centimeters long.	

ten percent to 64,705 stem/ha by 1988. Four years after brushsawing, total stem density levels and total stem lengths were approximately 15 and 21 percent lower, respectively, than that of the pre-treatment vegetation (Figure 9). Among the taxa most negatively impacted by brushsawing were tree species in the C- and B-strata. Other woody plants such as *Salix* spp., *Amelanchier alnifolia, Cornus stolonifera, Ribes oxyacanthoides*, and *Shepherdia canadensis* showed increased densities following treatment (Table 13).

The herb stratum was dominated by *Calamagrostis canadensis* (median cover 15 percent), *Rosa acicularis* (7 percent), *Fragaria virginiana* (7 percent), *Epilobium angustifolium* (5 percent), *Rubus pubescens* (3 percent), and *Vicia americana* (3 percent). Graminoids represented approximately one-quarter of the overall vegetation cover in the herb stratum. Bryophytes had a median cover of 15 percent.

Seventy-four species were found in the three replicate plots that formed this treatment in 1993. Approximately 56 species occurred in each individual treatment plot. During sampling approximately 19 taxa were normally encountered in each subplot quadrant. Percent cover was relatively evenly distributed among the species that occurred in the vegetation based on Simpson's and Shannon-Wiener's Indices (Table 15). A comparison of plant taxa cover values suggests that approximately 90 percent of the total vegetation cover was concentrated within 30 percent of the flora.

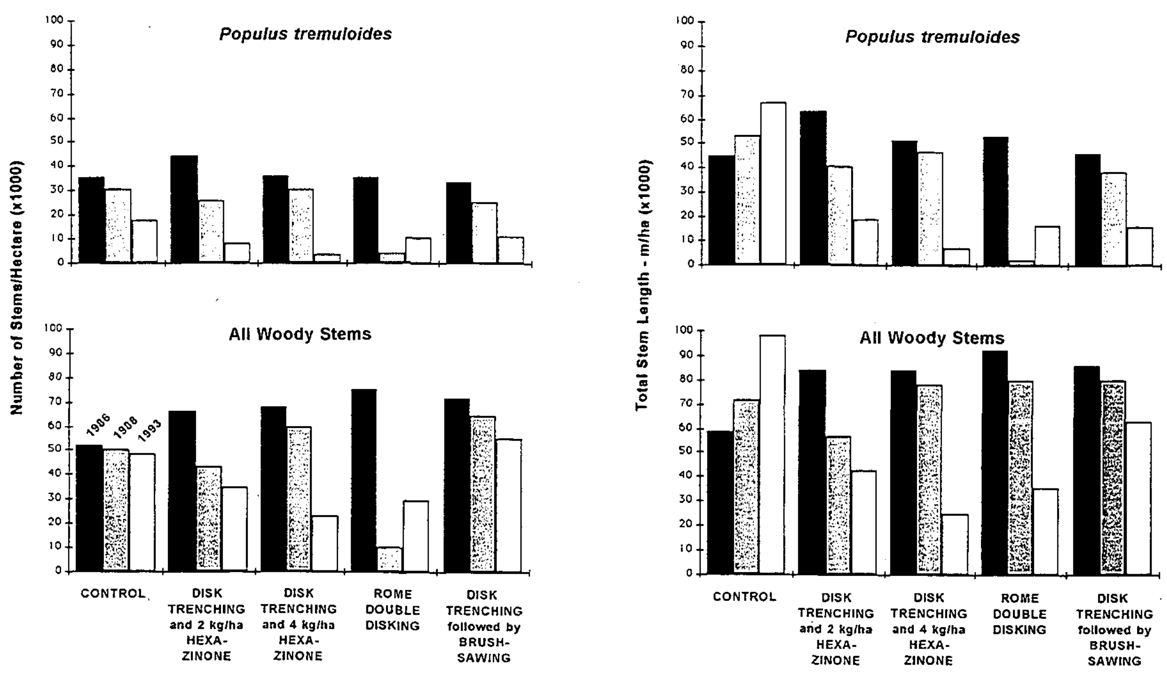
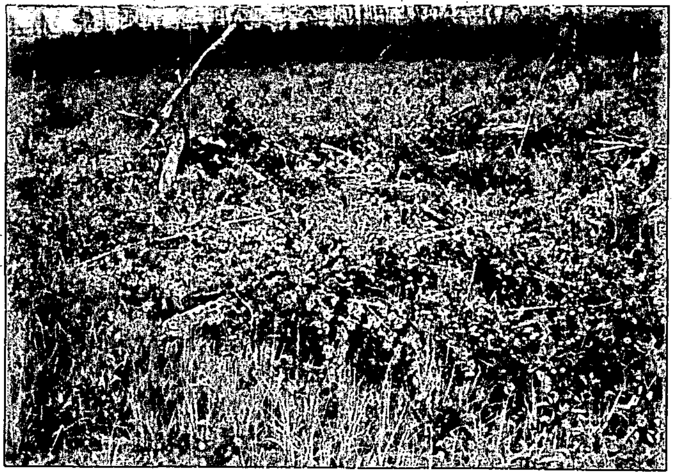


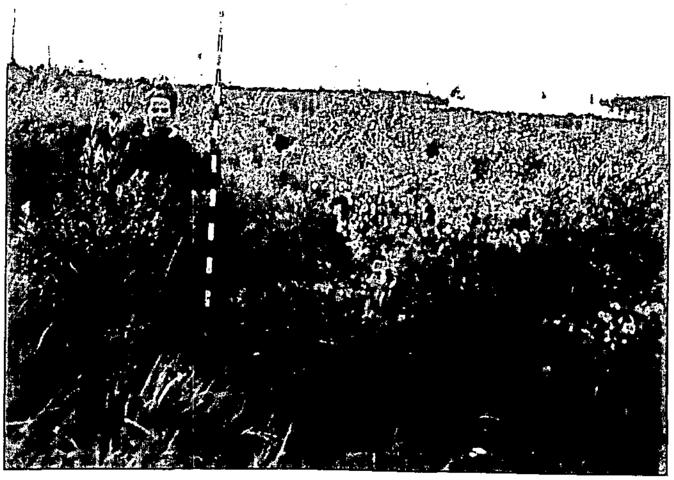
Figure 9. Total number of woody and *Populus tremuloides* stems (stem/ha) and their total lengths (m/ha) by treatment within Conifer Release experiment blocks in 1993.

Photograph 10. Conifer Release Experiment - Disk Trenching and Brushsawing Plots.

Photograph 10A - This photograph was taken July 1989 or approximately two months after brushsawing. Brushsawing reduced the vegetation in this from a regenerating *Populus tremuloides* stand to a herb dominated community. The site was disk trenched two years prior to brushsawing (May 1987).



Photograph 10B - In July 1993 or four years after brushsawing, patches of *Populus tremuloides* and *Salix* spp. were common in this treatment. Herbs occurs in the intervening spaces. Increments on the scale are ten centimeters long.



This vegetation was dominated by an open-growing stand of *Salix* spp. and *Populus tremuloides* with a height usually less than 300 cm. Graminoids and forbs dominated the herb stratum.

4.2.2 Comparison of Treatments

A comparison of median species cover values with those found in the control plots suggests that chemical and mechanical treatments had an effect on six growth-forms and 21 species (Table 16). All treatment methods reduced the overall cover of the C-stratum and woody stem densities. The woody species most significantly impacted was *Populus tremuloides*. In all treatments, the C-stratum was reduced from an average cover of 59 percent in the control plots to 15 percent or less (Table 14). Rome double disking was the more effective treatment for reducing and maintaining low levels of *Populus tremuloides* cover, when the two years difference in treatment times is taken into consideration (e.g., disking in 1987 and brushsawing or chemical treatment in 1989). The use of 4 kg/ha of hexazinone eliminated more B-stratum cover than a 2 kg/ha dose of hexazinone or mechanical treatment (Table 16). The species associated with this reduction were probably *Populus tremuloides* and *Salix* spp. based on stem numbers, although they were not specifically recognized in Table 16. All treatments except the brushsawing had a moderate reduction in the amount of foliar cover in the A-stratum. Increases occurred in bryophyte cover within the 4 kg/ha hexazinone and brushsawing treatments, and to a lesser extent in the Rome double disking plot.

Within the hexazinone treatment plots, several understory species had decreased cover values relative to the control vegetation. In addition, a trend of decreased cover occurred with increased hexazinone dosage levels (Table 16). The most severely impacted herb species was *Calamagrostis canadensis* which was reduced from a median cover value of 15 percent to less than 2 percent. *Rosa acicularis* was also substantially reduced in cover in the 4 kg/ha hexazinone treatment plots. Several species in the hexazinone treatment plots had increased cover levels relative to the control vegetation: *Achillea millefolium*, *Agropyron trachycaulum*, *Bromus ciliatus*, *Cornus canadensis*, *Galium boreale*, *Symphoricarpos albus*, and *Taraxacum officinale*. Many of these species are often associated with disturbance sites and/or open-canopied forest stands. Despite the impacts of Rome double disking and brushsawing on the structure of the native plant community, the effects of these treatments on the herbaceous vegetation were less severe than chemical treatment (Table 16). Czekanowski's Index of Similarity indicates that the 4 kg/ha hexazinone plots had the least amount of compositional similarity among the tested treatment and control plots (Table 15).

The results of a cluster analysis based on 598 quadrats from the Conifer Release treatment blocks are presented in Figure 10. Three broad groupings of quadrats were identified within the dendrogram:

A. Closed-canopied (juvenile) forest quadrats (Cluster 1)
B. Open-canopied (juvenile) forest and tall shrub quadrats (Clusters 2, 3, 4, 5, and 6)
C. Herb-dominated quadrats (Clusters 7, 8, and 9)

Table 16. Qualitative synopsis of vegetation differences among Conifer Release treatments relative to control plots based on 1993/4 data. A "-", "+", and "0" represents a decrease, increase, and little or no difference in percent cover, respectively. The occurrence of multiple symbols indicates increasing degrees of difference (e.g., two dashes represent a greater difference than a single dash).

	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing
Total "C" stratum	- - -	- - -	- - -	- - -
Total "B" stratum	0	- -	0	0
Total "A" stratum	- -	- -	- -	0
Total Graminoid cover	- -	0	0	0
Total Forb cover	0	-	0	-
Total Bryophyte cover	0	+ +	+	+ + +
Achillea millefolium	+	+	+	0
Agropyron trachycaulum	+	+ +	+	0
Aster ciliolatus	0	-	0	0
Aster conspicuus	-	-	-	-
Bromus ciliatus	+	+	+	0
Calamagrostis canadensis	- - -	- - -	0	0
Cornus canadensis	+	+	-	-
Epilobium angustifolium	0	-	+	-
Fragaria virginiana	-	-	+	+
Galium boreale	+	+ +	0	0
Lathyrus ochroleucus	0	-	-	0
Petasites palmatus	0	-	0	0
Populus tremuloides - C	- - -	- - -	- - -	- - -
Populus tremuloides - A	0	0	+	+
Rosa acicularis - A	-	-	-	-
Rosa acicularis	0	- -	0	0
Rubus pubescens	0	-	0	0
Salix spp. - A	0	0	0	+
Symphoricarpos albus	0	+	0	0
Taraxacum officinale	+	+	0	0
Vicia americana	-	-	0	0

Table 16. Continued.

		Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing
Number of woody stems/hectare	1986	+43%	+44%	+58%	+47%
	1988	-20%	+ 9%	-89%	-12%
	1992	-57%	-75%	-64%	-36%
Number of *Populus tremuloides* stems/hectare	1986	+25%	+ 1%	0%	+ 5%
	1988	-16%	-34%	-88%	-18%
	1992	-54%	-82%	-42%	-36%
Total length of woody stems (m/ha)	1986	+28%	+32%	+45%	+38%
	1988	-15%	+19%	-80%	+29%
	1992	-28%	-52%	-39%	+14%
Total length of *Populus tremuloides* stems (m/ha)	1986	+41%	+15%	+18%	+ 3%
	1988	-24%	-13%	-96%	-28%
	1992	-72%	-90%	-76%	-77%

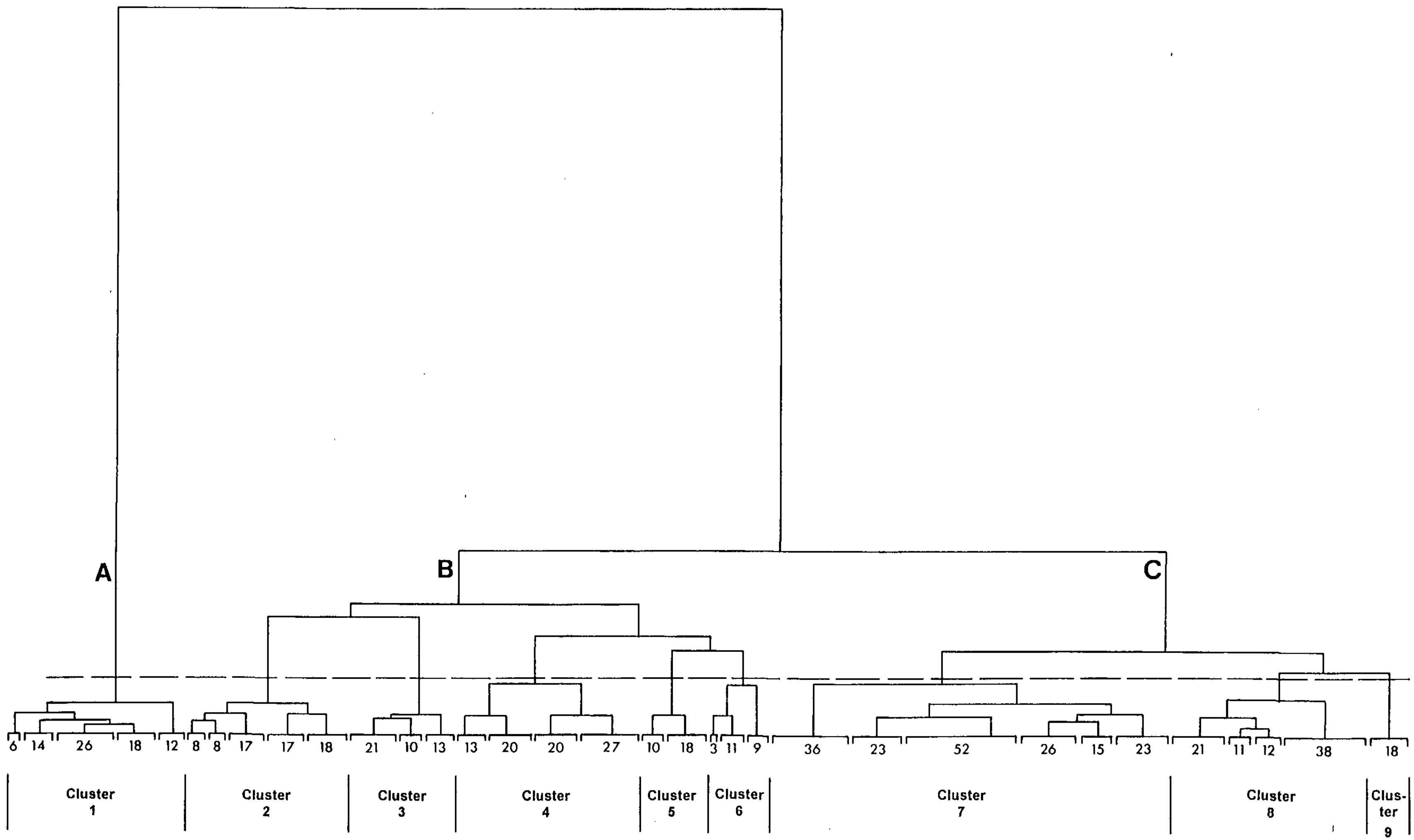


Figure 10. A cluster analysis dendrogram of vegetation plots from the Conifer Release experimental treatment blocks. The dashed line indicates the point where clustering was stopped. The numbers along the bottom of the diagram identify how many quadrats occurred within subsets of the cluster. See Appendix II for listing of subplot quadrat membership by cluster.

Group A was composed of one cluster with 76 quadrats. This cluster was compositionally distinct from the Groups B and C, since it does not fuse with them until the end of the analysis. The vegetation within this cluster consisted of quadrats with closed-canopied (80 percent) *Populus tremuloides* overstory with an understory dominated by *Rosa acicularis* and *Calamagrostis canadensis* with *Aster conspicuus* and *Epilobium angustifolium* (Table 17). This cluster was largely composed of quadrats from the control plots (Table 18).

Group B included two distinctive types of vegetation. Clusters 2, 3, and 4 have an open *Populus tremuloides* overstory canopy with an understory that contained a varied mixture of *Calamagrostis canadensis*, *Epilobium angustifolium*, *Rosa acicularis*, and several other species with less cover. The basic difference between these three clusters appears to be structural. For example, *Populus tremuloides* occurred in the C-stratum in Cluster 3, the B-stratum in Cluster 2, and the A-stratum in Cluster 4. Cluster 2 was composed of quadrats from all of the treatments, whereas Cluster 3 was composed of quadrats primarily from the control and 2 kg/ha hexazinone treatment plots. Cluster 4 was composed of plots mostly from the Rome double disking and brushsawing treatments. Clusters 5 and 6 were compositionally similar to Clusters 2, 3, and 4; but were dominated by an open-growing tall and medium height *Salix* spp. overstory (Table 17). Quadrats from various treatments and the control plots occurred in these clusters.

Group C consisted of Clusters 7, 8, and 9. The vegetation within this grouping was dominated by quadrats that lacked C- and B-strata (Table 17). Cluster 7 included 175 quadrats and was relatively distinct from the other two clusters within this grouping. Its vegetation was compositionally similar to that of Clusters 1 through 6, but lacked a woody overstory canopy. Clusters 8 and 9 are also dominated by herbaceous vegetation. *Galium boreale* and *Agropyron trachycaulum* are high cover species in Cluster 8, while *Trifolium repens* and *Agropyron trachycaulum* are diagnostic species for Cluster 9. Both of these clusters represent vegetation that has developed as a result of significant disturbance. Quadrats for Cluster 8 and 9 primarily came from the 4 kg/ha hexazinone treatment plots (Table 18).

4.2.3 Crop Seedling Characteristics

Pinus contorta -- Median seedling heights ranged from 68 to 132 cm within the Conifer Release plots. The largest amount of *Pinus contorta* height growth, basal diameter, and corresponding volume occurred in the 4 kg/ha of hexazinone and the Rome double disking treatments (Figure 11 and Table 19). Height growth in these treatments was almost double that of the control plots. Seedlings within the brushsawing treatment had somewhat better growth than those in the control plots. Survival rates for *Pinus contorta* were greatest within the Rome double disking and brushsawing treatments (84 and 88 percent respectively), and double those of the control plots (Figure 12). Chemical treatment of the vegetation improved survival rates by 50 percent.

Picea glauca -- Height growth for *Picea glauca* was similar ($P < 0.05$) among the control and three of the treatment plots at about 69 cm (Figure 11). The exception was the 2 kg/ha hexazinone treatment which had approximately 30 percent more height (Table 19). The largest basal diameters and estimated stem volumes were associated with seedlings in the hexazinone

Table 17. Median percent species composition of groups recognized within a cluster analysis of sampled quadrats from Conifer Release experimental treatment plots. H values represent Kruskal-Wallis tests to determine whether differences occurred in cover values among the clusters (P <0.05 = 23.6, P <0.01 = 29.1). Only species with significantly different (P <0.05) H values and at least one median cover greater than zero among the clusters were included in the table. Shading indicates key diagnostic species in each cluster and within groups of similar clusters (e.g., Clusters 7, 8, and 9).

	Cluster									H
	1	2	3	4	5	6	7	8	9	
	C- AND B-STRATA (>150 cm)									
Populus tremuloides - C	80	0	38	0	0	0	0	0	0	439
Populus tremuloides - B	0	30	0	0	0	0	0	0	0	246
Salix spp. - B	0	0	0	0	38	0	0	0	0	286
	A-STRATUM (>50 to 150 cm)									
Salix spp. - A	0	0	0	0	0	35	0	0	0	57
Populus tremuloides - A	0	0	0	10	0	0	0	0	0	97
Rosa acicularis - A	8	0	3	0	0	0	0	0	0	93
	HERB STRATUM (≤50 cm)									
Achillea millifolium	0	0	0	0	+	0	+	1	+	48
Agrostis scabra	0	0	0	0	0	0	0	+	1	130
Agropyron trachycaulum	0	0	0	0	0	0	+	5	4	172
Aster ciliolatus	2	3	3	3	5	4	3	0	+	32
Aster conspicuus	8	3	3	1	0	0	1	0	0	97
Bromus ciliolatus	0	0	0	0	0	0	+	3	2	161
Calamagrostis canadensis	15	6	5	30	10	10	7	0	0	243
Cornus canadensis	0	0	1	0	0	0	0	1	0	43
Epilobium angustifolium	8	10	8	10	6	6	10	4	3	66
Fragaria virginiana	2	5	4	6	3	7	5	0	0	120
Galium boreale	2	3	2	2	2	2	2	12	4	116
Mertensia paniculata	2	1	0	1	1	0	1	0	0	25
Petasites palmatus	1	2	2	2	+	3	2	0	0	54
Ribes oxyacanthoides	0	0	0	0	1	0	0	0	0	29
Rosa acicularis	10	10	8	8	8	7	8	1	+	105
Rubus pubescens	3	1	+	3	1	2	2	0	0	54
Symphoricarpos albus	1	0	0	1	0	0	0	2	0	37
Taraxacum ceratophorum	0	0	0	0	0	0	0	2	2	172
Trifolium repens	0	0	0	0	0	0	0	0	30	156
Vicia americana	2	3	2	3	3	2	2	3	1	19
Number of Samples	76	68	44	80	28	23	175	86	18	598

Table 18. Number of Conifer Release plots by treatment within each group from cluster analysis. Clusters with a substantially higher than expected frequency of quadrats are highlighted. Assessment was based on Contingency Table Analysis (See Methods Section 3.3.1).

Treatment	Cluster									No. of Samples
	1	2	3	4	5	6	7	8	9	
Control	67	14	18	9	4	4	4	0	0	120
Disk Trenching and 2 kg/ha Hexazinone	6	19	15	5	5	3	49	18	0	120
Disk Trenching and 4 kg/ha Hexazinone	2	6	6	1	5	1	16	66	17	120
Rome Double Disking	1	20	5	26	2	5	61	0	0	120
Disk Trenching followed by Brushsawing	0	9	0	39	12	10	45	2	1	118
No. of Samples	76	68	44	80	28	23	175	86	18	598

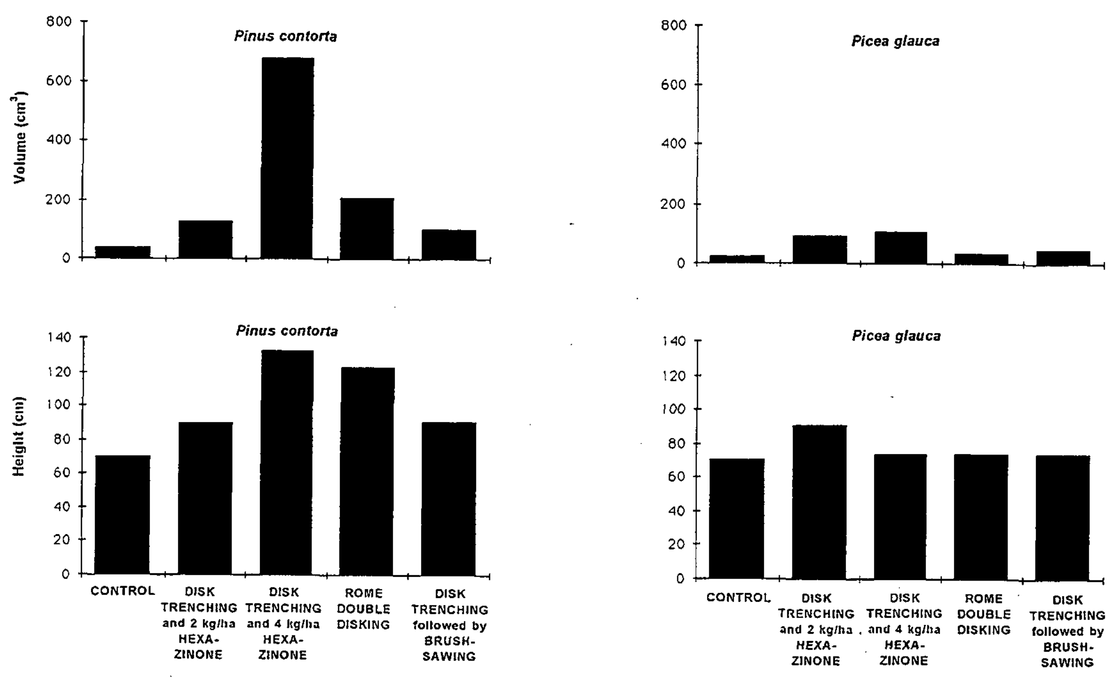


Figure 11. Average *Pinus contorta* and *Picea glauca* seedling stem volumes and heights as of 1993 by treatment in the Conifer Release experiment blocks.

Table 19. *Pinus contorta* and *Picea glauca* seedling characteristics within Conifer Release experimental treatment plots as of 1993. Q1 and Q2 values represent first and second quartile values; H and X^2 values represent the results of Kruskal-Wallis ($P < 0.05 = 9.5$, $P < 0.01 = 13.8$) and Chi-square Goodness of Fit ($P < 0.05 = 7.8$, $P < 0.01 = 11.3$) tests. Values followed by the same letter do not differ ($P < 0.05$) among the different treatments according to nonparametric Scheffe' tests.

Pinus contorta

	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H	X^2
Median (Q1, Q3) Height (cm)	68 (39-100)a	76 (50-120)a	132 (102-170)c	127 (74-157)bc	89 (57-109)ab	25	
Median (Q1,Q3) Basal Diameter (mm)	12 (8-14)a	17 (11-26)ab	39 (29-47)c	22 (13-27)b	15 (12-21)ab	70	
Median (Q1,Q3) Stem Volume (cm^3)	32 (6-51)a	57 (16-197)ab	563 (235-953)c	167 (32-302)b	52 (22-131)	61	
Median (Q1,Q3) Vigor Rating	2 (1-3)	3 (2-4)	3 (3-4)	4 (2-4)	3 (2-4)	-	40
Number of Live Seedlings/Number of Sampled Quadrants	24/54	38/60	36/60	62/74	51/58	-	80
Survival Rate (%)	44	63	60	84	88	-	-

Picea glauca

	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H	X^2
Median (Q1, Q3) Height (cm)	69 (57-82)a	91 (68-112)b	68 (43-101)ab	69 (61-86)ab	70 (58-96)ab	13	-
Median (Q1,Q3) Basal Diameter (mm)	10 (8-13)a	16 (11-20)b	18 (13-24)b	12 (11-13)ab	13 (11-16)ab	38	-
Median (Q1,Q3) Stem Volume (cm^3)	21 (9-36)a	77 (23-109)b	58 (15-192)b	24 (19-39)ab	34 (20-52)ab	25	-
Median (Q1,Q3) Vigor Rating	3 (2-4)	4 (4-5)	3 (2-3)	3 (3-4)	3 (3-4)	-	33
Number of Live Seedlings/Number of Sampled Quadrants	49/66	45/60	28/60	25/46	33/60	-	12
Survival Rate (%)	74	75	47	54	55	-	-

treatment plots. Vigor appeared to be greatest within the 2 kg/ha hexazinone treatment which also had a survival rate of 75 percent. Only the control vegetation had a similar level of survival (Figure 12), while the treatments were substantially lower (i.e., 45 to 55 percent).

An analysis of cover values according to relative seedling height growth categories indicated that significant ($P < 0.05$) differences were present in the Conifer Release data. For example, a negative relationship appears to exist between *Pinus contorta* growth and the amount of cover associated with the C-stratum (*Populus tremuloides*), *Aster conspicuus*, *Calamagrostis canadensis*, *Lonicera involucrata*, and *Mertensia paniculata* (Table 20). The latter two species have relatively low cover values compared to the other species. A positive association was found for two species: *Agrostis scabra* and *Trifolium repens*. Fewer associations were found when *Picea glauca* was analyzed. *Calamagrostis canadensis* and *Petasites palmatus* abundance was negatively associated with growth, while *Bromus ciliatus* cover increased with increasing *Picea glauca* growth rates (Table 20).

Figure 12. Comparison of *Pinus contorta* and *Picea glauca* survival rates as of 1993 by treatment in the Conifer Release experimental blocks.

Table 20. Comparison of growth-form and species median (average) percent cover values according to relative *Pinus contorta* (n = 211 seedlings) and *Picea glauca* (n = 180 seedlings) height categories in Conifer Release experimental treatment blocks. H values represent the results of Kruskal-Wallis tests ($P < 0.05 = 6.0$, $P < 0.01 = 9.2$). Nonparametric Scheffe' range tests were used to differentiate groups ($P < 0.05$). The trend category indicates the general relationship of forest species to the increase in seedling height (a "+", "-", and "~" represents an increase, decrease, and mixed change in percent cover, respectively). Trend was based on changes in the percent cover and Scheffe' tests; however, when no distinctive pattern occurred among the groups, trend was based on changes in average rank according to Kruskal-Wallis tests.

Pinus contorta

	Group 1 (<70 cm)	Group 2 (70 - 130 cm)	Group 3 (>130 cm)	H	Trend
Total Number of Seedlings	61	72	78		
Total "C"Stratum	0 (17)a	0 (7)ab	0 (4)b	13	-
Total "A" Stratum	14 (17)ab	19 (20)a	8 (13)b	15	~
Agrostis scabra	0 (0)a	0a	0 (1)a	9	+
Aster conspicuus	1 (5)a	1 (4)ab	0 (1)b	9	-
Bromus ciliatus	0 (1)ab	0 b	0 (2)a	9	~
Calamagrostis canadensis	9 (12)ab	10 (12)a	5 (9)b	11	-
Fragaria virginiana	5 (8)ab	8 (10)a	3 (6)b	10	~
Lonicera involucrata	0 (2)a	0 (1)a	0 (1)a	8	-
Mertensia paniculata	1 (2)a	1 (2)a	0 (1)a	6	-
Populus tremuloides - C	0 (16)a	0 (6)ab	0 (3)b	18	-
Trifolium repens	0 (1)a	0 (1)a	0 (4)a	8	+

Picea glauca

	Group 1 (<60 cm)	Group 2 (60 - 100 cm)	Group 3 (>100 cm)	H	Trend
Total Number of Seedlings	46	89	45		
Bromus ciliatus	0 (1)a	0 (1)a	0 (2)a	9	+
Calamagrostis canadensis	12 (14)a	10 (14)a	2 (6)b	16	-
Cornus stolonifera	0 (0)a	0 (0)a	0 (1)a	8	~
Fragaria virginiana	3 (6)ab	4 (7)a	1 (3)b	11	~
Petasites palmatus	2 (5)a	1 (3)a	0 (2)a	6	-
Rosa acicularis	6 (8)ab	8 (10)a	5 (6)b	10	~
Taraxacum officinale	0 (1)ab	0 (0)b	0 (2)a	21	~

5.0 A PRELIMINARY ANALYSIS OF COMPETITION VARIABLES

The following sections contain results of analyses of selected variables used in the assessment of competition between coniferous crop seedlings and native vegetation. The objectives of these analyses were:

1. To test selected competition variables and indices to determine which was best related to the growth of *Pinus contorta* and *Picea glauca* seedlings.
2. To assess how the competition variables differed in different Site Preparation and Conifer Release treatments.
3. To determine which variables were the best indicators of crop seedling growth.

The competition variables included the height and basal diameters of the nearest and tallest *Populus tremuloides*; and nearest woody shrub greater than 50 cm tall within 180 cm of the crop seedlings as well as the distance between their stem bases. Several competition indices for *Pinus contorta* were calculated based on previous analyses by Navratil and MacIsaac (1993).[4] Because this study was not specifically designed for the calculation of these indices, it was necessary to modify the formulas in some cases to accommodate the available data (Table 21). These indices were applied to both *Pinus contorta* and *Picea glauca*, except RelHT2 which was applied only to *Picea glauca* seedlings.

Other variables were added to these analyses such as percent cover of various growth-forms (e.g., total C-stratum cover) and selected species that showed a significant ($P < 0.05$) difference in abundance according to crop seedling height classes based on previously summarized analyses (See Tables 11, 12, and 20).

In addition to the summarization of competition variable values and calculation of indices, simple and multiple regression models were developed to predict crop seedling height based on the various competition variables (e.g., distance to nearest *Populus tremuloides*), species cover, and stem density data; and the Competition Indices, excluding RelHT2 which had seedling height as a formula variable (Table 21). It was assumed that the amount of seedling growth was at least in part influenced by the degree of competition experienced by the seedling. However, this and related analyses were abandoned because most variables or combination of variables produced correlation coefficients which were not statistically significant ($P < 0.05$) or did not account for a large percent of the variance with the exception of selected Competition Indices. Many of the Competition Indices when used as independent variables in the simple and multiple regressions produced significant models with moderate to strong correlations (i.e., $r = 0.60$ to 0.87 or 36 to 76 percent variance explanation). However, all the calculated Competition Indices except CI-3 used the basal diameter of the crop seedling as a denominator in the formula and basal diameter is strongly correlated with seedling height (e.g., $r = +0.87$ for *Pinus contorta*).

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4 Indices suggested by Stan Navratil, Canadian Forest Service, Northern Forest Centre, Edmonton, Alberta.

Table 21. Formulae for calculating Competition Indices (CI) as applied to Site Preparation and Conifer Release experimental block data.

CI - 1 (tallest *P. tremuloides*)[1] = $\frac{\text{Tallest } Populus\ tremuloides \text{ - Conifer seedling height}}{\text{Tallest } Populus\ tremuloides \text{ stem to Conifer seedling stem distance}}$

CI - 1 (nearest *P. tremuloides*)[1] = $\frac{\text{Nearest } Populus\ tremuloides \text{ - Conifer seedling height}}{\text{Nearest } Populus\ tremuloides \text{ stem to Conifer seedling stem distance}}$

CI - 3 (P. *tremuloides* - C)[1] = $\frac{\text{Percent Cover of } Populus\ tremuloides}{(\text{Distance to Nearest } Populus\ tremuloides)^2}$

CI - 3 (P. *tremuloides* - B)[1] = $\frac{\text{Percent Cover of } Populus\ tremuloides}{(\text{Distance to Nearest } Populus\ tremuloides)^2}$

CI - 4[1] = $\frac{\text{Nearest } Populus\ tremuloides \text{ basal diameter/Conifer basal diameter}}{Populus\ tremuloides \text{ stem to Conifer seedling stem distance}}$

CI - 5[1] = $\frac{\text{Nearest } Populus\ tremuloides \text{ basal diameter}}{\text{Conifer seedling basal diameter}}$

CI - 6[1] = $\frac{\text{Tallest } Populus\ tremuloides \text{ basal diameter}}{\text{Conifer seedling basal diameter}}$

RelHT2[2] = $\frac{\text{Conifer seedling height}}{\text{Height of tallest } Populus\ tremuloides}$

1 Data adapted to formula developed by Navratil and MacIsaac (1993).
2 Index suggested by Dan MacIsaac, Canadian Forest Service, Northern Forest Centre, Edmonton, Alberta.

5.1 Site Preparation Experiment Blocks

5.1.1 *Pinus contorta* Crop Seedlings

A comparison of the competition and other related variables by treatment identified several statistically significant ($P < 0.05$) differences within the Site Preparation experimental block data (Table 22). In many cases, the greatest distances between a tree or a shrub and the *Pinus contorta* seedlings, the fewest and least amount of woody stems, and the smallest tree basal diameter were associated with the Rome double disking treatment, while the reverse occurred in the control and disk trenching treatments and sometimes the 2 kg/ha hexazinone treatment plots.

Table 22. Median (average) values for selected *Pinus contorta* competition variables based on 1992 and 1993 data from Site Preparation experimental treatment blocks. H values represent Kruskal-Wallis test results (P <0.05 = 9.5, P <0.01 = 13.3), while letters following averages are multiple range nonparametric Scheffe' tests.

Variable	Control	2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching	H
Nearest *P. tremuloides* - Distance (cm)	35(42)a	43(55)a	49(56)ab	69(77)b	44(52)a	32
Nearest *P. tremuloides* - Height (cm)	202(216)c	155(187)bc	154(157)bc	83(90)a	133(143)b	101
Nearest *P. tremuloides* - Basal Diameter (mm)	22(23)b	19(21)b	19(20)b	11(12)a	15(16)a	72
Tallest *P. tremuloides* - Distance (cm)	114(110)	103(107)	116(115)	108(111)	118(122)	4
Tallest *P. tremuloides* - Height (cm)	370(360)c	315(307)bc	280(267)b	110(119)a	340(349)c	180
Tallest *P. tremuloides* - Basal Diameter (mm)	40(40)b	40(38)b	35(36)b	16(17)a	40(41)b	150
Shrub >50 cm tall - Distance (cm)	36(42)a	59(65)ab	62(67)b	70(77)b	43(48)a	27
Shrub >50 cm tall - Height (cm)	69(79)	63(76)	61(67)	61(69)	62(70)	6
Shrub >50 cm tall - Basal Diameter (mm)	6(7)	7(9)	7(8)	7(8)	7(8)	6
Density of Woody Stems (number/m^2)	5.44(5.60)c	3.20(3.52)b	3.20(4.64)b	1.28(1.76)a	4.32(4.16)bc	90
Total Woody Stem Length (m/m^2)	7.52(7.99)c	4.84(5.70)b	4.19(5.26)b	0.90(1.39)a	4.76(5.03)b	123
Percent Cover *P. tremuloides* - C	17(25)b	0(13)ab	0(5)a	0a	0(6)a	71
Percent Cover *P. tremuloides* - B	20(20)b	15(17)b	15(19)b	0(1)a	2(10)b	78
Percent Cover *Aster conspicuus*	10(11)a	0(7)b	1(3)b	3(4)b	8(11)a	54
CI - 1 (tallest *P. tremuloides*)	2.84(3.85)c	2.51(3.02)bc	1.64(2.01)b	-0.02(0.01)a	2.31(2.42)bc	169
CI - 1 (nearest *P. tremuloides*)	3.75(5.03)c	2.79(3.66)bc	1.64(2.17)b	-0.37(-0.45)a	1.32(1.49)b	146
CI - 3 (*P. tremuloides* - C)	0.01(0.03)b	0(0.01)ab	0(0.01)a	0a	0a	70
CI - 3 (*P. tremuloides* - B)	0.01(0.02)b	0.01(0.02)b	0(0.01)b	0a	0(0.01)b	74
CI - 4	0.06(0.09)c	0.04(0.07)bc	0.02(0.04)b	0.01(0.01)a	0.02(0.03)b	123
CI - 5	2.38(3.28)d	1.87(2.46)cd	1.16(1.57)bc	0.47(0.51)a	1.10(1.40)b	144
CI - 6	4.24(5.63)c	4.28(4.51)bc	2.26(2.92)b	0.57(0.72)a	3.08(3.43)bc	169
Shrub Basal Diameter/ Conifer Basal Diameter	0.69(0.94)c	0.79(0.84)bc	0.53(0.59)b	0.29(0.35)a	0.50(0.63)bc	83
Approx. No. of Samples	58	52	64	80	63	317

The typical distance between the nearest tree or shrub and the crop seedling was about 35 cm in the control, but this distance was extended to approximately 69 cm in the Rome double disking Plots. No significant differences occurred in the height of the tallest *Populus tremuloides*, nor height and basal diameter of the nearest shrub greater than 50 cm tall (Table 22). A comparison of Competition Indices by treatments produced significant (P <0.05) Kruskal-Wallis test values for all indices. In general, a gradient of values occurred from the control to the 2 kg/ha and 4 kg/ha hexazinone treatments. The lowest Competition Index values were usually associated with the Rome double disking treatment and presumably represent the least amount of competition. Indices from the disk trenching treatment were usually similar to one of the hexazinone treatments. Another possible index with a formula structure similar to that of Competition Indices CI - 1, 4, 5, 6, and 7 is a ratio between the basal diameter of the nearest shrub and *Pinus contorta* (Table 22).[5] This ratio had patterns of occurrence similar to those of the other indices.

Correlation of competition variables and seedling heights often resulted in coefficients (r) that were insignificant (P >0.05) or had a low level of explained variance (r^2). Most of the tested variables explained less than 20 percent of the total variance in *Pinus contorta* height (Table 23). The exceptions included: (i) height and (ii) basal diameter of the tallest *Populus tremuloides* within 180 cm of the crop seedling; (iii) density of woody stems; (iv) total woody stem length; and (v) shrub basal diameter. These exceptions had explained variance of 24 to 32 percent and all occurred in 2 kg/ha hexazinone treatment.

The aggregation and analysis of control and hexazinone data to represent a chemical dosage gradient (i.e., 0, 2, 4 kg/ha) resulted in ten significant correlations out of 18 possible variables. The strongest of these variables was total woody stem length which was inversely related to seedling height (r^2 = 17). When data from all treatments were combined and correlated with *Pinus contorta* height, 14 variables had statistically significant correlation coefficients. The strongest coefficients were associated with total woody stem length, height and basal diameter of the tallest tree which had explained variance of 18 to 25 percent.

Several competition variables had significantly different values when stratified according to *Pinus contorta* height classes (Table 24).[6] The results indicate that distance between the nearest *Populus tremuloides* or nearest shrub, and the *Pinus contorta* seedling increased with increasing seedling height. A similar relationship did not occur for the tallest *Populus tremuloides*. However, shorter (<60 cm) *Pinus contorta* seedlings were associated with taller *Populus tremuloides*. *Populus tremuloides* basal diameter also decreased with increased seedling height.

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5 Suggested by Surin Sidhu, Canadian Forest Service, Northern Forest Centre, Edmonton, Alberta.

6 In setting the class limits for both the *Pinus contorta* and *Picea glauca* seedling height categories, an attempt was made to create categories with a similar range of height values and a similar number of cases in class. The number of height categories was based on the general range of values that occurred in each data set (i.e., the smaller the range in seedling height values, the fewer the number of categories).

Table 23. Summary of correlation coefficients of selected variables against *Pinus contorta* heights based on 1992 and 1993 data from Site Preparation experimental treatment blocks. A "*" and "**" indicates a coefficient that is significant at P <0.05 or P <0.01, respectively.

Variable	Control	2 kg/ha Hexa-zinone	4 kg/ha Hexa-zinone	Rome Double Disking	Disk Trench-ing	Control, 2 and 4 kg/ha Hexa-zinone	All Treat-ments
Nearest *P. tremuloides* - Distance (cm)	+0.03	+0.34*	+0.14	+0.09	+0.17	+0.21**	+0.30**
Nearest *P. tremuloides* - Height (cm)	-0.03	-0.27*	-0.13	+0.11	+0.09	-0.21**	-0.34**
Nearest *P. tremuloides* - Basal Diameter (mm)	-0.01	-0.18	-0.09	+0.17	+0.08	-0.13	-0.25**
Tallest *P. tremuloides* - Distance (cm)	-0.07	+0.25	+0.08	+0.20	+0.10	+0.11	+0.10
Tallest *P. tremuloides* - Height (cm)	-0.02	-0.52**	-0.23	+0.31*	-0.15	-0.37**	-0.50**
Tallest *P. tremuloides* - Basal Diameter (mm)	-0.05	-0.49**	-0.24	+0.15	-0.15	-0.32**	-0.48**
Shrub >50 cm tall - Distance (cm)	+0.01	+0.19	+0.01	+0.15	+0.13	+0.12	+0.22**
Shrub >50 cm tall - Height (cm)	+0.11	+0.14	+0.08	+0.15	+0.01	+0.04	+0.01
Shrub >50 cm tall - Basal Diameter (mm)	+0.06	+0.41**	+0.26*	+0.20	+0.06	+0.25**	+0.16**
Density of Woody Stems (number/m^2)	-0.08	-0.56**	-0.11	+0.09	-0.26	-0.22**	-0.35**
Total Woody Stem Length (m/m^2)	-0.26	-0.57**	-0.24	+0.24*	-0.38**	-0.41**	-0.42**
Percent Cover *P. tremuloides* - C	+0.17	-0.38**	-0.17	0.00	+0.18	-0.23**	-0.25**
Percent Cover *P. tremuloides* - B	-0.06	-0.24	+0.01	+0.31**	-0.03	-0.08	-0.25**
Percent Cover *Aster conspicuus*	-0.26	-0.27	+0.25	-0.15	-0.03	-0.21**	-0.21**
CI - 3 (*P. tremuloides* - C)	+0.12	-0.29	-0.17	0	+0.09	-0.11	-0.17**
CI - 3 (*P. tremuloides* - B)	-0.01	-0.15	-0.01	+0.29*	-0.03	-0.08	-0.22**
Approximate Number of Samples	58	52	64	80	63	174	317

Table 24. Median (average) values for various competition variables stratified by *Pinus contorta* and *Picea glauca* height classes in the Site Preparation experimental treatment blocks. H values represent Kruskal-Wallis test results (P <0.05 = 7.8, P <0.01 = 11.3), while letters following averages are multiple range nonparametric Scheffe' tests which identify similar groups.

Pinus contorta

	Group 1 <34 cm	Group 2 34-67 cm	Group 3 68-111 cm	Group 4 >111 cm	H
Nearest *P. tremuloides* - Distance (cm)	42(48)ab	40(51)a	59(62)abc	63(75)c	26
Nearest *P. tremuloides* - Height (cm)	165(192)b	155(170)b	104(131)a	91(106)a	53
Nearest *P. tremuloides* - Basal Diameter (mm)	19(21)c	18(19)bc	15(16)ab	12(14)a	30
Tallest *P. tremuloides* - Distance (cm)	112(106)	114(112)	118(119)	116(118)	5
Tallest *P. tremuloides* - Height (cm)	350(344)b	320(307)b	205(226)a	145(174)a	88
Tallest *P. tremuloides* - Basal Diameter (mm)	41(41)c	38(37)c	30(30)b	19(22)a	77
Shrub >50 cm tall - Distance (cm)	41(52)a	44(56)a	53(62)ab	70(77)b	17
Shrub >50 cm tall - Height (cm)	63(71)	66(75)	61(66)	69(75)	7
Shrub >50 cm tall - Basal Diameter (mm)	7(7)a	7(7)a	7(7)a	8(9)a	9
Number of Samples	87	87	77	66	

Picea glauca

	Group 1 (<42 cm)	Group 2 (42-59 cm)	Group 3 (60-77 cm)	Group 4 (>77 cm)	H
Nearest *P. tremuloides* - Distance (cm)	43(51)a	48(54)a	51(55)ab	60(68)b	15
Nearest *P. tremuloides* - Height (cm)	161(188)	161(181)	179(195)	155(169)	2
Nearest *P. tremuloides* - Basal Diameter (mm)	18(20)	18(20)	18(22)	18(21)	<1
Tallest *P. tremuloides* - Distance (cm)	118(108)	112(114)	113(112)	128(117)	2
Tallest *P. tremuloides* - Height (cm)	330(320)	330(291)	320(305)	290(276)	4
Tallest *P. tremuloides* - Basal Diameter (mm)	40(37)	35(34)	35(35)	35(34)	4
Shrub >50 cm tall - Distance (cm)	44(49)	48(58)	46(56)	52(56)	1
Shrub >50 cm tall - Height (cm)	64(70)	62(70)	61(70)	64(70)	1
Shrub >50 cm tall - Basal Diameter (mm)	6(6)	7(8)	7(8)	6(7)	4
Number of Samples	74	78	86	69	

Rosa acicularis (frequency 44 percent) and *Amelanchier alnifolia* (frequency 28 percent) were the most commonly encountered woody shrubs greater than 50 cm tall and within 180 cm of measured *Pinus contorta* seedlings. The most significant deviations from this general pattern occurred in the Rome double disk treatment where the frequency of *Amelanchier alnifolia* equalled *Rosa acicularis*, and in the disk trenching treatment where *Rosa acicularis* frequency reached 60 percent.

5.1.2 *Picea glauca* Crop Seedlings

Significant differences occurred in various variables such as the competition parameters, shrub height, density and length of woody stems, and percent cover with respect to *Picea glauca* heights in the Site Preparation treatment plots. In general, the control, disk trenching, 2 kg/ha and sometimes 4 kg/ha hexazinone treatments had similar *Populus tremuloides* heights and basal diameters. These same variables were smallest in the Rome double disking plots (Table 25). Within the control plots, the typical nearest *Populus tremuloides* was approximately 40 cm from the crop seedling and had a height of 212 cm. The height of the nearest *Populus tremuloides* in the control and related treatments was typically twice that of its equivalent in the Rome double disking plots, while the distance between the nearest *Populus tremuloides* and the crop seedlings was 20 to 30 percent greater in the Rome double disking treatment. The distances to the nearest shrub and *Populus tremuloides* were similar in the control plots, but shrubs were approximately 20 percent closer than *Populus tremuloides* in the Rome double disking treatment (Table 25). The Competition Indices showed a pattern of response similar to other measured variables with the control and Rome double disking plots at opposite ends of each scale, and a gradient of change with increased dosage of hexazinone.

Few of the competition variables, density measures, or cover values were significantly correlated with *Picea glauca* heights within the treatment plots, and the coefficients that were significant tended to be weak with explained variances of less than 15 percent (Table 26). When all treatments were combined for analysis, the overall level of explained variance was usually less than five percent for any particular variable. A similar response was also obtained when the control and hexazinone treatments were combined as a dosage gradient, although correlation coefficients tended to be greater. The strongest correlations with *Picea glauca* heights were associated with distance to the nearest *Populus tremuloides* and its percent cover in the B-stratum. In general, *Picea glauca* height increased as *Populus tremuloides* cover and the abundance of woody stems decreased, and the distance of these trees increased from the seedling.

A significant difference in competition variables according to *Picea glauca* height classes occurred only with respect to the distance between the nearest tree and the crop seedlings (Table 24). Seedling height increased with increasing distance from the nearest tree.

Rosa acicularis and *Amelanchier alnifolia* were the most commonly encountered woody shrubs greater than 50 cm tall and within 180 cm of measured *Picea glauca* seedlings. In most treatments the *Rosa acicularis* (frequency 43 percent) was encountered approximately 2 to 2.5 times more frequently than *Amelanchier alnifolia*, except in the control plots where *Amelanchier alnifolia* (41 percent) was more frequent than *Rosa acicularis* (32 percent).

Table 25. Median (average) values for selected *Picea glauca* competition variables based on 1992 and 1993 data from Site Preparation experimental blocks. H values represent Kruskal-Wallis test results (P <0.05 = 9.5, P <0.01 = 13.3), while letters following averages are multiple range nonparametric Scheffe' tests.

Variable	Control	2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching	H
Nearest *P. tremuloides* - Distance (cm)	40(44)a	47(54)a	48(58)ab	69(75)b	55(60)b	24
Nearest *P. tremuloides* - Height (cm)	212(216)b	210(225)b	165(179)b	83(91)a	159(183)b	83
Nearest *P. tremuloides* - Basal Diameter (mm)	20(21)b	21(24)b	19(21)b	11(12)a	18(22)b	52
Tallest *P. tremuloides* - Distance (cm)	121(115)a	100(107)a	123(118)a	101(101)a	124(122)a	12
Tallest *P. tremuloides* - Height (cm)	350(357)c	370(345)c	290(288)b	123(120)a	335(338)bc	130
Tallest *P. tremuloides* - Basal Diameter (mm)	38(38)b	38(39)b	38(36)b	15(17)a	40(41)b	110
Shrub >50 cm tall - Distance (cm)	40(48)	43(53)	53(66)	54(63)	33(44)	8
Shrub >50 cm tall - Height (cm)	63(76)b	68(73)b	64(70)b	56(59)a	63(68)ab	18
Shrub >50 cm tall - Basal Diameter (mm)	7(7)	7(8)	7(8)	6(7)	7(7)	2
Density of Woody Stems (number/m^2)	8.00(7.82)c	7.41(7.49)bc	5.08(5.68)b	0.89(1.31)a	5.45(5.73)bc	108
Total Woody Stem Length (m/m^2)	5.28(5.44)c	4.64(4.64)bc	3.04(4.32)b	1.28(1.76)a	4.32(4.48)bc	79
Percent Cover Total - C	12(19)b	20(25)b	0(6)a	0a	0(5)a	79
Percent Cover Total - B	22(29)b	15(20)b	20(24)b	0a	10(15)b	82
Percent Cover *P. tremuloides* - C	12(19)b	20(25)b	0(6)a	0a	0(5)a	79
Percent Cover *P. tremuloides* - B	20(27)c	10(19)bc	15(20)bc	0a	9(13)b	78
CI - 1 (tallest *P. tremuloides*)	2.53(3.31)c	2.90(3.36)c	1.86(2.33)b	0.44(0.64)a	2.29(2.46)bc	104
CI - 1 (nearest *P. tremuloides*)	3.61(4.26)d	3.59(5.44)cd	2.14(2.64)bc	0.27(0.46)a	1.33(2.00)b	86
CI - 3 (*P. tremuloides* - C)	0.01(0.02)b	0.01(0.02)b	0(0.01)a	0a	0(0.01)a	79
CI - 3 (*P. tremuloides* - B)	0.01(0.03)c	0.01(0.16)bc	0.01(0.02)bc	0(0.01)a	0.01(0.01)b	85
CI - 4	0.05(0.07)c	0.04(0.14)bc	0.03(0.04)b	0.01(0.02)a	0.03(0.04)bc	53
CI - 5	2.12(2.54)b	2.18(2.53)b	1.67(1.86)b	0.94(1.20)a	1.54(2.17)b	39
CI - 6	3.79(4.40)c	3.67(4.35)bc	3.00(3.19)b	1.29(1.53)a	3.32(4.51)bc	81
RelHT2	0.15(0.16)a	0.15(0.19)a	0.22(0.27)b	0.59(0.60)c	0.18(0.20)ab	111
Shrub Basal Diameter/ Conifer Basal Diameter	6.36(8.38)c	6.46(7.99)bc	5.19(6.09)ab	4.83(5.62)a	5.52(7.55)abc	24
Approx. No. of Samples	72	67	67	49	52	307

Table 26. Summary of correlation coefficients of selected variables against *Picea glauca* heights based on 1992 and 1993 data from Site Preparation experimental treatment blocks. A "*" and "**" indicates a coefficient that is significant at P <0.05 or P <0.01, respectively.

Variable	Control	2 kg/ha Hexa-zinone	4 kg/ha Hexa-zinone	Rome Double Disking	Disk Trench-ing	Control, 2 and 4 kg/ha Hexa-zinone	All Treat-ments
Nearest *P. tremuloides* - Distance (cm)	+0.34**	+0.31**	+0.13	-0.13	+0.08	+0.27**	+0.16**
Nearest *P. tremuloides* - Height (cm)	+0.06	+0.11	-0.32**	-0.09	+0.05	-0.08	-0.08
Nearest *P. tremuloides* - Basal Diameter (mm)	+0.08	+0.24*	-0.15	-0.10	+0.09	+0.05	+0.02
Tallest *P. tremuloides* - Distance (cm)	+0.12	-0.04	+0.27*	-0.08	+0.04	+0.11	+0.07
Tallest *P. tremuloides* - Height (cm)	+0.07	+0.02	-0.13	+0.23	-0.09	-0.09	-0.10
Tallest *P. tremuloides* - Basal Diameter (mm)	+0.03	+0.10	-0.13	+0.12	-0.23	-0.03	-0.07
Shrub >50 cm tall - Distance (cm)	-0.06	+0.07	+0.07	-0.26	+0.10	+0.08	+0.02
Shrub >50 cm tall - Height (cm)	+0.07	-0.02	+0.17	+0.11	-0.32	+0.05	-0.01
Shrub >50 cm tall - Basal Diameter (mm)	+0.30*	-0.01	+0.36**	-0.03	-0.15	+0.14*	+0.07
Density of Woody Stems (number/m^2)	+0.02	-0.36**	+0.21	+0.18	+0.07	-0.05	-0.04
Total Woody Stem Length (m/m^2)	-0.09	-0.41**	-0.01	+0.14	-0.14	-0.22**	-0.20**
Percent Cover Total - C	-0.07	-0.23*	-0.21	0	+0.01	-0.22**	-0.20**
Percent Cover Total - B	-0.17	-0.14	-0.32**	+0.28*	-0.08	-0.22**	-0.20**
Percent Cover *P. tremuloides* - C	-0.06	-0.23*	-0.21	0	-0.01	-0.21**	-0.19**
Percent Cover *P. tremuloides* - B	-0.21	-0.13	-0.41**	+0.28*	+0.01	-0.26**	-0.22**
CI - 3 (*P. tremuloides* - C)	-0.02	-0.30*	-0.20	0	-0.18	-0.20**	-0.19**
CI - 3 (*P. tremuloides* - B)	-0.05	-0.10	-0.30*	+0.30*	+0.08	-0.07	-0.06
Approximate Number of Samples	72	67	67	49	52	206	307

5.2 Conifer Release Experiment Blocks

5.2.1 *Pinus contorta* Crop Seedlings

No significant differences in the distance between the crop seedling and the nearest *Populus tremuloides* occurred among the treatment and control plots in the Conifer Release experiments. Trees in the control plots, however, were taller and had a larger basal diameter (Table 27). The distance to the tallest *Populus tremuloides* within 180 cm of the crop seedling was generally shortest in the control and Rome double disking plots. Height and basal diameters for the tallest tree were often 25 to 60 percent larger in the control plots than in the treatments. The 2 kg/ha hexazinone treatment ranked second to the control plots for the size of these variables. The distance between the crop seedling and the nearest shrub tended to be greatest in the 4 kg/ha hexazinone and Rome double disking treatments, but no significant differences occurred in height or basal diameter between the two plots. Stem densities and length of woody stems were highest in the control and brushsawed treatments at about five stems/m^2 and seven m/m^2, respectively (Table 27). Among the assessed cover values, all tested species except *Lonicera involucata* showed a significant difference between the treatment and control plots. Total C and *Populus tremuloides* - C cover were greatest in the control plots. The amount of cover in the B-stratum was similar among the plots, except within the 4 kg/ha hexazinone treatment which had a median cover value of two percent compared with 8 to 13 percent in the other treatments. *Aster conspicuus* had a similar pattern of cover but with much lower values. *Calamagrostis canadensis* had the least amount of cover in the hexazinone plots (Table 27). The Competition Indices were consistently larger in the control than the treatment plots. The smallest values were associated with the 4 kg/ha hexazinone treatment, but sometimes also included the Rome double disking and brushsawing treatments.

Few of the tested variables were significantly correlated with *Pinus contorta* seedling height. Of the 12 significant coefficients, nine were overstory canopy height or cover variables (Table 28). These variables also included the three strongest coefficients which were negatively associated with seedling height (r = -0.52). Half of all significant correlation coefficients occurred in the 4 kg/ha hexazinone treatment plot, which also included the strongest correlations. Within the hexazinone dosage series (i.e., control or 0 kg/ha, 2 kg/ha and 4 kg/ha), half the tested variables were negatively and significantly correlated with *Pinus contorta* seedling height. Among the most strongly correlated variables were total C-stratum cover, Height of the tallest *Populus tremuloides*, density and length of woody stems. A similar pattern of correlation occurred when all five plots were combined into a single data set, but no correlation coefficients were greater than 0.28.

Only two variables were significantly different among the three *Pinus contorta* height groups (Table 29). In general, seedling height tended to increase with increasing distance from the nearest *Populus tremuloides* and with decreasing height of the trees.

Rosa acicularis (frequency 51 percent) and *Salix* spp. (29 percent) were the two most common shrubs within 180 cm of measured *Pinus contorta* seedlings in the Conifer Release experimental treatment plots. In the 2 kg/ha hexazinone treatment plots, the frequency of *Rosa acicularis* tended to higher than the general average (71 percent).

Table 27. Median (average) values for selected *Pinus contorta* competition variables based on 1993 and 1994 data from Conifer Release experimental treatment blocks. H values represent Kruskal-Wallis test results ($P < 0.05 = 9.5$, $P < 0.01 = 13.3$), while letters following averages are multiple range nonparametric Scheffe' tests.

Variable	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H
Nearest *P. tremuloides* - Distance (cm)	42(49)	46(61)	86(86)	42(50)	43(52)	9
Nearest *P. tremuloides* - Height (cm)	300(309)b	142(167)a	132(145)a	138(165)a	111(125)a	38
Nearest *P. tremuloides* - Basal Diameter (mm)	27(29)b	14(17)a	17(18)b	12(16)a	12(12)a	36
Tallest *P. tremuloides* - Distance (cm)	87(93)a	122(120)a	110(106)a	84(91)a	103(108)a	11
Tallest *P. tremuloides* - Height (cm)	505(496)c	310(312)b	196(205)a	270(263)ab	207(210)a	74
Tallest *P. tremuloides* - Basal Diameter (mm)	43(42)c	32(33)b	26(25)ab	27(27)ab	24(24)a	52
Shrub >50 cm tall - Distance (cm)	38(44)ab	38(41)a	58(71)b	59(65)b	42(45)ab	20
Shrub >50 cm tall - Height (cm)	66(78)	60(65)	61(65)	65(74)	67(73)	5
Shrub >50 cm tall - Basal Diameter (mm)	8(8)	8(7)	6(6)	7(9)	7(7)	7
Density of Woody Stems (number/m^2)	4.96(4.96)c	3.20(3.36)b	0.96(1.32)a	2.40(2.88)ab	5.12(5.28)c	83
Total Woody Stem Length (m/m^2)	7.83(7.97)d	3.40(3.78)bc	0.69(1.25)a	2.61(3.56)ab	5.95(6.07)cd	87
Percent Cover Total - C	30(37)b	0(13)a	0(2)a	0(6)a	0(1)a	68
Percent Cover Total - B	12(15)ab	10(16)ab	2(9)a	8(18)ab	13(18)b	11
Percent Cover *P. tremuloides* - C	27(33)b	0(10)a	0(2)a	0(5)a	0(1)a	65
Percent Cover *Aster conspicuus*	4(7)b	1(3)ab	0(1)a	1(3)b	2(3)ab	15
Percent Cover *Calamagrostis canadensis*	12(15)b	2(5)a	0(2)a	12(15)b	13(16)b	76
Percent Cover *Lonicera involucrata*	0(1)	0(2)	0(2)	0(1)	0(2)	4
Percent Cover *Mertensia paniculata*	1(2)a	1(2)a	0a	1(2)a	1(2)a	10
CI - 1 (tallest *P. tremuloides*)	4.62(5.73)c	1.84(2.01)b	0.06(0.02)a	1.40(2.47)b	0.98(1.56)ab	63

Table 27. Concluded.

Variable	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H
CI - 1 (nearest *P. tremuloides*)	5.76(7.51)b	1.84(1.75)a	-0.22(-0.63)a	0.43(2.34)a	0.54(1.35)a	48
CI - 3 (Total - C)	0.02(0.10)b	0(0.04)ab	0(0.02)a	0(0.02)a	0(0.01)a	57
CI - 3 (Total - B)	0.01(0.02)	0.01(0.04)	0(0.03)	0.01(0.05)	0.01(0.03)	2
CI - 4	0.07(0.11)c	0.02(0.03)b	0.01(0.01)a	0.02(0.04)b	0.02(0.03)ab	38
CI - 5	2.94(3.19)c	0.97(1.16)b	0.52(0.67)a	0.74(0.99)ab	0.71(0.88)ab	46
CI - 6	3.61(4.85)c	1.95(2.38)b	0.67(1.13)a	1.39(1.61)ab	1.32(1.74)b	57
Shrub Basal Diameter/ Conifer Basal Diameter	0.69(0.86)c	0.44(0.51)bc	0.17(0.25)a	0.32(0.55)b	0.45(0.51)bc	57
Approx. No. of Samples	24	34	22	58	51	189

Table 28. Summary of correlation coefficients of selected variables against *Pinus contorta* heights based on 1993 and 1994 data from Conifer Release experimental treatment blocks. A "*" and "**" indicates a coefficient that is significant at P <0.05 or P <0.01, respectively.

Variable	Control	Disk Trench-ing & 2 kg/ha Hexa-zinone	Disk Trench-ing & 4 kg/ha Hexa-zinone	Rome Double Disking	Disk Trench-ing & Brush-sawing	Control, 2 and 4 kg/ha Hexa-zinone	All Treat-ments
Nearest *P. tremuloides* - Distance (cm)	+0.31	+0.13	+0.03	-0.06	-0.01	+0.27*	+0.12
Nearest *P. tremuloides* - Height (cm)	-0.20	+0.25	+0.23	+0.09	-0.17	-0.18	-0.06
Nearest *P. tremuloides* - Basal Diameter (mm)	-0.17	+0.47**	+0.31	+0.04	-0.08	+0.04	+0.05
Tallest *P. tremuloides* - Distance (cm)	+0.23	-0.24	-0.23	+0.06	+0.03	-0.07	-0.05
Tallest *P. tremuloides* - Height (cm)	-0.27	+0.22	-0.52*	+0.12	-0.44**	-0.44**	-0.22*
Tallest *P. tremuloides* - Basal Diameter (mm)	-0.01	+0.15	-0.35	+0.05	+0.02	-0.31**	-0.14
Shrub >50 cm tall - Distance (cm)	+0.35	+0.12	+0.04	-0.17	-0.08	+0.31**	+0.12
Shrub >50 cm tall - Height (cm)	+0.15	+0.30	+0.04	+0.09	+0.01	+0.03	+0.05
Shrub >50 cm tall - Basal Diameter (mm)	+0.12	+0.05	-0.21	-0.13	+0.39**	-0.17	-0.06
Density of Woody Stems (number/m^2)	-0.11	-0.03	-0.35	+0.13	-0.12	-0.49**	-0.28**
Total Woody Stem Length (m/m^2)	-0.29	-0.06	-0.29	+0.18	-0.26	-0.49**	-0.28**
Percent Cover Total - C	-0.40*	-0.01	-0.46*	+0.07	-0.30*	-0.42**	-0.23*
Percent Cover Total - B	+0.33	+0.27	-0.52*	+0.28*	-0.03	+0.12	+0.12
Percent Cover *P. tremuloides* - C	-0.28	-0.06	-0.46*	-0.04	-0.29	-0.39**	-0.21*
Percent Cover *Aster conspicuus*	-0.21	-0.17	-0.45*	-0.15	-0.01	-0.30**	-0.19*
Percent Cover *Calamagrostis canadensis*	-0.19	+0.05	-0.09	-0.06	+0.03	-0.21	-0.13
Percent Cover *Lonicera involucrata*	+0.01	-0.20	+0.38	-0.08	-0.04	+0.04	-0.04
Percent Cover *Mertensia paniculata*	+0.13	-0.22	+0.15	-0.01	+0.03	-0.18	-0.10
CI - 3 (Total - C)	-0.22	-0.27	-0.52*	-0.09	-0.23	-0.28*	-0.21*
CI - 3 (Total - B)	-0.05	-0.20	-0.02	-0.20	-0.24	-0.09	-0.09*
Approximate Number of Samples	24	34	21	58	51	80	188

Table 29. Median (average) values for various competition variables stratified by *Pinus contorta* or *Picea glauca* height classes in the Conifer Release experimental treatment blocks. H values represent Kruskal-Wallis test results ($P < 0.05 = 6.0$, $P < 0.01 = 9.2$), while letters following averages are multiple range nonparametric Scheffe' tests which identify similar groups

Pinus contorta

	Group 1 (<70 cm)	Group 2 (70-130 cm)	Group 3 (>130 cm)	H
Nearest *P. tremuloides* - Distance (cm)	35(47)a	52(62)a	55(57)a	6
Nearest *P. tremuloides* - Height (cm)	180(191)	132(166)	125(155)	2
Nearest *P. tremuloides* - Basal Diameter (mm)	17(18)	13(16)	14(17)	2
Tallest *P. tremuloides* - Distance (cm)	97(101)	122(111)	87(86)	5
Tallest *P. tremuloides* - Height (cm)	300(331)b	230(264)a	240(250)a	11
Tallest *P. tremuloides* - Basal Diameter (mm)	28(31)	26(28)	29(28)	3
Shrub >50 cm tall - Distance (cm)	42(49)	43(53)	53(60)	4
Shrub >50 cm tall - Height (cm)	62(69)	64(71)	65(73)	1
Shrub >50 cm tall - Basal Diameter (mm)	7(8)	7(7)	8(8)	1
Number of Samples	57	75	57	

Picea glauca

	Group 1 (<60 cm)	Group 2 (60-100 cm)	Group 3 (>100 cm)	H
Nearest *P. tremuloides* - Distance (cm)	48(59)	47(54)	43(57)	<1
Nearest *P. tremuloides* - Height (cm)	178(227)	170(229)	147(186)	<1
Nearest *P. tremuloides* - Basal Diameter (mm)	17(21)	18(21)	17(20)	<1
Tallest *P. tremuloides* - Distance (cm)	103(97)	96(97)	111(112)	3
Tallest *P. tremuloides* - Height (cm)	420(400)	310(358)	265(318)	3
Tallest *P. tremuloides* - Basal Diameter (mm)	40(39)	33(35)	35(35)	3
Shrub >50 cm tall - Distance (cm)	40(47)	38(45)	35(45)	<1
Shrub >50 cm tall - Height (cm)	62(73)	67(73)	66(74)	<1
Shrub >50 cm tall - Basal Diameter (mm)	8(8)	7(8)	7(7)	4
Number of Samples	45	88	36	

5.2.2 *Picea glauca* Crop Seedlings

The largest trees and shortest distances between the nearest or tallest *Populus tremuloides* and the crop seedling occurred in the control plots (Table 30). The smallest *Populus tremuloides* based on either nearest or tallest tree measurements occurred within the brushsawed treatment. No significant difference occurred in the distance between the nearest shrub and the crop seedling, although shrubs were taller in the control plots. The density of woody stems was greatest in the control and brushsawed plots with approximately 4.5 stems/m^2. Median total woody stem lengths were 8.6 m/m^2 in the control plots and approximately half or less in the treatment plots (Table 30). Plant cover values were significantly different among the treatments for all the tested species and growth-forms, except Total - B cover. The most striking differences occurred in the large differential of Total - C cover in the control plots and the reduced amount of *Calamagrostis canadensis* cover in the hexazinone plots relative to other treatments. Within the Competition Indices, little differentiation occurred among the treated plots, although they were consistently larger in the control plots (Table 30).

Picea glauca height was significantly correlated with total woody stem lengths in the 2 kg/ha hexazinone plots, height of the tallest and nearest *Populus tremuloides* in the 4 kg/ha hexazinone plots, and Competition Index CI - 3 based on the total amount of cover within the B-stratum in the brushsawed treatment (Table 31). The two former variables were negatively correlated with seedling height. The largest portion of explained variance was given by the correlation of seedling height and the height of the tallest *Populus tremuloides* (40 percent). The number of variables that were correlated with crop seedling height increased when the control and hexazinone plots were analyzed together as a dosage series, but no individual variable explained more than 16 percent of the variance in seedling height. The analysis of all treatments together produced similar but weaker correlation coefficients. Total woody stem length and density of woody stems produced the strongest correlation coefficient in both of these data sets.

No significant difference was found among the competition variables when *Picea glauca* seedlings were stratified according to height classes (Table 28).

Rosa acicularis (frequency 50 percent) and *Salix* spp. (33 percent) were the most frequently encountered shrubs within 180 cm of the *Picea glauca* seedling in the control, Rome double disking and brushsawed plots. In the 2 kg/ha hexazinone treatment, *Rosa acicularis* (51 percent) with *Cornus stolonifera* (13 percent) and *Lonicera dioica* (9 percent) were the most common shrubs. *Salix* spp. (30 percent) with *Cornus stolonifera* (18 percent) and *Rosa acicularis* (18 percent) were the most frequently encountered shrubs in the 4 kg/ha hexazinone treatment.

Table 30. Median (average) values for selected *Picea glauca* competition variables based on 1993 and 1994 data from Conifer Release experimental blocks. H values represent Kruskal-Wallis test results (P <0.05 = 9.5, P <0.01 = 13.3), while letters following averages are multiple range nonparametric Scheffe' tests.

Variable	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H
Nearest *P. tremuloides* - Distance (cm)	38(39)a	53(72)ab	77(84)b	29(51)ab	46(47)ab	16
Nearest *P. tremuloides* - Height (cm)	300(349)c	152(171)bc	184(200)bc	133(174)ab	128(131)a	57
Nearest *P. tremuloides* - Basal Diameter (mm)	27(28)b	14(18)a	20(25)b	16(16)a	13(14)a	47
Tallest *P. tremuloides* - Distance (cm)	63(73)a	112(115)b	120(118)b	130(115)b	98(100)ab	30
Tallest *P. tremuloides* - Height (cm)	550(553)c	310(360)b	244(281)ab	240(265)ab	182(192)a	89
Tallest *P. tremuloides* - Basal Diameter (mm)	46(46)c	35(40)bc	40(38)c	25(28)ab	21(21)a	69
Shrub >50 cm tall - Distance (cm)	34(40)	38(49)	46(54)	37(45)	45(45)	3
Shrub >50 cm tall - Height (cm)	73(81)b	61(70)a	62(73)ab	62(67)ab	63(73)ab	11
Shrub >50 cm tall - Basal Diameter (mm)	7(7)	7(7)	6(8)	7(11)	8(8)	5
Density of Woody Stems (number/m^2)	4.64(4.64)b	3.04(3.36)a	2.08(2.60)a	2.40(2.72)a	4.32(5.12)b	52
Total Woody Stem Length (m/m^2)	8.64(9.38)d	3.25(4.19)b	1.68(2.50)a	2.25(3.20)ab	4.34(5.86)c	77
Percent Cover Total - C	60(56)b	0(13)a	0(7)a	0(6)a	0a	99
Percent Cover Total - B	10(15)	10(14)	0(6)	0(7)	0(10)	7
Percent Cover *Calamagrostis canadensis*	15(18)c	1(3)b	0(2)a	15(21)c	10(15)c	85
Percent Cover *Fragaria virginiana*	3(5)bc	1(1)ab	0a	12(14)d	8(11)cd	76
Percent Cover *Petasites palmatus*	2(4)b	2(4)b	0a	2(4)b	0(2)ab	18
Percent Cover *Rosa acicularis*	8(11)a	8(9)b	2(3)b	8(10)b	8(9)b	14
CI - 1 (tallest *P. tremuloides*)	7.20(8.47)b	2.24(2.88)a	1.14(1.97)a	1.61(3.72)a	1.27(1.45)a	77
CI - 1 (nearest *P. tremuloides*)	5.95(8.08)b	1.01(1.25)a	1.16(1.83)a	1.81(0.65)a	1.18(1.80)a	52

Table 30. Concluded.

Variable	Control	Disk Trenching and 2 kg/ha Hexazinone	Disk Trenching and 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing	H
CI - 3 (Total - C)	0.04(0.07)b	0(0.19)a	0(0.01)a	0(0.05)a	0a	76
CI - 3 (Total - B)	0.01(0.02)	0.01(0.32)	0.01(0.01)	0(0.06)	0(0.05)	7
CI - 4	0.07(0.09)b	0.02(0.03)a	0.02(0.03)a	0.03(0.13)a	0.03(0.04)a	40
CI - 5	2.37(2.98)b	1.18(1.28)a	1.33(1.65)ab	1.09(1.35)a	1.08(1.15)a	55
CI - 6	4.56(4.86)b	2.50(3.26)a	2.33(2.76)a	2.08(2.31)a	1.53(1.70)a	63
RelHT2	0.12(0.13)a	0.27(0.33)b	0.30(0.33)b	0.32(0.33)b	0.38(0.42)b	62
Shrub Basal Diameter/ Conifer Basal Diameter	0.64(0.79)b	0.45(0.50)a	0.35(0.53)a	0.54(0.91)a	0.58(0.65)a	63
Approx. No. of Samples	49	45	33	25	19	171

Table 31. Summary of correlation coefficients of selected variables against *Picea glauca* heights based on 1993 and 1994 data from Conifer Release experimental treatment blocks. A "*" and "**" indicates a coefficient that is significant at P <0.05 or P <0.01, respectively.

Variable	Control	Disk Trench-ing and 2 kg/ha Hexa-zinone	Disk Trench-ing and 4 kg/ha Hexa-zinone	Rome Double Disking	Disk Trench-ing followed by Brush-sawing	Control, 2 and 4 kg/ha Hexa-zinone	All Treat-ments
Nearest *P. tremuloides* - Distance (cm)	-0.02	-0.19	-0.17	+0.28	-0.42	-0.01	+0.01
Nearest *P. tremuloides* -Height (cm)	-0.02	+0.03	-0.49*	+0.13	-0.06	-0.23*	-0.13
Nearest *P. tremuloides* - Basal Diameter (mm)	-0.02	+0.12	-0.24	+0.12	-0.14	-0.12	-0.04
Tallest *P. tremuloides* - Distance (cm)	+0.09	+0.02	-0.12	+0.11	-0.08	+0.17	+0.10
Tallest *P. tremuloides* - Height (cm)	+0.01	+0.25	-0.63**	+0.02	-0.02	-0.40**	-0.21
Tallest *P. tremuloides* - Basal Diameter (mm)	+0.02	-0.18	-0.23	-0.02	+0.13	-0.22*	-0.07
Shrub >50 cm tall - Distance (cm)	+0.18	-0.04	-0.24	-0.24	+0.06	-0.01	-0.01
Shrub >50 cm tall - Height (cm)	-0.02	+0.18	-0.35	+0.10	+0.07	-0.09	-0.05
Shrub >50 cm tall - Basal Diameter (mm)	-0.20	-0.01	-0.33	-0.09	-0.06	-0.18	-0.10
Density of Woody Stems (number/m^2)	-0.18	-0.24	-0.36	-0.19	-0.15	-0.35**	-0.31**
Total Woody Stem Length (m/m^2)	-0.09	-0.32*	-0.41	-0.22	-0.11	-0.40**	-0.33**
Percent Cover Total - C	-0.03	-0.14	-0.23	+0.03	0	-0.31**	-0.19
Percent Cover Total - B	-0.18	-0.02	-0.16	-0.16	+0.05	-0.08	-0.08
Percent Cover *Calamagrostis canadensis*	-0.01	-0.24	-0.29	-0.02	+0.01	-0.29**	-0.26**
Percent Cover *Fragaria virginiana*	-0.13	+0.05	-0.30	+0.09	-0.16	-0.23*	-0.20*
Percent Cover *Petasites palmatus*	-0.19	-0.13	0	+0.14	-0.18	-0.22*	-0.17
Percent Cover *Rosa acicularis*	+0.03	-0.41	+0.25	-0.02	-0.04	-0.31**	-0.23*
CI - 3 (Total - C)	-0.14	+0.03	-0.30	-0.09	0	+0.03	+0.03
CI - 3 (Total - B)	+0.02	+0.05	+0.38	+0.06	+0.37**	+0.05	+0.16
Approximate Number of Samples	49	45	19	25	33	111	169

6.0 SUMMARY AND INTERPRETATIONS

The objectives of this study were to: 1) evaluate the early effects of various mechanical and chemical site treatment methods on the botanical composition, structure, and development of mixedwood forest vegetation after six to seven years of growth on two separate experimental sites; 2) assess the relative success of these treatments on lodgepole pine and white spruce seedling survival and growth; and 3) interpret the potential long-term ecological implications of the tested site preparation and conifer release techniques on native mixedwood forests. The following conclusions and interpretations were drawn from the data and the previous analyses.

6.1 Site Preparation Experiments

1. The initial botanical conditions within the three established experimental blocks were very similar based on the floristic composition, general plant community composition and structure, and number of woody stems per hectare. Variations did occur among the treatments (e.g., greater abundance of *Calamagrostis canadensis* in the control plots (median 5 percent) than in the hexazinone plots (median less than one percent)), but in most cases compositional variations were considered within the limits of acceptability for field based experiments.

2. Vegetation development in the control plots generally followed a pattern of increasing height, vertical stratification, overall plant cover, and floristic diversity as the stands aged during the last seven years (1986-1992) of growth following clearcutting in 1983. The control plot vegetation was dominated by a 350 cm tall overstory (median 12 percent cover) and a B-stratum (>150 cm tall) composed of *Populus tremuloides* (combined median cover 35 percent) with a combined density of 18,328 stems/ha in 1992. The understory vegetation was dominated by medium height stratum composed of a mixture of shrubs, forbs, and graminoids: *Rosa acicularis* (median 12 percent cover), *Calamagrostis canadensis* (15 percent), *Epilobium angustifolium* (6 percent), *Aster conspicuus* (5 percent), *Aralia nudicaulis* (2 percent), *Aster ciliolatus* (2 percent), and *Fragaria virginiana* (2 percent) (Table 4).

3. Approximately 52,789 woody stems per hectare occurred in the control plots at the time of their establishment in 1986. Density increased 39 percent to 73,448 stems/ha by 1988, but declined to 54,129 stem by 1992, which represents a 2.5 percent net gain over the initial establishment level. While the net number of stems per hectare increased only slightly during the seven year period of study, the total length of woody stems increased 73 percent to a total of 81,131 m/ha. Slightly less than half of this change was attributed to a net increase in *Populus tremuloides* stem lengths with *Amelanchier alnifolia* and *Rosa acicularis* contributing similar amounts.

4. All site preparation methods had at least some impact on the vegetation during the first six years of stand development after treatment. The relative impact of these treatments on native vegetation was ranked in the following order: Rome double disking > 4 kg/ha hexazinone > 2 kg/ha hexazinone ~ disk trenching > control. These changes included modifications of the physiognomy, general composition, and the length of all woody plant

stems in the vegetation.

4a. Rome double disking converted what would have been a juvenile forest to medium height (<150 cm tall) mixed shrub and herb plant community. In 1992, the vegetation in this treatment was dominated by *Calamagrostis canadensis* (median cover 20 percent), *Rosa acicularis* (10 percent), and *Epilobium angustifolium* (7 percent). It is unlikely that vegetation equivalent to the control plots will develop within the rotation age of the site due to the severity of the treatment. Furthermore, the development of conifer dominated vegetation will further inhibit the development of deciduous dominated mixedwood stands due to changes in litter composition and related ecological conditions.

4b. The application of 4 kg/ha of hexazinone resulted in a ten percent reduction in overall plant cover; a general increase in floristic diversity; a 34 percent reduction in the number of stems per hectare, primarily due to the loss of *Populus tremuloides* stems; a net loss of 73 percent in the amount of woody stems; a large increase in the number of *Corylus cornuta* stems; a substantial reduction in the total amount of C-stratum (average 22 versus 9 percent), *Calamagrostis canadensis* (19 versus 2 percent), and *Aster conspicuus* (11 versus 4 percent) cover; and substantial increases in *Epilobium angustifolium* (average 8 versus 12 percent) and *Galium boreale* (2 versus 9 percent) cover relative to the control plots. The recorded increase in floristic richness may be real or the result of greater species differentiation in the later vegetation surveys, particularly within the genus *Carex*. Development of this vegetation over the next 50 to 70 years should result in an open-canopied (<60 percent cover) *Populus tremuloides* forest community with a greater abundance of shrubs than the control plots. This greater abundance of shrub may develop due to the increased amount of solar radiation that reaches the lower levels of the vegetation. The increased openness of the forest canopy may enhance crop tree growth rates after their height exceeds the B-stratum.

4c. The application of 2 kg/ha of hexazinone had less effect on the vegetation than 4 kg/ha. In general, the 2 kg/ha dosage appears to have had only about one-third the overall impact of 4 kg/ha based on recorded changes in total plant cover, number and total length of woody stems per hectare. The 2 kg/ha application resulted in an equivalent reduction in total *Calamagrostis canadensis* cover, increased *Epilobium angustifolium* cover, and a substantial increase in the number of *Corylus cornuta* stems per hectare as compared to the 4 kg/ha hexazinone treatment. The vegetation in this treatment should develop into a plant community similar to the control plots in the future (10 to 30 years).

4d. The impact of disk trenching on the native vegetation was primarily along the trenching lines; otherwise the structure and general composition of the vegetation after six years of growth was similar to the control vegetation. The reduction in overall plant cover relative to the control plots was approximately equal to the amount of area affected by trenching. It is anticipated that the visual and structural effects created by trenching will decrease as the vegetation matures, and increases in height, and the density of *Populus tremuloides* trees decreases. This treatment may result in accelerated secondary succession by *Picea glauca*.

5. In 1992, the number of plant species was greatest in the hexazinone plots. Although these plots had a greater number of species in 1986 relative to the control plots, the gain in species was also greater (12 and 18 species versus 5 species, respectively). The largest net gain was in the 4 kg/ha hexazinone treatment. This increase in species richness is probably due to reduced homogeneity of the vegetation which created a greater diversity of niches. However, when individual treatments plots are considered separately (n=3 blocks) rather than as a group (n=1 type of treatment), species richness was greatest within the control, 4 kg/ha hexazinone, and disk trenching plots. These inconsistencies suggest that one of the treatment blocks was probably floristically more diverse.

   Simpson's Index (λ) suggests that a high degree of diversity with respect to cover occurs among species in the control plots. No major differences were found in Simpson's Index of dominance between 1986 and 1992 or among the treatment plots, except the Rome double disking treatment which had a slightly greater λ value. This greater value suggests a slightly higher degree of species dominance among few species than in the other treatments. Shannon-Wiener's Index (H') values among species increased in the control plots between 1986 and 1992, but remained relatively constant or decreased slightly in the treatment plots. The largest reduction in the evenness in cover among species occurred in Rome double disking treatments. However, these differences in diversity within the Rome double disking treatment are conservative relative to the drastic modifications that occurred in vegetation physiognomy, structure, species composition, and overall reduction of plant cover.

6. *Pinus contorta* growth to 1992 was best (median 112 cm; mean 113 cm, standard error five cm) in the Rome double disking plots where median heights were approximately double the second best treatments (i.e., disk trenching and 4 kg/ha hexazinone) after six years of growth. Stem volumes were typically 3.3 to 4.4 times greater in the Rome double disking plots. Survival rates were also substantially higher (94 percent) in the Rome double disking plots relative to the other treatments or the control plots (e.g., 55 percent). This improved growth and level of survival was probably due to the elimination of most competing vegetation and an increase in the relative portion of resources available for conifer seedling growth. Relative to the control plots, the other treatments resulted in somewhat better height growth, but only slightly better survival rates (e.g., 53 percent versus 56 to 62 percent). Rome double disking appears to be the most effective treatment for promoting *Pinus contorta* growth based on stem height, stem volume, and survival rates.

7. *Picea glauca* height growth was best in the 4 kg/ha hexazinone treatment plots, while no significant statistical difference occurred in seedling height among the other treatments. However, relative to the control plots growth among all the treatments was small (e.g., median 56 cm versus 57 to 67 cm). Survival rates were similar in the control and hexazinone treatments (80 percent). The reduced levels of survival for *Picea glauca* were probably poorer (58 percent) in the Rome double disking treatment due to increased solar radiation exposure which increased transpiration demands and decreased soil moisture availability due to increased ground surface evaporation. The reason for poor survival in

the disk trenching treatment was not obvious (possibly herbivory), but the surviving seedlings tended to have higher than normal vigor ratings. Among the tested site preparation methods, no treatment appears to be as effective for promoting *Picea glauca* growth as the application of 4 kg/ha of hexazinone based on a combination of total stem height, stem volume, and survival rates.

8. Based on 1991 forest regeneration standards (Alberta Forest Service 1993, pp. 11-12), only the Rome double disking plots would be considered stocked under the mixedwood standard and very close to meeting the criteria for the conifer standard, if *Pinus contorta* had been the only conifer planted in the treatments (Table 31). However, poor conifer stocking levels in the other treatments tended to be better than in the control plots. If *Picea glauca* had been the only conifer species planted, only the 2 kg/ha and 4 kg/ha hexazinone plots would be considered adequately stocked, although the control and disk trenching plots were close to adequate (Table 32). If three of the conditionally acceptable (>40 cm tall) *Picea glauca* seedlings in the control plots had been taller (e.g., five centimeters), the plot would have qualified as adequately stocked according to the mixedwood criteria. Aside from Rome double disking, all treatments had tree stocking rates between 85 and 100 percent.

9. Among the tested competition variables, height and basal diameter of the tallest *Populus tremuloides*, and total woody stem length provided the strongest and most consistent correlation coefficients for predicting *Pinus contorta* seedling height. Percent cover of overstory components (e.g., Total B, Total C, *Populus tremuloides* - C, CI - 3) and total woody stem length were the better parameters for predicting *Picea glauca* seedling height. It is anticipated that the relationship between seedling height and these competition variables will change with time. For example, the competitive impact of understory vegetation on coniferous seedlings is probably most severe during the early stages of establishment, but once the seedling exceeds the general height of this vegetation other factors such as percent cover of B-stratum or the tree canopy may be more important influences. Once the seedling exceeds the height of the understory vegetation their competitive roles probably start to be reversed.

   Total woody stem length per hectare is a potentially useful variable for assessing competition between conifer crop seedling and competing vegetation. Considering total woody stem length is an indicator of the demand on available nutrients, moisture, and light resources, reducing its volume probably allows a greater allocation to coniferous seedlings which would tend to promote greater height growth and increased stem volume. Therefore, it is as important to control the abundance of woody shrubs as well as *Populus tremuloides* during the early stages of forest regeneration following clearcutting.

   In general, correlations of competition variables and seedling heights tended to be stronger for *Pinus contorta* than *Picea glauca*.

10. Statistically significant differences ($P < 0.01$) occurred among all of the calculated Competition Index values. In most cases, smallest values and presumably the least amount of competitor - conifer seedling interaction was associated with Rome double disking treatment plots. The largest values were usually associated with the control plots. Values

Table 32. Assessment of stocking in Site Preparation experimental blocks based on 1991 mixedwood regeneration standards (Alberta Forest Service 1993, pp. 11-12). Summary based on the assumption that only one coniferous species was planted in each treatment. To be considered stocked, at least 80 percent of the sampled plots must contain a *Pinus contorta* or *Picea glauca* seedling greater than 100 or 50 cm tall, respectively; or more than 45 percent of these seedlings in combination with an additional 35 percent of *Pinus contorta*, *Picea glauca*, or *Populus tremuloides* greater than 75, 40, and 150 cm tall, respectively.

Pinus contorta

Treatment	Percent *Pinus contorta* >100 cm	Percent *Pinus contorta* >75 cm	Percent Deciduous Trees >150 cm	Adequate Conifer for Mixedwood Standards
Control	0	2	96	NO
2 kg/ha Hexazinone	9	6	83	NO
4 kg/ha Hexazinone	14	9	72	NO
Rome Double Disking	59	19	3	YES
Disk Trenching	8	17	75	NO

Picea glauca

Treatment	Percent *Picea glauca* >50 cm	Percent *Picea glauca* >40 cm	Percent Deciduous Trees >150 cm	Adequate Conifer for Mixedwood Standards
Control	43	11	40	NO
2 kg/ha Hexazinone	52	7	33	YES
4 kg/ha Hexazinone	60	7	23	YES
Rome Double Disking	41	10	8	NO
Disk Trenching	39	3	58	NO

for the RelHT2 index were inverse to the other indices. Although these different measures produced numbers with different ranges of values, they had similar relative rankings. Assessments based on competition indices CI - 1, CI - 5, CI - 6, RelHT2 provided numbers with a wider range of values (e.g., 0 to 4) than did the other indices (e.g., 0.01 to -0.02), which potentially makes differentiation among tested groups more convenient.

It was difficult to assess the relative merits of the tested indices with respect to their ability to reflect the degree of competition that occurs between conifer seedlings and competitors, because an independent variable would be required for such an analysis. A measurable characteristic of seedlings such as height, basal diameter, or current leader growth would be a good candidate variable. However, only one Competition Index (CI - 3) did not use either seedling height or basal diameter as a parameter in the calculation formula. This nullifies the possible use of seedling height parameters as independent variables for assessing competition, since seedling height and basal diameter are strongly correlated.

11. The following summarizes the relative (best to poorest, 1 to 4 scale) efficacy of various site preparation treatment methods with respect to meeting various forest management objectives based on seven years of growth.

Objectives	2 kg/ha Hexazinone	4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching
Control Target Species				
Total *P. tremuloides* Length (m/ha)	4	3	1	3
Shrub Length (m/ha)	3	4	1	4
Graminoid Cover	1	1	4	4
Forb Cover	4	4	1	2
Total Vegetation Cover	4	3	1	2
Plant Community Structure	3	2	1	2
Non-Target Forest Characteristics				
Maintain Species Richness	2	1	4	3
Maintain Species Dominance (λ)	2	1	4	1
Maintain Species Diversity (H')	3	1	4	2
Establishment of *Pinus contorta*				
High Survival Rate	4	3	1	4
Good Health/Vigor	4	3	1	2
Good Height Growth	3	2	1	3
Adequate Conifer Stocking	4	4	1	4
80% Tree Stocking Standard	2	2	3	1
Establishment of *Picea glauca*				
High Survival Rate	1	1	4	4
Good Health/Vigor	2	2	2	1
Good Height Growth	2	1	2	2
Adequate Conifer Stocking	2	1	3	4
80% Tree Stocking Standard	2	2	4	1

Of these methods, the Rome double disking treatment was the more effective method for controlling a variety of different plant growth-forms, but had a severe impact on the ecological characteristics of the vegetation. Rome double disking was better for promoting *Pinus contorta*, while 4 kg/ha of hexazinone was more favorable for *Picea glauca* during the early stages of seedling growth following clearcutting.

6.2 Conifer Release Experiments

12. In 1993, the control plots within the Conifer Release experimental blocks were dominated by a five meter tall *Populus tremuloides* stand (median 67 percent cover) with an understory composed of *Calamagrostis canadensis* (15 percent), *Rosa acicularis* (8 percent), *Epilobium angustifolium* (8 percent), *Aster conspicuus* (6 percent), *Fragaria virginiana* (4 percent), *Vicia americana* (3 percent), *Aster ciliolatus* (2 percent),*Galium boreale* (2 percent), *Lathyrus ochroleucus* (2 percent), *Petasites palmatus* (2 percent), and *Rubus pubescens* (2 percent). Shrub densities within the control plots totalled 48,200 stems/ha. *Populus tremuloides* composed approximately one-third of these stems, while *Rosa acicularis* represented approximately one-quarter of the total.

13. At the time of establishment, the control plots contained approximately 51,903 stems per hectare (ca. 190 cm tall), while individual treatment plots contained pre-treatment densities that ranged from 66,388 to 75,400 woody stems per hectare. These densities were statistically ($P <0.05$) higher than those in the control plot. Between 1986 and 1993, the number of woody stems in the control plots declined by seven percent, while the total volume of woody stems increased by 68 percent.

14. All the treatments or combination of treatment methods in the Conifer Release experimental blocks had a significant impact on vegetation. The majority of this impact occurred during and after the application of the final phase of treatment. Approximately five years has elapsed since these treatments were applied, except Rome double disking which was carried out the summer after plot establishment in 1987. The relative severity of these impacts on the native vegetation was ranked as follows: Rome double disking > disk trenching and 4 kg/ha hexazinone > disk trenching and brushsawing > disk trenching = 2 kg/ha hexazinone > control. These changes included modification of the physiognomy, general composition, and the length of all woody plant stems in the vegetation.

    14a. Rome double disking destroyed all the native vegetation that regenerated after clearcutting in 1983, and converted the plots to a medium height, open-growing tall shrub community with a mixed herb and shrub stratum. *Rosa acicularis* (median cover 7 percent), *Populus tremuloides* (5 percent), and *Salix* spp. (4 percent) were the principal woody plants, while *Calamagrostis canadensis* (14 percent) and *Epilobium angustifolium* (13 percent) were the dominant herb species. Woody stem densities were probably only one-quarter (17,000 stem/ha) their pre-treatment levels four years after disking which was the lowest density among the four tested methods. It is unlikely that vegetation equivalent to the control plots will develop within the rotation age of the site due to the severity of the treatment. Furthermore, the development of conifer dominated vegetation will further inhibit the development of deciduous dominated mixedwood stands due to changes in litter composition and related ecological conditions.

14b. The application of 4 kg/ha of hexazinone destroyed much of the woody vegetation that occurred in this treatment plot. Many of the trees that still occurred in the plot appeared to have been missed during application of the herbicides, since they occurred in linear strips. Where treated the developing vegetation was reduced to a medium height, mixed shrub and herb plant community dominated primarily by *Rosa acicularis*, *Cornus stolonifera*, *Salix* spp., *Epilobium angustifolium* (4 percent), *Galium boreale* (10 percent), *Agropyron trachycaulum* (4 percent), and *Bromus ciliatus* (2 percent). *Calamagrostis canadensis*, a common species in the control plots, appears to have been substantially reduced (15 percent versus zero percent median cover) in abundance as a result of the hexazinone application. This treatment reduced the total number of woody stems per hectare by 66 percent and the total volume of stems by 71 percent as of 1993. It is expected that this vegetation will require several decades to develop a semi-mature forest stand, and will probably not develop vegetation equivalent to the control plots within the logging rotational age of the site. In addition, the more rapid development of conifers in the vegetation may direct the succession away from a deciduous dominated forest towards an open-canopied *Pinus contorta-Populus tremuloides* stand with a rich understory of shrubs. The increased openness of the forest canopy may enhance crop tree growth rates after their height exceeds the tall shrub stratum.

14c. Brushsawing converted a potentially closed-canopied juvenile forest stand into an open-canopied tall shrub (>150 cm tall) community dominated by *Salix* spp. and to a lesser extent *Populus tremuloides*. The understory vegetation is presently dominated by *Rosa acicularis* (7 percent) and *Calamagrostis canadensis* (15 percent). Four years after brushsawing, the density and volume of woody stems was approximately 15 and 21 percent less than its 1988 pre-treatment levels. This treatment appears to have a greater impact on the structure of the vegetation than its floristic composition. It is possible that given sufficient time (40 to 70 years), vegetation similar to the control plots may redevelop, although successionally retarded and with a greater than normal proportion of conifers in the overstory.

14d. The application of 2 kg/ha of hexazinone reduced the density of the overstory vegetation (e.g., 13,000 to 7,300 stem/ha) resulting in an open-canopied *Populus tremuloides* stand. Opening of the canopy probably enhanced the growth of shrubs such as *Salix* spp. and the development of *Populus tremuloides* suckers that occurred in the understory. Application of hexazinone also substantially reduced the abundance of *Calamagrostis canadensis* (15 percent versus one percent) but allowed the expansion of species such as *Achillea millefolium*, *Agropyron trachycaulum*, *Bromus ciliatus*, *Galium boreale*, and *Taraxacum officinale*. Between 1989 (the date of hexazinone application) and 1993, a 20 and 26 percent reduction in the total number and length of woody stems per hectare occurred, respectively. The vegetation in this treatment will probably develop into a semi-closed canopied mixedwood stand with a higher than normal amount of conifers. The more open overstory will probably allow a greater proportion of tall shrubs to develop in the understory. Once openings in the canopy have been filled by trees and tall shrubs, many of the species associated with disturbed sites (e.g., *Achillea millefolium* and *Taraxacum officinale*) will decline in abundance as native species increase their cover. It may require between 10 and 40 years for this vegetation to reach a state of ecological stability.

15. In 1993 or approximately five and six years after treatment, species richness was greater in the hexazinone and brushsawed plots. Simpson's Index (λ) values suggest a higher degree of diversity within the treatments than the control plots with respect to cover. Simpson's values were also similar to those calculated for Site Preparation treatments. These various botanical indices suggest that chemical and mechanical treatments in the Conifer Release experiments produced vegetation which was somewhat floristically richer and more diverse with a lower degree of dominance than the control plots.

16. *Pinus contorta* growth was best (median approximately 130 cm height) in the 4 kg/ha hexazinone and Rome double disking treatments. This overall height was almost double that found in the control plots after six years of growth. However, survival rates were greatest in the Rome double disking and brushsawing treatments (approximately 85 percent), less in the hexazinone plots (approximately 60 percent), and poorest in the control (44 percent) plots. The improved growth and level of survival relative to the control plots was probably due to the elimination of most competing vegetation and increase of the relative portion of resources available for conifer seedling growth. In general, the greater the reduction in competing vegetation the better the growth. Rome double disking appears to promote the best growth, stem volume, and survival among the tested methods.

17. *Picea glauca* height growth was best in the 2 kg/ha hexazinone treatment plot (median 91 cm), but only slightly better than the other treatments (approximately 69 cm). The poorest growth was associated with the control plots (69 cm). The highest survival rates (75 percent) occurred in the control and 2 kg/ha hexazinone plots compared with 45 to 55 percent in the other treatments. The poorer survival rates in the 4 kg/ha hexazinone, Rome double disking, and brushsawing treatments may be due to increased exposure of the seedlings to solar radiation. Based on a combination of height growth, stem volume, and survival rates, the 2 kg/ha hexazinone application appears be the more favorable treatment for promoting *Picea glauca* development during the early stages of growth.

18. Based on 1991 mixedwood forest regeneration standards (Alberta Forest Service 1993, pp. 11-12), if *Pinus contorta* had been the only conifer planted in the treatments (Table 33), only the Rome double disking plots would be considered stocked. However, poor stocking levels in the other treatments tended to be better than in the control plots. If *Picea glauca* had been the only conifer species planted, the control and 2 kg/ha hexazinone plots would be considered adequately stocked, although the brushsawed plots were close (Table 33). The brushsawed plots would have been classified as stocked if a few more conditionally acceptable *Picea glauca* seedlings or *Populus tremuloides* saplings had been present in the surveyed plots. The 4 kg/ha hexazinone plots with *Pinus contorta* did not have an 80 percent stocking of either conifer seedlings or deciduous saplings, while only the control and 2 kg/ha hexazinone plots with *Picea glauca* were similarly stocked.

Table 33. Assessment of stocking in Conifer Release experimental blocks based on 1991 mixedwood regeneration standards (Alberta Forest Service 1993, pp. 11-12). Summary based on the assumption that only one coniferous species was planted in each treatment. To be considered stocked at least 80 percent of the sampled plots must contain a *Pinus contorta* or *Picea glauca* seedling greater than 100 or 50 cm tall, respectively; or more than 45 percent of these seedlings in combination with an additional 35 percent of *Pinus contorta*, *Picea glauca*, or *Populus tremuloides* greater than 75, 40, and 150 cm tall, respectively.

Pinus contorta

Treatment	Percent *Pinus contorta* >100 cm	Percent *Pinus contorta* >75 cm	Percent Deciduous Trees >150 cm	Adequate Conifer for Mixedwood Standards
Control	11	9	77	NO
2 kg/ha Hexazinone and Disk Trenching	23	8	53	NO
4 kg/ha Hexazinone and Disk Trenching	22	3	30	NO
Rome Double Disking	55	7	26	YES
Brushsawed and Disk Trenching	34	22	34	NO

Picea glauca

Treatment	Percent *Picea glauca* >50 cm	Percent *Picea glauca* >40 cm	Percent Deciduous Trees >150 cm	Adequate Conifer for Mixedwood Standards
Control	62	11	27	YES
2 kg/ha Hexazinone and Disk Trenching	68	3	18	YES
4 kg/ha Hexazinone and Disk Trenching	27	0	33	NO
Rome Double Disking	50	2	15	NO
Brushsawed and Disk Trenching	47	7	22	NO

19. Statistically significant differences (P <0.05) occurred among most of the tested Competition Index values. Among the competition variables, the density of woody stems, total woody stem length, percent cover of the C-stratum or *Populus tremuloides*, and height of the tallest *Populus tremuloides* within 180 cm of the crop seedling were usually the better predictors of *Pinus contorta* and *Picea glauca* seedling height in the Conifer Release experimental blocks. The problems and limitations associated with interpreting these competition indices were the same as those in the Site Preparation treatments.

20. The following summarizes the relative (best to poorest, 1 to 4 scale) efficacy of various conifer release treatment methods with respect to meeting various forest management objectives based on seven years of growth.

Objectives	Disk Trenching followed by 2 kg/ha Hexazinone	Disk Trenching followed by 4 kg/ha Hexazinone	Rome Double Disking	Disk Trenching followed by Brushsawing
Control Target Species				
Total *P. tremuloides* Length (m/ha)	4	1	2	3
Shrub Length (m/ha)	3	1	2	4
Graminoid Cover	1	4	4	4
Forb Cover	2	3	1	3
Total Vegetation Cover	2	1	2	2
Plant Community Structure	3	2	1	1
Non-Target Forest Characteristics				
Maintain Species Richness	1	2	4	2
Maintain Species Dominance (λ)	1	1	4	3
Maintain Species Diversity (H')	1	2	4	3
Establishment of *Pinus contorta*				
High Survival Rate	3	3	1	1
Good Health/Vigor	3	3	1	3
Good Height Growth	4	1	2	3
Adequate Conifer Stocking	4	4	1	2
80% Tree Stocking Standard	2	4	1	1
Establishment of *Picea glauca*				
High Survival Rate	1	4	4	4
Good Health/Vigor	1	3	3	2
Good Height Growth	1	4	4	4
Adequate Conifer Stocking	1	4	2	2
80% Tree Stocking Standard	1	4	3	2

Rome double disking treatment was the more effective method for promoting *Pinus contorta*, but also had a severe impact on the ecological characteristics of the treated vegetation. The 2 kg/ha application of hexazinone was the more favorable method for establishing *Picea glauca* following clearcutting.

7.0 RECOMMENDATIONS

A primary objective of this project when it was initiated in 1986 was to "evaluate the impact of PRONONE 10G (hexazinone) and other vegetation management methods on vegetation changes in structure, composition, and dynamics of vegetation" and (Sidhu and Feng 1991, p. 171). To date, the effects of these treatments have been analyzed for only a small portion of the rotational life span of these forest stands (e.g., 7 of 80 years or more). What the long-term biological and ecological implications are for the treated vegetation can only be speculated, since subtle ecological changes could have significant influence on plant community development. If the long-term effects of the tested site preparation and conifer release methods are to be documented, it will be necessary to continue this study. The following are recommendations for continuing this baseline research.

1. Assess vegetation composition, cover, and woody stem densities during the summer of 2002. The time between detailed sampling has been doubling since initiation of the project in 1986. Therefore, it would be appropriate to conduct another vegetation survey in 10 years To accommodate the permanent plot layout and anticipated growth of the coniferous seedings, it may be necessary to redesign the sampling format since the coniferous seedlings may grow to occupy a large proportion of the 2.5 x 2.5 m quadrants used for sampling. Sampling of individual quadrants in this situation could result in unrepresentative data, if the purpose of the analysis was to evaluate vegetation development and track changes in biodiversity. It is suggested that the center post of each plot should be used as the plot center to minimize the influence of the conifers.

   Long-term monitoring projects are relatively rare in forest or ecological research. This particular study, if continued, could provide first-hand documentation on the development of mixedwood forests following clearcutting. Most studies of this type are based on an examination of several forest stands with different ages. The primary difficulties with this approach are the assurance that site conditions and the initial vegetation on all sites are identical, and all sites have had the same development history (e.g., wildlife, pest, fire impacts, etc.).

2. Assess conifer seedling development in 1997/8 (five years after last sampling) and again in 2002/3 using the same seedlings that were measured in 1992.

3. Rome double disking appears to be a very effective treatment for minimizing native vegetation and *Pinus contorta* seedling competition, but the use of this technique has a severe impact on the native vegetation. This impact may be sufficient enough that the vegetation is unable to recover within the forestry rotation life span of the site. Use of this technique on a very limited basis over a large area could increase habitat diversity in areas dominated by deciduous forest, but its widespread use could have a significant impact on environmental conditions in the boreal forest. Therefore, it is recommended that additional research be initiated on the environmental impact of Rome double disking. This work should evaluate the long-term implications for wildlife and hydrology. Similar assessments should also be applied to the use of high dosages of hexazinone as a conifer release technique, since this treatment also drastically alters the native vegetation, probably beyond its ability to recover

within the rotation age of the site.

4. It is important that the two study sites (Site Preparation and Conifer Release) be maintained in an undisturbed condition if this study is to continue. Maintenance of their integrity will require restricting access (e.g., all-terrain vehicles) and not allowing surface disturbances (e.g., seismic lines). Such disturbances already occur within some of the study treatments. In addition, some maintenance work on the plot center posts and number tags, and re-establishment of treatment plot designation markers would be helpful to facilitate the relocation of plots in the future.

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APPENDIX I. PLOT MEMBERSHIP OF SITE PREPARATION DENDROGRAM.

B - block, T - treatment, P - plot, QD - quadrant, and C - cluster.

B	T	P	QD	C
1	1	2	NE	6
1	1	2	SW	1
1	1	4	NE	9
1	1	4	SW	9
1	1	6	NE	9
1	1	6	SW	9
1	1	8	NE	9
1	1	8	SW	9
1	1	10	NE	3
1	1	10	SW	6
1	1	12	NE	3
1	1	12	SW	3
1	1	14	NE	3
1	1	14	SW	6
1	1	16	NE	3
1	1	16	SW	2
1	1	18	NE	3
1	1	18	SW	9
1	1	20	NE	5
1	1	20	SW	6
1	1	22	NE	6
1	1	22	SW	6
1	1	24	NE	1
1	1	24	SW	1
1	1	26	NE	6
1	1	26	SW	9
1	1	28	NE	9
1	1	28	SW	9
1	1	30	NE	6
1	1	30	SW	1
1	1	32	NE	9
1	1	32	SW	8
1	1	34	NE	6
1	1	34	SW	3
1	1	36	NE	8
1	1	36	SW	8
1	1	38	NE	1
1	1	38	SW	1
1	1	40	NE	5
1	1	40	SW	6
1	1	42	NE	9
1	1	42	SW	9
1	1	44	NE	6
1	1	44	SW	6
1	1	46	NE	6
1	1	46	SW	1
1	1	48	NE	6
1	1	48	SW	6
1	1	50	NE	6
1	1	50	SW	1
1	1	52	NE	9
1	1	52	SW	8
1	1	54	NE	6
1	1	54	SW	2
1	1	56	NE	9
1	1	56	SW	8
1	1	58	NE	8
1	1	58	SW	9
1	1	60	NE	8
1	1	60	SW	9
1	2	2	NE	6
1	2	2	SW	9
1	2	4	NE	9
1	2	4	SW	8
1	2	6	NE	9
1	2	6	SW	9
1	2	8	NE	6
1	2	8	SW	2
1	2	10	NE	9
1	2	10	SW	9
1	2	12	NE	1
1	2	12	SW	1
1	2	14	NE	9
1	2	14	SW	6
1	2	16	NE	1
1	2	16	SW	1
1	2	18	NE	9
1	2	18	SW	6
1	2	20	NE	1
1	2	20	SW	1
1	2	22	NE	6
1	2	22	SW	6
1	2	24	NE	9
1	2	24	SW	9
1	2	26	NE	9
1	2	26	SW	9
1	2	28	NE	9
1	2	28	SW	9
1	2	30	NE	9
1	2	30	SW	9
1	2	32	NE	9
1	2	32	SW	1
1	2	34	NE	6
1	2	34	SW	9
1	2	36	NE	6
1	2	36	SW	9
1	2	38	NE	9
1	2	38	SW	1
1	2	40	NE	3
1	2	40	SW	1
1	2	42	NE	9
1	2	42	SW	6
1	2	44	NE	9
1	2	44	SW	4
1	2	46	NE	6
1	2	46	SW	6
1	2	48	NE	9
1	2	48	SW	9
1	2	50	NE	9
1	2	50	SW	9
1	2	52	NE	6
1	2	52	SW	1
1	2	54	NE	6
1	2	54	SW	6
1	2	56	NE	1
1	2	56	SW	1
1	2	58	NE	1
1	2	58	SW	6
1	2	60	NE	1
1	2	60	SW	1
1	5	2	NE	1
1	5	2	SW	5
1	5	4	NE	3
1	5	4	SW	3
1	5	6	NE	7
1	5	6	SW	2
1	5	8	NE	1
1	5	8	SW	9
1	5	10	NE	5
1	5	10	SW	8
1	5	12	NE	8
1	5	12	SW	7
1	5	14	NE	1
1	5	14	SW	1
1	5	16	NE	1
1	5	16	SW	9
1	5	18	NE	7
1	5	18	SW	7
1	5	20	NE	1
1	5	20	SW	7
1	5	22	NE	1
1	5	22	SW	7
1	5	24	NE	5
1	5	24	SW	3
1	5	28	NE	7
1	5	28	SW	1
1	5	30	NE	1
1	5	30	SW	1
1	5	32	NE	7
1	5	32	SW	7
1	5	34	NE	1
1	5	34	SW	1
1	5	36	NE	5
1	5	36	SW	3
1	5	38	NE	2
1	5	38	SW	5
1	5	40	NE	5
1	5	40	SW	1
1	5	42	NE	8
1	5	42	SW	9
1	5	44	NE	9
1	5	44	SW	2
1	5	46	NE	7
1	5	46	SW	1
1	5	48	NE	1
1	5	48	SW	1
1	5	50	NE	6
1	5	50	SW	9
1	5	52	NE	7
1	5	52	SW	7
1	5	54	NE	7
1	5	54	SW	7
1	5	56	NE	1
1	5	56	SW	8
1	5	58	NE	1
1	5	58	SW	3
1	5	60	NE	6
1	5	60	SW	2
1	6	2	NE	4
1	6	2	SW	5
1	6	4	NE	7
1	6	4	SW	5
1	6	6	NE	5
1	6	6	SW	5
1	6	8	NE	5
1	6	8	SW	5
1	6	10	NE	5
1	6	10	SW	7
1	6	12	NE	9
1	6	12	SW	5
1	6	14	NE	5
1	6	14	SW	5

Appendix I. Continued.

B	T	P	QD	C
1	6	16	NE	4
1	6	16	SW	5
1	6	18	NE	5
1	6	18	SW	4
1	6	20	NE	5
1	6	20	SW	4
1	6	22	NE	7
1	6	22	SW	9
1	6	24	NE	5
1	6	24	SW	4
1	6	26	NE	4
1	6	26	SW	5
1	6	28	NE	5
1	6	28	SW	4
1	6	30	NE	9
1	6	30	SW	5
1	6	32	NE	9
1	6	32	SW	5
1	6	34	NE	7
1	6	34	SW	7
1	6	36	NE	9
1	6	36	SW	9
1	6	38	NE	4
1	6	38	SW	4
1	6	40	NE	5
1	6	40	SW	5
1	6	42	NE	5
1	6	42	SW	5
1	6	44	NE	5
1	6	44	SW	4
1	6	46	NE	5
1	6	46	SW	5
1	6	48	NE	4
1	6	48	SW	4
1	6	50	NE	5
1	6	50	SW	5
1	6	52	NE	9
1	6	52	SW	5
1	6	54	NE	5
1	6	54	SW	5
1	6	56	NE	5
1	6	56	SW	5
1	6	58	NE	4
1	6	58	SW	4
1	6	60	NE	4
1	6	60	SW	4
1	7	31	NE	5
1	7	31	SW	5

B	T	P	QD	C
1	7	32	NE	5
1	7	32	SW	5
1	7	33	NE	5
1	7	33	SW	7
1	7	34	NE	7
1	7	34	SW	9
1	7	35	NE	5
1	7	35	SW	5
1	7	36	NE	5
1	7	36	SW	5
1	7	37	NE	4
1	7	37	SW	5
1	7	38	NE	3
1	7	38	SW	8
1	7	39	NE	5
1	7	39	SW	8
1	7	40	NE	5
1	7	40	SW	9
1	7	41	NE	5
1	7	41	SW	5
1	7	42	NE	5
1	7	42	SW	7
1	7	43	NE	2
1	7	43	SW	5
1	7	44	NE	5
1	7	44	SW	4
1	7	45	NE	5
1	7	45	SW	8
1	7	46	NE	7
1	7	46	SW	9
1	7	47	NE	5
1	7	47	SW	5
1	7	48	NE	5
1	7	48	SW	5
1	7	49	NE	5
1	7	49	SW	5
1	7	50	NE	5
1	7	50	SW	4
1	7	51	NE	5
1	7	51	SW	7
1	7	52	NE	8
1	7	52	SW	8
1	7	53	NE	5
1	7	53	SW	5
1	7	54	NE	6
1	7	54	SW	5
1	7	55	NE	5
1	7	55	SW	9

B	T	P	QD	C
1	7	56	NE	5
1	7	56	SW	5
1	7	57	NE	4
1	7	57	SW	7
1	7	58	NE	5
1	7	58	SW	5
1	7	59	NE	5
1	7	59	SW	5
1	7	60	NE	7
1	7	60	SW	5
2	1	2	NE	9
2	1	2	SW	1
2	1	4	NE	9
2	1	4	SW	9
2	1	6	NE	9
2	1	6	SW	3
2	1	8	NE	2
2	1	8	SW	3
2	1	10	NE	1
2	1	10	SW	1
2	1	12	NE	3
2	1	12	SW	4
2	1	14	NE	9
2	1	14	SW	10
2	1	16	NE	10
2	1	16	SW	10
2	1	18	NE	9
2	1	18	SW	9
2	1	20	NE	3
2	1	20	SW	9
2	1	22	NE	3
2	1	22	SW	1
2	1	24	NE	3
2	1	24	SW	3
2	1	26	NE	6
2	1	26	SW	1
2	1	28	NE	2
2	1	28	SW	1
2	1	30	NE	1
2	1	30	SW	1
2	1	32	NE	9
2	1	32	SW	1
2	1	34	NE	1
2	1	34	SW	1
2	1	36	NE	2
2	1	36	SW	2
2	1	38	NE	1
2	1	38	SW	1

B	T	P	QD	C
2	1	40	NE	1
2	1	40	SW	1
2	1	42	NE	2
2	1	42	SW	10
2	1	44	NE	6
2	1	44	SW	9
2	1	46	NE	1
2	1	46	SW	9
2	1	48	NE	1
2	1	48	SW	1
2	1	50	NE	3
2	1	50	SW	9
2	1	52	NE	9
2	1	52	SW	1
2	1	54	NE	9
2	1	54	SW	8
2	1	56	NE	2
2	1	56	SW	8
2	1	58	NE	1
2	1	58	SW	1
2	1	60	NE	9
2	1	60	SW	6
2	2	2	NE	2
2	2	2	SW	2
2	2	4	NE	2
2	2	4	SW	8
2	2	6	NE	3
2	2	6	SW	1
2	2	8	NE	1
2	2	8	SW	3
2	2	10	NE	1
2	2	10	SW	2
2	2	12	NE	6
2	2	12	SW	1
2	2	14	NE	9
2	2	14	SW	10
2	2	16	NE	3
2	2	16	SW	1
2	2	18	NE	6
2	2	18	SW	3
2	2	20	NE	6
2	2	20	SW	9
2	2	22	NE	2
2	2	22	SW	2
2	2	24	NE	8
2	2	24	SW	9
2	2	26	NE	10
2	2	26	SW	3

Appendix I. Continued.

B	T	P	QD	C
2	2	28	NE	10
2	2	28	SW	2
2	2	30	NE	1
2	2	30	SW	10
2	2	32	NE	1
2	2	32	SW	10
2	2	34	NE	1
2	2	34	SW	8
2	2	36	NE	3
2	2	36	SW	1
2	2	38	NE	10
2	2	38	SW	8
2	2	40	NE	3
2	2	40	SW	7
2	2	42	NE	3
2	2	42	SW	3
2	2	44	NE	8
2	2	44	SW	10
2	2	46	NE	2
2	2	46	SW	1
2	2	48	NE	3
2	2	48	SW	10
2	2	50	NE	1
2	2	50	SW	2
2	2	52	NE	3
2	2	52	SW	1
2	2	54	NE	3
2	2	54	SW	3
2	2	56	NE	3
2	2	56	SW	3
2	2	58	NE	3
2	2	58	SW	3
2	2	60	NE	6
2	2	60	SW	8
2	5	2	NE	3
2	5	2	SW	3
2	5	4	NE	3
2	5	4	SW	3
2	5	6	NE	3
2	5	6	SW	1
2	5	8	NE	1
2	5	8	SW	7
2	5	10	NE	3
2	5	10	SW	4
2	5	12	NE	7
2	5	12	SW	1
2	5	14	NE	4
2	5	14	SW	7
2	5	16	NE	1

B	T	P	QD	C
2	5	16	SW	7
2	5	18	NE	3
2	5	18	SW	9
2	5	20	NE	8
2	5	20	SW	7
2	5	22	NE	2
2	5	22	SW	9
2	5	24	NE	1
2	5	24	SW	7
2	5	26	NE	2
2	5	26	SW	7
2	5	28	NE	6
2	5	28	SW	6
2	5	30	NE	5
2	5	30	SW	5
2	5	32	NE	6
2	5	32	SW	7
2	5	34	NE	7
2	5	34	SW	3
2	5	36	NE	1
2	5	36	SW	5
2	5	38	NE	5
2	5	38	SW	8
2	5	40	NE	7
2	5	40	SW	7
2	5	42	NE	5
2	5	42	SW	9
2	5	44	NE	1
2	5	44	SW	7
2	5	46	NE	7
2	5	46	SW	7
2	5	48	NE	7
2	5	48	SW	7
2	5	50	NE	1
2	5	50	SW	1
2	5	52	NE	7
2	5	52	SW	3
2	5	54	NE	7
2	5	54	SW	1
2	5	56	NE	7
2	5	56	SW	5
2	5	58	NE	1
2	5	58	SW	7
2	5	60	NE	7
2	5	60	SW	9
2	6	2	NE	4
2	6	2	SW	4
2	6	4	NE	9
2	6	4	SW	5

B	T	P	QD	C
2	6	6	NE	5
2	6	6	SW	4
2	6	8	NE	4
2	6	8	SW	4
2	6	10	NE	4
2	6	10	SW	4
2	6	12	NE	5
2	6	12	SW	9
2	6	14	NE	9
2	6	14	SW	5
2	6	16	NE	9
2	6	16	SW	9
2	6	18	NE	9
2	6	18	SW	8
2	6	20	NE	5
2	6	20	SW	5
2	6	22	NE	5
2	6	22	SW	9
2	6	24	NE	5
2	6	24	SW	5
2	6	26	NE	5
2	6	26	SW	7
2	6	28	NE	7
2	6	28	SW	7
2	6	30	NE	7
2	6	30	SW	9
2	6	32	NE	5
2	6	32	SW	9
2	6	34	NE	9
2	6	34	SW	9
2	6	36	NE	9
2	6	36	SW	9
2	6	38	NE	6
2	6	38	SW	5
2	6	40	NE	5
2	6	40	SW	5
2	6	42	NE	9
2	6	42	SW	9
2	6	44	NE	5
2	6	44	SW	7
2	6	46	NE	5
2	6	46	SW	5
2	6	48	NE	7
2	6	48	SW	7
2	6	50	NE	9
2	6	50	SW	5
2	6	52	NE	5
2	6	52	SW	9
2	6	54	NE	9

B	T	P	QD	C
2	6	54	SW	9
2	6	56	NE	7
2	6	56	SW	4
2	6	58	NE	6
2	6	58	SW	5
2	6	60	NE	9
2	6	60	SW	4
2	7	31	NE	5
2	7	31	SW	4
2	7	32	NE	7
2	7	32	SW	5
2	7	33	NE	7
2	7	33	SW	9
2	7	34	NE	9
2	7	34	SW	9
2	7	35	NE	9
2	7	35	SW	7
2	7	36	NE	7
2	7	36	SW	9
2	7	37	NE	7
2	7	37	SW	4
2	7	38	NE	7
2	7	38	SW	7
2	7	39	NE	7
2	7	39	SW	7
2	7	40	NE	7
2	7	40	SW	7
2	7	41	NE	7
2	7	41	SW	7
2	7	42	NE	9
2	7	42	SW	5
2	7	43	NE	9
2	7	43	SW	6
2	7	44	NE	1
2	7	44	SW	5
2	7	45	NE	6
2	7	45	SW	3
2	7	46	NE	1
2	7	46	SW	1
2	7	47	NE	9
2	7	47	SW	9
2	7	48	NE	7
2	7	48	SW	9
2	7	49	NE	6
2	7	49	SW	9
2	7	50	NE	7
2	7	50	SW	7
2	7	51	NE	9
2	7	51	SW	2

Appendix I. Continued.

B	T	P	QD	C
2	7	52	NE	9
2	7	52	SW	6
2	7	53	NE	7
2	7	53	SW	9
2	7	54	NE	10
2	7	54	SW	10
2	7	55	NE	3
2	7	55	SW	9
2	7	56	NE	9
2	7	56	SW	1
2	7	57	NE	9
2	7	57	SW	5
2	7	58	NE	7
2	7	58	SW	1
2	7	59	NE	7
2	7	59	SW	9
2	7	60	NE	7
2	7	60	SW	3
3	1	1	NE	9
3	1	1	SW	9
3	1	2	NE	10
3	1	2	SW	9
3	1	3	NE	9
3	1	3	SW	9
3	1	4	NE	4
3	1	4	SW	5
3	1	5	NE	9
3	1	5	SW	1
3	1	6	NE	1
3	1	6	SW	6
3	1	7	NE	6
3	1	7	SW	9
3	1	8	NE	6
3	1	8	SW	7
3	1	9	NE	6
3	1	9	SW	10
3	1	10	NE	9
3	1	10	SW	9
3	1	11	NE	7
3	1	11	SW	7
3	1	12	NE	10
3	1	12	SW	6
3	1	13	NE	10
3	1	13	SW	1
3	1	14	NE	6
3	1	14	SW	1
3	1	15	NE	9
3	1	15	SW	9
3	1	16	NE	6
3	1	16	SW	5
3	1	17	NE	8
3	1	17	SW	3
3	1	18	NE	9
3	1	18	SW	9
3	1	19	NE	3
3	1	19	SW	9
3	1	20	NE	6
3	1	20	SW	6
3	1	21	NE	1
3	1	21	SW	9
3	1	22	NE	6
3	1	22	SW	9
3	1	23	NE	6
3	1	23	SW	9
3	1	24	NE	5
3	1	24	SW	8
3	1	25	NE	6
3	1	25	SW	1
3	1	26	NE	1
3	1	26	SW	6
3	1	27	NE	6
3	1	27	SW	1
3	1	28	NE	10
3	1	28	SW	1
3	1	29	NE	6
3	1	29	SW	8
3	1	30	NE	9
3	1	30	SW	6
3	2	1	NE	4
3	2	1	SW	3
3	2	2	NE	8
3	2	2	SW	1
3	2	3	NE	3
3	2	3	SW	3
3	2	4	NE	1
3	2	4	SW	2
3	2	5	NE	2
3	2	5	SW	2
3	2	6	NE	2
3	2	6	SW	2
3	2	7	NE	2
3	2	7	SW	2
3	2	8	NE	2
3	2	8	SW	3
3	2	9	NE	8
3	2	9	SW	2
3	2	10	NE	3
3	2	10	SW	3
3	2	11	NE	3
3	2	11	SW	9
3	2	12	NE	1
3	2	12	SW	7
3	2	13	NE	1
3	2	13	SW	2
3	2	14	NE	3
3	2	14	SW	2
3	2	15	NE	3
3	2	15	SW	2
3	2	16	NE	2
3	2	16	SW	6
3	2	17	NE	1
3	2	17	SW	6
3	2	18	NE	1
3	2	18	SW	3
3	2	19	NE	4
3	2	19	SW	5
3	2	20	NE	3
3	2	20	SW	2
3	2	21	NE	4
3	2	21	SW	5
3	2	22	NE	4
3	2	22	SW	5
3	2	23	NE	4
3	2	23	SW	4
3	2	24	NE	5
3	2	24	SW	3
3	2	25	NE	9
3	2	25	SW	3
3	2	26	NE	2
3	2	26	SW	3
3	2	27	NE	7
3	2	27	SW	2
3	2	28	NE	6
3	2	28	SW	3
3	2	29	NE	3
3	2	29	SW	2
3	2	30	NE	2
3	2	30	SW	9
3	5	1	NE	1
3	5	1	SW	2
3	5	2	NE	3
3	5	2	SW	1
3	5	3	NE	3
3	5	3	SW	2
3	5	4	NE	3
3	5	4	SW	3
3	5	5	NE	3
3	5	5	SW	2
3	5	6	NE	3
3	5	6	SW	7
3	5	7	NE	2
3	5	7	SW	3
3	5	8	NE	7
3	5	8	SW	2
3	5	9	NE	2
3	5	9	SW	1
3	5	10	NE	1
3	5	10	SW	1
3	5	11	NE	3
3	5	11	SW	2
3	5	12	NE	7
3	5	12	SW	7
3	5	13	NE	3
3	5	13	SW	2
3	5	14	NE	7
3	5	14	SW	3
3	5	15	NE	2
3	5	15	SW	2
3	5	16	NE	1
3	5	16	SW	5
3	5	17	NE	1
3	5	17	SW	1
3	5	18	NE	2
3	5	18	SW	2
3	5	19	NE	7
3	5	19	SW	2
3	5	20	NE	2
3	5	20	SW	3
3	5	21	NE	7
3	5	21	SW	1
3	5	22	NE	2
3	5	22	SW	1
3	5	23	NE	2
3	5	23	SW	1
3	5	24	NE	2
3	5	24	SW	1
3	5	25	NE	1
3	5	25	SW	7
3	5	26	NE	1
3	5	26	SW	3
3	5	27	NE	2
3	5	27	SW	7
3	5	28	NE	7
3	5	28	SW	9
3	5	29	NE	1
3	5	29	SW	7

Appendix I. Concluded.

B	T	P	QD	C
3	5	30	NE	2
3	5	30	SW	3
3	6	1	NE	4
3	6	1	SW	5
3	6	2	NE	4
3	6	2	SW	6
3	6	3	NE	4
3	6	3	SW	5
3	6	4	NE	5
3	6	4	SW	4
3	6	5	NE	5
3	6	5	SW	4
3	6	6	NE	5
3	6	6	SW	8
3	6	7	NE	9
3	6	7	SW	9
3	6	8	NE	5
3	6	8	SW	7
3	6	9	NE	9
3	6	9	SW	9
3	6	10	NE	5
3	6	10	SW	9
3	6	11	NE	9
3	6	11	SW	9
3	6	12	NE	5
3	6	12	SW	5
3	6	13	NE	9
3	6	13	SW	5
3	6	14	NE	5
3	6	14	SW	5
3	6	15	NE	6
3	6	15	SW	4
3	6	16	NE	5
3	6	16	SW	4
3	6	17	NE	5
3	6	17	SW	5
3	6	18	NE	4
3	6	18	SW	5
3	6	19	NE	8
3	6	19	SW	5
3	6	20	NE	5
3	6	20	SW	5
3	6	21	NE	5
3	6	21	SW	9
3	6	22	NE	4
3	6	22	SW	5
3	6	23	NE	5
3	6	23	SW	5
3	6	24	NE	5
3	6	24	SW	4
3	6	25	NE	5
3	6	25	SW	5
3	6	26	NE	5
3	6	26	SW	5
3	6	27	NE	9
3	6	27	SW	5
3	6	28	NE	8
3	6	28	SW	4
3	6	29	SW	7
3	6	29	SW	9
3	6	30	NE	9
3	6	30	SW	5
3	7	31	NE	5
3	7	31	SW	7
3	7	32	NE	5
3	7	32	SW	5
3	7	33	NE	3
3	7	33	SW	7
3	7	34	NE	8
3	7	34	SW	6
3	7	35	NE	3
3	7	35	SW	8
3	7	36	NE	9
3	7	36	SW	9
3	7	37	NE	6
3	7	37	SW	1
3	7	38	NE	4
3	7	38	SW	9
3	7	39	NE	1
3	7	39	SW	6
3	7	40	NE	6
3	7	40	SW	8
3	7	41	NE	8
3	7	41	SW	1
3	7	42	NE	5
3	7	42	SW	9
3	7	43	NE	6
3	7	43	SW	9
3	7	44	NE	5
3	7	44	SW	5
3	7	45	NE	6
3	7	45	SW	5
3	7	46	NE	9
3	7	46	SW	7
3	7	47	NE	8
3	7	47	SW	8
3	7	48	NE	8
3	7	48	SW	5
3	7	49	NE	9
3	7	49	SW	7
3	7	50	NE	9
3	7	50	SW	5
3	7	51	NE	2
3	7	51	SW	2
3	7	52	NE	2
3	7	52	SW	1
3	7	53	NE	3
3	7	53	SW	9
3	7	54	NE	5
3	7	54	SW	5
3	7	55	NE	4
3	7	55	SW	8
3	7	56	NE	9
3	7	56	SW	8
3	7	57	NE	7
3	7	57	SW	8
3	7	58	NE	6
3	7	58	SW	1
3	7	59	NE	7
3	7	59	SW	1
3	7	60	NE	1
3	7	60	SW	8

APPENDIX II. PLOT MEMBERSHIP OF CONIFER RELEASE DENDROGRAM.
B - block, T - treatment, P - plot, QD - quadrant, and C - cluster.

B	T	P	QD	C
4	1	8	NE	1
4	1	8	SW	2
4	1	10	NE	3
4	1	10	SW	1
4	1	14	NE	2
4	1	14	SW	3
4	1	16	NE	7
4	1	16	SW	2
4	1	22	NE	1
4	1	22	SW	5
4	1	24	NE	1
4	1	24	SW	2
4	1	26	NE	4
4	1	26	SW	7
4	1	28	NE	7
4	1	28	SW	3
4	1	34	NE	2
4	1	34	SW	2
4	1	36	NE	2
4	1	36	SW	2
4	1	38	NE	2
4	1	38	SW	3
4	1	40	NE	1
4	1	40	SW	3
4	1	42	NE	2
4	1	42	SW	4
4	1	46	NE	3
4	1	46	SW	4
4	1	48	NE	5
4	1	48	SW	2
4	1	50	NE	3
4	1	50	SW	1
4	1	52	NE	3
4	1	52	SW	3
4	1	54	NE	6
4	1	54	SW	2
4	1	56	NE	5
4	1	56	SW	3
4	1	58	NE	4
4	1	58	SW	1
4	2	6	NE	7
4	2	6	SW	7
4	2	8	NE	7
4	2	8	SW	7
4	2	14	NE	7
4	2	14	SW	7
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4	2	18	NE	4
4	2	18	SW	2
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4	2	32	SW	7
4	2	38	NE	4
4	2	38	SW	7
4	2	42	NE	7
4	2	42	SW	5
4	2	44	NE	7
4	2	44	SW	7
4	2	46	NE	7
4	2	46	SW	7
4	2	48	NE	6
4	2	48	SW	4
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4	3	8	SW	2
4	3	10	NE	3
4	3	10	SW	7
4	3	12	NE	2
4	3	12	SW	5
4	3	14	NE	4
4	3	14	SW	4
4	3	18	NE	2
4	3	18	SW	5
4	3	20	NE	5
4	3	20	SW	4
4	3	26	NE	2
4	3	26	SW	7
4	3	30	NE	5
4	3	30	SW	7
4	3	34	NE	2
4	3	34	SW	2
4	3	36	NE	7
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4	3	40	NE	2
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4	5	12	SW	4
4	5	14	NE	7
4	5	14	SW	6
4	5	16	NE	4
4	5	16	SW	5
4	5	18	NE	4
4	5	18	SW	4
4	5	20	NE	7
4	5	20	SW	5
4	5	22	NE	7
4	5	22	SW	8
4	5	26	NE	5
4	5	26	SW	5
4	5	30	NE	5
4	5	30	SW	5
4	5	32	NE	5
4	5	32	SW	7
4	5	34	NE	4
4	5	34	SW	7
4	5	38	NE	6
4	5	38	SW	4

Appendix II. Continued.

B	T	P	QD	C
4	5	40	NE	5
4	5	40	SW	5
4	5	42	NE	7
4	5	42	SW	7
4	5	48	NE	4
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5	1	40	SW	1
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5	1	44	SW	1
5	1	46	NE	6
5	1	46	SW	3
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5	1	48	SW	1
5	1	50	NE	1
5	1	50	SW	1
5	1	54	NE	1
5	1	54	SW	5
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5	2	4	SW	7
5	2	6	NE	4
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5	2	20	SW	7
5	2	24	NE	7
5	2	24	SW	1
5	2	28	NE	7
5	2	28	SW	5
5	2	30	NE	4
5	2	30	SW	2
5	2	34	NE	2
5	2	34	SW	2
5	2	36	NE	7
5	2	36	SW	7
5	2	38	NE	7
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5	2	44	SW	7
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5	2	60	SW	3
5	3	2	NE	7
5	3	2	SW	7
5	3	6	NE	8
5	3	6	SW	5
5	3	8	NE	2
5	3	8	SW	7
5	3	10	NE	8
5	3	10	SW	7
5	3	12	NE	7
5	3	12	SW	7
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5	4	12	NE	7
5	4	12	SW	7
5	4	14	NE	7
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5	4	16	SW	3
5	4	18	NE	7
5	4	18	SW	8
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5	4	22	NE	9
5	4	22	SW	8
5	4	24	NE	2
5	4	24	SW	8
5	4	26	NE	8
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5	4	48	SW	3
5	4	50	NE	7
5	4	50	SW	9
5	4	52	NE	8
5	4	52	SW	5
5	4	54	NE	6
5	4	54	SW	5
5	4	58	NE	8
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5	5	26	NE	4
5	5	26	SW	2
5	5	32	NE	4
5	5	32	SW	2
5	5	36	NE	5
5	5	36	SW	4
5	5	40	NE	2
5	5	40	SW	7
5	5	42	NE	7
5	5	42	SW	4
5	5	44	NE	4
5	5	44	SW	4
5	5	48	NE	4
5	5	48	SW	4
5	5	50	NE	5
5	5	50	SW	4
5	5	52	NE	4
5	5	52	SW	4
5	5	54	NE	5
5	5	54	SW	4

Appendix II. Concluded.

B	T	P	QD	C
5	5	56	NE	4
5	5	56	SW	5
6	1	6	NE	3
6	1	6	SW	1
6	1	8	NE	1
6	1	8	SW	1
6	1	14	NE	1
6	1	14	SW	1
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6	1	18	SW	1
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6	1	24	SW	1
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6	1	26	SW	1
6	1	30	NE	1
6	1	30	SW	1
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6	1	34	SW	1
6	1	38	NE	1
6	1	38	SW	1
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6	1	44	NE	1
6	1	44	SW	1
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6	1	48	SW	2
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6	2	4	SW	7
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6	2	8	SW	7
6	2	10	NE	7
6	2	10	SW	3
6	2	12	NE	4
6	2	12	SW	7
6	2	14	NE	4

B	T	P	QD	C
6	2	14	SW	2
6	2	16	NE	7
6	2	16	SW	2
6	2	18	NE	6
6	2	18	SW	7
6	2	26	NE	7
6	2	26	SW	2
6	2	28	NE	7
6	2	28	SW	7
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6	2	40	SW	2
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6	2	60	SW	6
6	3	2	NE	3
6	3	2	SW	3
6	3	6	NE	7
6	3	6	SW	6
6	3	10	NE	7
6	3	10	SW	7
6	3	12	NE	2
6	3	12	SW	4
6	3	16	NE	3
6	3	16	SW	7
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6	3	28	NE	3
6	3	28	SW	2
6	3	32	NE	7
6	3	32	SW	7
6	3	34	NE	8
6	3	34	SW	7

B	T	P	QD	C
6	3	36	NE	7
6	3	36	SW	7
6	3	38	NE	7
6	3	38	SW	4
6	3	40	NE	8
6	3	40	SW	7
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6	4	38	SW	7
6	4	42	NE	9
6	4	42	SW	9
6	4	44	NE	9
6	4	44	SW	7
6	4	46	NE	9
6	4	46	SW	8

B	T	P	QD	C
6	4	48	NE	2
6	4	48	SW	8
6	4	50	NE	8
6	4	50	SW	8
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6	5	44	SW	7
6	5	46	NE	7
6	5	46	SW	2
6	5	50	NE	4
6	5	50	SW	7
6	5	52	NE	4
6	5	52	SW	2
6	5	56	NE	7
6	5	56	SW	7
6	5	60	NE	7
6	5	60	SW	7