PLANTATION ESTABLISHMENT FOLLOWING CHEMICAL SITE PREPARATION WITH TRICLOPYR AND PLANTATION RELEASE WITH TRICLOPYR-GLYPHOSATE HERBICIDE MIXTURES

by

Joseph L. Ladouceur ©

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Name of Candidate: Joseph L. Ladouceur

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This thesis has been prepared under my supervision and the candidate has complied with the regulations for the degree:

Supervisor	Date
Chairman, Graduate Studies	Date

Joseph L. Ladouceur

ABSTRACT

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Key Words: Boreal, jack pine, chemical site preparation, crop tree release, non-crop vegetation, competition, vegetation index, herbicide, herbicide mixtures, triclopyr ester, glyphosate.

Two field studies were conducted to evaluate the use of Release™ (triclopyr ester) for chemical site preparation and its use in mixture with glyphosate for jack pine (*Pinus banksiana* Lamb.) plantation release.

The objective of the first field study was to determine the minimum time interval between chemical site preparation with 3.84 kg ae/ha of triclopyr ester and planting containerized jack pine seedlings. In July 1992, a randomized complete block design was established on a well- drained, coarse sandy outwash, west of Thunder Bay, Ontario. The herbicide was applied on July 20th, 1992, and seedlings were planted into treated and untreated plots 1, 7, 28, 56 and 84 days after application. Seedling responses were assessed one year later. Seedlings planted 1, 7 and 28 days after the herbicide application had consistently poorer survival, physical condition and volume growth than the controls. Needle length of seedlings planted 1 day after treatment were shorter in the treated plots than in the control plots. A minimum time interval of at least one month between the application of 3.84 kg ae/ha of triclopyr ester and the planting of jack pine is recommended.

The objectives of the second field study were to: 1) test the efficacy of a variety tank mixtures of Release™, Touchdown 480™ (glyphosate) and Vision™ (glyphosate) herbicides in controlling common boreal forest weed species; and 2) document the growth response, if any, of planted containerized jack pine seedlings. In August 1992, a randomized complete block design was established on an upland mixedwood clearcut west of Thunder Bay, Ontario. Twenty-one herbicide treatments, one manually weeded control and one untreated control were compared. One year after treatment application, non-crop vegetation and jack pine seedling survival, physical condition, needle length and volume growth were greatly affected by the composition of the herbicides when applied alone and in mixtures. In general, herbicide mixtures offered no advantage over herbicides applied alone for jack pine plantation release because of the detrimental effects induced on the crop. Vision™ applied alone at 2.14 kg ae/ha resulted in the best control of non-crop vegetation and in the least damage to the crop trees.

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INTRODUCTION

Non-crop vegetation (brush and herbaceous plants) may compete with conifer crop species for growing space, light, soil moisture and nutrients. This can result in: 1) failures or delays in the regeneration and establishment of crop trees; 2) losses in future harvest volumes (Deloitte & Touche, 1992) and; 3) higher variability in the size of individual trees (Brand & Weetman, 1986). The major objective of vegetation control with herbicides in commercial forestry is to stimulate the establishment and growth of desirable timber species (Deloitte & Touche, 1992).

Herbicides are among the most economical silvicultural tools used to control non-crop vegetation in North American forestry operations. They are rarely used to kill non-crop vegetation outright, but to suppress it for a short period of time to provide crop trees with favourable establishment and growing conditions (Malik & Vanden Born, 1986). Often, the control of one or more species will allow other new species to invade the environment of the crop tree [Day, (pers. comm., 1993)]. Vegetation control treatments more often result in a partial or temporary reduction in the overall vegetation biomass coupled with a shift in the dominant non-crop vegetative species (Morris *et al.* 1993).

In Ontario, the mandate of the Vegetation Management Alternatives Program (VMAP) is to develop approaches to managing non-crop forest vegetation that will reduce the dependence on herbicides. Unfortunately, adequate alternatives do not currently exist for most of Ontario's forest conditions (Wagner *et al.* 1993). Buse *et al.* (1994) present the results of a recent province wide survey that illustrates the magnitude of herbicide use by the forest industry and the Ontario Ministry of Natural Resources (OMNR) (over a three year period; 1990-1992). On average, 15% of site preparation and 90% of forest tending was accomplished with herbicides.

Herbicides can be viewed as having specific "**silvicultural niches**". A silvicultural niche is defined by the vegetation management objective(s), the type of silvicultural activity (site preparation, release or cleaning, precommercial thinning) and the specific site conditions (time of year, vegetation types, soil types, topography, etc.). For a herbicide 'to fit' in a specific niche, it must be biologically, logistically and economically efficient to coincide with the criteria and conditions associated with the niche.

In Canada, there are only a few herbicides registered that are available for use in vegetation management. Each of these herbicides have specific silvicultural niches, which are defined by a variety of product attributes, including: the types of vegetation controlled; the method of herbicide application; the time of application; the herbicide mode of action; and the silvicultural activity for which the herbicide can be applied.

The following are three common silvicultural activities, where the opportunity for vegetation control with herbicides exists.

1) **Site preparation** is the control of non-crop vegetation on recently harvested areas prior to seeding or planting, to provide a suitable environment for planting or seeding, and to ensure the crop seedlings sufficient time to become established before the regrowth of undesirable species (Deloitte & Touche, 1992; Stewart, 1987). The herbicide chosen must, among other things, be able to control the undesirable vegetation effectively, must not have residual adverse effects on the future planted crop trees and could be applied concurrent with mechanical site preparation to reduce costs.

2) **Release or cleaning** is the control of non-crop vegetation that is overtopping, surrounding or threatening crop trees, to permit a 'free-growing' condition that increases survival, vigour and growth of desired tree species (Deloitte & Touche, 1992; Stewart, 1987). The herbicide chosen must, among other things, not have adverse effects on planted crop trees and must be easily applied at the appropriate time for effective vegetation control.

3) **Precommercial thinning** is the removal of poorly formed, slow growing, diseased or excess unmerchantable trees of desirable species, between 5 and 15 years after establishment to control spacing (Deloitte & Touche, 1992). The herbicide chosen must, among other things, be economically applied (e.g. inexpensive use of EZJECT™ relative to hack and squirt or girdling techniques) and must not translocate through grafted root systems or indirectly cause damage to crop trees (e.g. the introduction of pathogens through dead stems).

An additional, relatively uncommon silviculture activity for which herbicides are being tested is herbicide application concurrent with timber harvest with a feller-buncher-sprayer (Vidrine, 1993). Figure 1 summarizes the general decision making process of determining an appropriate herbicide for a specific silvicultural niche in accordance with the objective(s), silvicultural activity and specific site conditions.

Glyphosate and triclopyr ester are two of only five commonly used herbicides registered for vegetation control in Canadian forest management (the other three being hexazinone, 2,4-D and simazine) (Campbell, 1991).

Glyphosate is a broad spectrum non-selective herbicide that is effective in the control of many undesirable woody and herbaceous plants and grasses in the boreal forest (Canadian Pulp & Paper Association (CPPA), 1994). However, it does not consistently control maple (*Acer* L. spp.) (Pitt *et al.* 1992). Glyphosate has been registered for ground and aerial use in Canadian forest vegetation management since 1984.

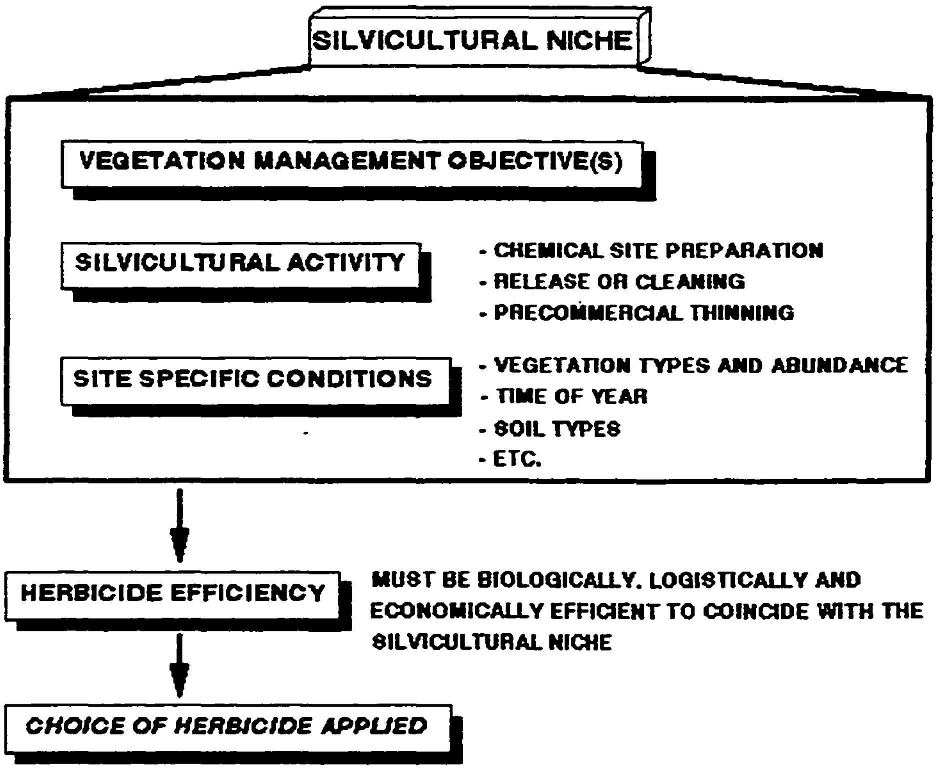

Figure 1. The decision making process for determining an appropriate herbicide for application.

As triclopyr ester has only recently been registered (in 1991) for Canadian forest vegetation management, its feasibility as a silvicultural herbicide has yet to be fully evaluated. Triclopyr is a broad spectrum, auxin type, selective herbicide used for the control of broadleaf herbaceous weeds and woody plants (DowElanco, n.d.). However, triclopyr is ineffective in the control of grasses and bracken fern (*Pteridium aquilinum* (L.) Kuhn.) (Buse, 1992). The resistance of *Carex* (Dill.) L. spp. to the application of triclopyr is not documented (Buse & Bell, 1992). This herbicide is equivalent to glyphosate in the control of many hardwood species (Deloitte & Touche, 1992). Information about the effectiveness and efficiency of this herbicide is not as abundant as compared to glyphosate. Additional baseline data are required to refine the use of triclopyr ester and determine its potential as a tool for vegetation management.

RESEARCH OBJECTIVES

Two field studies were conducted to assist DowElanco Canada Inc. with further evaluation of Release™ Silvicultural Herbicide (triclopyr ester). Based on DowElanco's experimental design criteria, both the studies were initiated in the summer of 1992, west of Thunder Bay, Ontario.

The objective of **Field Study #1** was:

To determine the minimum safe time interval between chemical site preparation with triclopyr ester and planting containerized jack pine (*Pinus banksiana* Lamb.) seedlings.

The incentive for this study lies in the fact that some herbicides used for chemical site preparation persist on a site for a period of time while their degradation takes place. It is important to know what effect such a persistence may have on conifer seedlings. The Release ™product label indicates that conifer planting should be delayed for at least one year after chemical site preparation (DowElanco, 1995). Shortening the time interval between chemical site preparation and planting will prolong the period which planted seedlings are able to grow in the absence of the effects of non-crop vegetation. With good initial preparation and the rapid initial growth of the crop trees, subsequent release treatments may be minimized or eliminated (Becker *et al.* 1990). It is essential to know both the negative effects of triclopyr herbicide on the jack pine crop and the time period during which such effects occur[1]. If it is not necessary to delay planting for one year following application, this herbicide's silvicultural niche could potentially be expanded for use on forest sites which require chemical site preparation and immediate (same year) regeneration.

The objectives of **Field Study #2** were:

a) To test the efficacy of tank mixtures of Release™ (triclopyr ester) and Touchdown 480™ (glyphosate) or Vision™ (glyphosate) herbicides in controlling common boreal forest weed species; and

b) To document the growth response, if any, of planted containerized jack pine seedlings one growing season after the application of triclopyr-glyphosate herbicide mixtures.

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[1] This field study also included containerized black spruce (Picea mariana (Mill.) B.S.P) seedlings. However this report focuses strictly on jack pine.

The incentive for this trial lies in the fact that many herbicides are limited in their ability to successfully control all species of non-crop vegetation on a forest site (Walstad *et al.* 1987). It is favourable to use a single herbicide or a herbicide mixture which will control/reduce either the most abundant species and/or those which are most threatening to the well-being of the crop trees. It is not economically desirable to have more than one herbicide application, per rotation, to release crop trees from the influence of non-crop vegetation. However, chemical site preparation followed by a post-plant chemical release from non-crop vegetation is commonly practiced worldwide.

Herbicide mixtures can be used to: a) widen the spectrum of vegetation control greater than that achieved from a single herbicide and; b) to control several different species with a single herbicide application (Bohmont, 1983; Hydrick & Shaw, 1994; Walstad *et al.* 1987). Therefore by applying a herbicide mixture, the silviculture niche in which both glyphosate and triclopyr ester may be used, may be broadened. It has recognized that there is an imminent need for a herbicide product that will control a broad spectrum of forest vegetation with a single application.

Literature Review

A comprehensive literature review was undertaken which addresses the following:

- Ecological disturbance and silviculture;
- Concepts of 'competition';
- Response of conifers to competing vegetation;
- Response of conifers to release from competing vegetation;
- Jack pine and competing vegetation;
- Triclopyr ester and glyphosate herbicides;
- Susceptibility of non-crop vegetation to triclopyr ester and glyphosate;
- Susceptibility of conifer crop trees to triclopyr ester and glyphosate;
- Minimum time intervals between chemical site preparation with triclopyr ester and plantation establishment; and,
- The use of herbicide mixtures.

LITERATURE REVIEW

ECOLOGICAL DISTURBANCE AND SILVICULTURE

Succession refers to the *process of change* by which biotic communities replace each other and by which the physical environment becomes altered over a period of time (Kimmins, 1987). An ecological disturbance refers to the total or partial destruction of plant biomass. Such disturbances can alter plant succession in terms of species composition, rate of change, spatial distribution and growth patterns (Wagner & Zasada, 1991). One objective of silviculture, from both the biological and economic standpoints, is to restrict the composition and structure of forest stands to those vegetative species that can maximize their growth on a particular site (Smith, 1986). This is achieved, essentially, through a controlled series of ecological disturbances. Nearly all silvicultural activities are disturbances to the forest ecosystem (Wagner & Zasada, 1991).

Understanding the patterns and mechanisms of plant succession following disturbance is important if successful control of non-crop vegetation is to occur. Wagner & Zasada (1991) indicate that the presence of non-crop vegetation on a forest site is determined by: 1) species composition of plants that are presently on the site, were on the site in the past and are capable of invading in the future, and 2) the type, intensity, timing and frequency of the disturbance. Plant succession is determined largely by how the ecological characteristics of plant species interact with each other and with the disturbance (silvicultural activity).

Ecological disturbance and the mechanisms of plant and forest succession are well addressed by Odum (1993), Kimmins (1987) and Walstad & Kuch (1987). However, in the context of this study, it is necessary to summarize some of the basic ecological concepts about the manipulation of vegetation in silviculture. Although, not always correct, plant species interactions with crop trees are often viewed by the silviculturist as *competition*.

CONCEPTS OF 'COMPETITION'

'Competition' Defined

The usage of the term 'competition' by forest managers generally makes reference to an abundance of non-crop vegetation associated with establishing crop trees. Competing vegetation is defined as unwanted or undesirable vegetation which suppresses or inhibits the growth and survival of conifer crop trees (Coates & Haeussler, 1986). This definition of competition is somewhat simplistic and misleading, because there are other types of plant-plant interactions which may influence crop tree growth.

Interference and Interaction

The term *interference* has been used to describe interactions caused by the presence of a plant population in the environment of one or more neighbouring plant populations. Interference is classified as neutral (no effect), positive (stimulation) or negative (depression or inhibition). The actual causes of interference may include: the production or consumption of resources, the production of growth stimulants or toxins, parasitism, predation, or protection (Radosevich & Osteryoung, 1987).

An *interaction* is defined as the effect that two or more plants or plant populations have on each other. Odum (1993) describes the possible interactions that may occur among plants growing together and they are defined by the type of interference that occurs. These include: neutralism, mutualism, protocooperation, commensalism, competition, amensalism, parasitism and predation. Table 1, adapted from Radosevich and Osteryoung (1987), summarizes possible interactions between plants and the types of interference associated with each (positive, neutral or negative).

Table 1. A summary of possible interactions between plants and the interference classification associated with each ('+' = positive; '0' = neutral; '-' = negative) (adapted from Radosevich & Osteryoung, 1987).

INTERACTION	INTERFERENCE ON SPECIES A	INTERFERENCE ON SPECIES B
Neutralism	0	0
Mutualism	+	+
Protocooperation	+	+
Commensalism	+	0
Competition	-	-
Amensalism	0	-
Parasitism, predation	+	-

This review focuses on three specific interactions which are particularly relevant in vegetation control strategies; commensalism, amensalism and competition. Commensalism is a positive interference; while both amensalism and competition are negative interferences.

Positive Interference

Commensalism is an interaction involved in positive interference, whereby one plant population is benefited, but the other is not (Odum, 1971; Begon & Mortimer, 1986; Odum, 1993). Non-crop vegetation may positively interact with conifer crop trees in several ways by:

- maintaining site productivity by reducing nutrient losses due to soil leaching (Comeau *et al.* 1993) or by fixing nitrogen (LePage & Coates, 1993; Richardson, 1993);
- retarding soil erosion through stabilization of soil by their root systems (Comeau *et al.* 1993);
- adding organic matter to the soil through leaf fall and root sloughing, thereby improving soil moisture and the cation exchange capacity of the soil;
- protecting the upper soil layers from temperature extremes (Radosevich & Osteryoung, 1987; Bell, 1991);
- shading seedlings in some circumstances, thereby moderating extremes of environmental factors such as temperature, moisture and light (Radosevich & Osteryoung, 1987; Bell, 1991);
- improving seedling growth and development by reducing moisture stress and respiration rates;
- reducing the potential for the development of additional non-crop vegetation; and by,
- reducing some types of pest damage (Comeau *et al.* 1993).

Initial conifer survival tends to be enhanced by the association with non-crop vegetation. It appears, however, that once the seedlings become established (approximately one year), the benefits of non-crop vegetation decrease as the crop tree's requirements for resources increase (Radosevich & Osteryoung, 1987).

Negative Interference

Amensalism and competition are two key interactions involved in negative interference. **Amensalism** is the interaction in which only one of the plant populations is depressed or inhibited, whereas the other is not. **Competition** is the interaction in which two or more plant populations, utilizing the same limited resource, depress or inhibit each other (Odum, 1971; Silvertown, 1982; Begon & Mortimer, 1986; Radosevich & Osteryoung, 1987).

Radosevich & Osteryoung (1987) state that amensalism and competition are often considered together and termed 'competition' because, in both the forms of interaction, one species usually is depressed or inhibited more than the other.

Artificial regeneration by planting generally results in a fixed number of trees and an invasion of numerous other plant species. It is unlikely that newly established crop trees suppress or inhibit invading vegetation. Hence, it may be more appropriate to use the term 'amensalism' (Begon & Mortimer, 1986). In such 'one-sided' cases of competition, it is impossible to discern any measurable detrimental effects on the stronger competitor (i.e. the crop trees' effect on non-crop vegetation) (Begon & Mortimer, 1986). In fact, many 'competition' experiments only measure the response of one species (the crop tree) to the interaction, which makes any differentiation between competition and amensalism impossible. Hence, the use of the term 'competition' may be incorrect, from an ecological standpoint, but it generally refers to the suppression of one plant species by another (Radosevich & Osteryoung, 1987).

Many species of non-crop vegetation have inherent biological advantages over desired crop trees. Some of these advantages are as follows:

- they often produce abundant seed crops at frequent intervals;
- they are often capable of rapid juvenile growth from either seed or sprouts (Deloitte & Touche, 1992; Newton *et al.* 1987);
- they often have a variable range of shade tolerance;
- they are often able to germinate in either softwood or hardwood litter;
- they may be faster growing than conifers;
- they often sprout prolifically from established roots, rhizomes and stolons (Deloitte & Touche, 1992; Walstad *et al.* 1987);
- they often have the ability to become established from seed banks (i.e. pin cherry (*Prunus pensylvanica* L.f.) and raspberry (*Rubus* L. spp.) (Bell, 1991; Newton *et al.* 1987); and,
- they are often able to survive various and severe disturbances in a relatively intact form and, thereby, are in a position to rapidly capture space previously occupied by conifers (Walstad *et al.* 1987).

Because of these advantages, non-crop vegetation can negatively interact with crop trees in several ways by:

- directly competing with seedlings for available light, moisture, nutrients and/or physical space (Comeau *et al.* 1993; Ross & Walstad, 1986; Bell, 1991);

- causing physical injury to seedlings (e.g. through abrasive action);
- smothering seedlings with fallen leaves or snow-pressed non- woody vegetation (Comeau *et al.* 1993);
- causing allelopathic effects;
- increasing fire potential (Sutton, 1985; Bell, 1991); and by
- providing a favourable habitat for biological pests or rodents which have the potential to damage or kill young seedlings (Comeau *et al.* 1993; Sutton, 1985; Ross & Walstad, 1986; Bell, 1991).

The direct competition, between crop trees and other vegetation for essential resources, becomes the focus of attention because these resources are required for the proper physiological functioning of establishing seedlings. Without an adequate supply of moisture, nutrient, light and space, seedlings may die or, at best, may grow well below their potential rate (Ross & Walstad, 1986; Bell, 1991). Crop trees are most susceptible to competition from other vegetation during the regeneration stage, but may still be susceptible up to the sapling and even the pole stages of growth (Stewart, 1987).

When assessing the effects of positive and negative interference of vegetation on the crop, the *net* effect must be determined. The potential benefits of non-crop vegetation (e.g. favourable seedling microenvironment) must be balanced against the potential liabilities caused by its presence (e.g. increased demand for resources) (Wagner & Zasada, 1991). The *net* effect of the concurrent presence of non-crop vegetation and conifer crop trees is usually negative (Greaves *et al.* 1978).

Intraspecific and Interspecific Competition

Plant density and/or rate growth will be reduced or held in 'check' by competition. Both competition within species and between species are important in determining the number and species of plants found on a particular site (Odum, 1993).

Radosevich & Osteryoung (1987) define *intraspecific competition* as the negative interactions between plants of the same species. It is very intense because closely related individuals must exist in similar, if not identical, niches. Conifer crop species often naturally regenerate at extremely high densities and this can be as disadvantageous as the establishment of non-crop vegetation (and more difficult to manage silviculturally) [Day, (pers. comm., 1993)]. Control of initial plantation spacing, the use of nurse crops and/or precommercial thinning are often the only silvicultural solutions to limiting intraspecific competition.

Interspecific competition involves negative interactions among plants of different species (Radosevich & Osteryoung, 1987). It includes both the amensalistic and/or competitive interactions between crop trees and other non-crop vegetation. Prompt reforestation after harvest to obtain fully stocked stands and crown closure, and the application of intensive silvicultural practices will limit interspecific competition. Such practices include mechanical and chemical site preparation, the use of nurse crop trees and/or crop tree release with herbicides (Kershaw, 1973; Stewart, 1987).

RESPONSE OF CONIFERS TO COMPETING VEGETATION

Although black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine comprise 75% of all planting stock in Ontario, little has been published regarding their response to non-crop vegetation (MacDonald & Weetman, 1993). However, there is abundant information pertaining to the responses of other conifer species to competition with undesirable vegetation for essential resources. There are two types of competition which may be identified: *below ground competition* for water and nutrients, and *above ground competition* for light. Although reference here has been made almost entirely to interspecific competition, the concepts discussed are similar for intraspecific competition.

No essential resource is more important than another; light, moisture and nutrients are *all* important. Moisture and nutrients are the probable primary factors contributing to the initial species composition of an establishing plant community, while light is the probable primary factor contributing to changes in species composition and structure of that community (Larsen, 1980; Kimmins, 1987).

Competition Below Ground for Available Water and Nutrients

Toumey *et al.* (1947) explain that development of trees, shrubs, grasses and mosses depends on the degree of soil desiccation caused by root competition. Root growth, size and geometry are the most important contributors to a plant's ability to compete successfully for a limited supply of water and nutrients (Nambiar & Sands, 1993). Differences in the amount of photosynthate allocated to root growth will affect the relative competitive abilities of different species (Radosevich & Osteryoung, 1987).

A plant species may have a competitive advantage over another for water and nutrients by: a) acquiring a greater proportion of available soil water and/or nutrients; b) using water and nutrients more efficiently in producing biomass and/or; c) allocating photosynthate in ways which maximize survival and growth (Nambiar & Sands, 1993). Different species of non-crop vegetation exhibit different water usage patterns because of their growth habit, physiological characteristics and type and depth of root system (Richardson, 1993).

Experimental evidence indicates that interspecific competition for available soil moisture poses great limitations on conifer survival and growth (Radosevich & Osteryoung, 1987; Morris *et al.* 1993). Available soil moisture and soil temperature will affect the soil nutrient supply because they regulate the rate of decomposition of dead vegetation (Greaves *et al.* 1978). In addition, the amount of available moisture regulates the availability of soluble nutrients and their uptake by plants. It is not possible for a seedling to experience water stress (through competition) without some degree of nutrient stress; but the opposite may not be true in some soil environments (Nambiar & Sands, 1993). Hence, competition for nutrients is difficult to identify because of its association with available soil water (Richardson, 1993).

Nambiar & Sands (1993) explain that water and nutrient deficits are caused by water and nutrients not being supplied to a plant at a rate required for maximum growth. This is caused by primary deficiencies of water and nutrients in the soil and/or by competition for these resources from other plants.

Toumey & Kienholz (1931) found that trenched quadrats in white pine (*Pinus strobus* L.) forests, initially without understory vegetation, soon became covered with invading vegetation. The roots of the white pines were severed at the time of trenching. In every case, irrespective of the density of the canopy, abundant vegetation appeared in the trenched quadrats, compared to untrenched quadrats, because the soil had been freed from the living roots of surrounding trees. It was also found that amount of available moisture was greatly increased by the elimination of root competition. Similar results were obtained with loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* Mill.) by Toumey *et al.* (1947).

Stiell (1970) attempted to differentiate between the intraspecific competitive effects of crowns from those of roots in a 13-year-old red pine (*Pinus resinosa* Ait.) plantation. Crown competition was artificially increased by inserting the tops of severed red pines in an upright position around live trees. The artificial crown competition did not affect the red pine growth and it was concluded that adequate allowance for root competition must be made by providing greater space for each tree than above-ground appearances might suggest. Excavated root systems were found to be very widely dispersed and to extend over many times the area occupied by the respective live crowns. Conard & Radosevich (1982) found similar results in young white fir (*Abies concolor*

(Gord. & Glend.) Lindle. ex Hildebr.) plantations. The effect of root competition on the white fir was reduced when the roots of shrubs were killed while leaving the shrub canopy in place.

Morris *et al.* (1993) found convincing evidence that the use of surface soil water by neighbouring plants, and the resulting water stress in loblolly pine seedlings during the first growing season, was the primary factor affecting pine growth. Nutrient deficiencies were associated with reduced water availability during this period. However, it was found that non-crop vegetation had less influence on seedling water use and nutrition during the second growing season. This concurs with observations on the growth of radiata pine (*Pinus radiata* D. Don); where competition for water is most pronounced in the first summer after planting and diminishes with each following summer as roots tap water from successively greater depths (Richardson, 1993; Nambiar & Sands, 1993). As trees establish deeper root systems, there is a critical shift from competition for water to competition for nutrients (Nambiar & Sands, 1993).

The amount of available water and the need for water uptake is influenced by the rate of transpiration by vegetation. Toumey *et al.* (1947) describe research which showed that a site covered with vegetation had a much lower soil moisture content over the growing season than did a similar site without any vegetation. The control of competing vegetation will subsequently reduce root competition yielding more available moisture for crop trees. Numerous studies have shown that the reduction of non-crop vegetation reduced competition for moisture with: loblolly pine (Carter *et al.* 1984; Lanini & Radosevich, 1986; Morris *et al.* 1993); ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) (Lanini & Radosevich, 1986); white pine (Sterrett & Adams, 1977); sugar pine (*Pinus lambertiana* Dougl.); white fir (Lanini & Radosevich, 1986); and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Cole & Newton, 1986; Wagner & Radosevich, 1991).

Radosevich & Holt (1984) state that it is undebatable that non-crop vegetation in proximity to crop trees consumes nutrient resources. It has been observed that the reduction of non-crop vegetation reduces the competition for nutrients with: loblolly pine (Carter *et al.* 1984; Morris *et al.* 1993); radiata pine (Smethurst & Nambiar, 1989); and Douglas-fir (Cole & Newton, 1986). The benefit of increased nutrient availability, through competition control, is determined by the ability of the crop tree to respond to and use the added resource, within the limits imposed by water or other resources.

Richardson (1993) states that the retention of non-crop vegetation at establishment can conserve nutrients. Although there may be competition in the short term, the benefits may be apparent in the long term; especially on forest sites susceptible to nutrient loss through leaching.

Competition Above Ground for Available Light

The magnitude of the capture of solar energy is determined by the magnitude and efficiency of plant foliage. The ultimate determinant of the economic productivity of crop trees is the presence of an adequate biomass of foliage, of the desired species, which is adequately supplied with moisture and nutrients. If most of the leaf biomass is that of non-crop vegetation, then growth and subsequent economic yields will be small (Kimmins, 1991).

The actual levels of light reduction caused by non-crop vegetation and the effects it has on the performance of Ontario conifers is not well documented (Bell, 1991). However, Nambiar & Sands (1993) indicate that the production of wood is linearly related to the amount of intercepted radiation and that this relationship is largely unaffected by water and nutrient stress. This is contradictory to Richardson (1993), who states that radiata pine stem diameter growth is very sensitive to competitor-induced water stress.

Competition for light occurs when one species, because of more rapid growth, taller stature or established presence, casts shade on and limits the growth of another (Radosevich & Osteryoung, 1987). Kramer & Kozlowski (1979) and Larcher (1980) explain how light intensity directly affects photosynthetic rates in plants. *Light compensation* is the point at which light intensity is high enough for a given plant to produce the same amount of photosynthate as it uses for respiration. As light intensity increases, photosynthetic rates will increase proportionally until *light saturation* occurs. The rate of photosynthesis then becomes more or less constant. These points of light compensation and saturation vary among species which are adapted to growing under different light intensities.

In the context of competition for light, the main physiological differences between species are found in: a) the adaptability of photosynthesis to different light regimes, and b) the change in carbon allocation caused by a change in the availability of resources (Cannell & Grace, 1993). *Shade tolerance* is the term used to describe plants with the ability to survive and grow under low light intensities. A shade tolerant plant will reach its point of light compensation, its point of light saturation and its maximum rate of photosynthesis sooner than a shade intolerant plant will. In addition, it will make more efficient use of low intensity light for the production of photosynthate than a shade intolerant plant will (Radosevich & Osteryoung, 1987). Intolerants are less efficient at photosynthesis and require more light for growth (Greaves *et al.* 1978). Therefore they must have the ability to: a) grow rapidly and overtop other vegetation, and b) produce high amounts of foliage (photosynthetic area) to keep growing rapidly. As the vegetative canopy closes (be it herbaceous, shrub or tree canopy), only the shade tolerant species will compete successfully under that canopy.

The amount of photosynthate produced by a plant decreases as competition for light increases (Bell, 1991). Comeau *et al.* (1993) observed that Engelmann spruce (*Picea engelmannii* Parry) seedling growth increased as needle biomass increased and non-crop vegetation abundance and shading decreased. Comeau (1988) observed a negative relationship between photosynthate production and light competition with Douglas fir seedlings under a canopy of fireweed (*Epilobium angustifolium* L.) and thimbleberry (*Rubus parviflorus* Nutt.). If a plant beneath a canopy is not shade tolerant, its photosynthetic rate will fall below its inherent light compensation point. It will, inevitably, not produce the required amount of photosynthate to maintain and grow new tissues (e.g. roots) for the uptake of other essential resources (e.g. moisture, nutrients). Results obtained by Brand & Weetman (1986) concur with those of Comeau (1988), indicating that, at least with Douglas-fir, competition for light is generally the limiting factor for successful growth. However, this also demonstrates the importance of recognizing the limiting factor(s) for successful crop tree growth and coordinating silvicultural activities so that they address the limiting factor(s).

Howard & Newton (1984) indicate that crop tree seedlings can be influenced by overtopping, encroaching and/or ground cover vegetation. It was observed with Douglas-fir, that the control of overtopping non-crop vegetation is more important than the control of encroaching shrubs and/or ground cover in the immediate environment of the crop tree. Encroaching and ground cover vegetation was defined as any vegetation in proximity to the crop tree within the distance of the seedling's longest lateral branch, but that was not overtopping the crop tree. Height, diameter and volume growth of overtopped Douglas-fir was significantly less for the first seven years than that of seedlings influenced by encroaching vegetation. Bracken fern, bigleaf maple (*Acer macrophyllum* Pursh), red alder (*Alnus rubra* Bong.) and dogwood (*Cornus* L. spp.) were the major overtopping species. After seven years, 75% of all the seedlings planted that were still alive and undamaged were influenced only by encroaching and ground cover vegetation. The seedlings in the study sites were in a low to medium range of moisture stress, which permitted the conclusion that overtopping vegetation competed more for light than for below ground resources.

Newton *et al.* (1992b) observed that the percentage of overtopping hardwood cover was the single best indicator of height growth in balsam fir (*Abies balsamea* (L.) Mill.). Crop trees grew an average of 40, 27.6 and 15 centimetres in height annually when 0%, 50% and 100% overtopped by non-crop vegetation, respectively. However, it must be remembered that a competitor species need not be in the immediate vicinity of a crop tree to compete for below ground resources (e.g. bracken fern).

It can often be practically impossible to determine and separate the effects of non-crop vegetation use of light, moisture and nutrients as individual causal agents of poor crop tree growth. For this reason, the concept of growing space has been developed.

The Capture and Occupation of Growing Space

The availability of essential resources (moisture, nutrients, light) to an individual plant growing in a plant community appears to be a function of the physical space that the individual occupies. A site has a specific carrying capacity for plant growth, until an essential resource becomes limiting. *Growing space* can be used to describe the combination or composite of all resources necessary for seedling growth (Begon & Mortimer, 1986; Radosevich & Osteryoung, 1987; Oliver & Larson, 1990). The more space available for use by the seedling, the less intra- and interspecific competition it experiences.

Growing space availability changes over time and may be described both in terms of stand dynamics and in terms of succession. Stand dynamics is a change in allocation of space to species in a relatively stable community, over a short period of time; whereas succession is a change in the allocation of space to species where there is a change or shift in plant community composition, over a longer period of time.

Oliver & Larson (1990) explain that the amount of growing space that each plant occupies is defined by surrounding plants. Plants must expand in size to grow. A plant first allocates the products (energy) obtained through photosynthesis, using its available growing space, to the maintenance of its presently living cells. Any extra or additional products are used for growth. A plant occupying a *fixed* growing space increases in size at a progressively slower rate. This is so, because it obtains a fixed amount of products through photosynthesis, while it requires an increasing amount of products to maintain its increasingly larger self. Its size eventually reaches a maximum in that *fixed* growing space because all the products are used to maintain itself, and there are none available for additional growth. The plant can not grow larger unless its growing space is increased.

Oliver & Larson (1990) also explain that once plants have filled all available growing space, they will compete with other plants to obtain additional space. If one plant has a competitive advantage, it will expand at the expense of another. The plant, whose growing space is reduced, may *only* be able to survive if it can use some space which its competitor can not (e.g. two species with different light tolerance levels or rooting depths). Otherwise it will die if there are no differences in space utilization.

Following a disturbance that kills or inhibits vegetation (e.g. fire, windthrow, site preparation), space become available and, hence, resources become available. There are several successional models which explain to varying degrees how space is captured and occupied. Such models include the classic Clementsian model, the Individualistic Concept of Plant Association, the three-pathway model and the multiple pathway model (Kimmins, 1987; Robertson, 1993). Perhaps the most useful model is the three-pathway model of ecological succession proposed by Connell & Slatyer (1977). Each of the three pathways described below is distinguished by the way in which non-crop vegetation reinvades the available growing space. Therefore each pathway may have significant effects on establishing conifers. Although all occur in the boreal forest, the second and third are most common (Towill, 1992).

The *facilitation pathway* assumes that only certain species are able to colonize a site in the conditions that immediately follow a disturbance (Connell & Slatyer, 1977). Early plant communities alter the chemical and/or the physical characteristics of the environment creating favourable conditions for the species in the next stage of succession. These early successional stages are necessary for satisfactory growth of the subsequent communities. This pathway may involve commensalistic interactions (Towill, 1992).

The *tolerance pathway* occurs when pioneer communities are not mandatory for the growth of subsequent communities, and many different species are capable of occupying the available space. Early successional species which establish first may prevent or delay the establishment of mid-successional species, but have little effect on late successional species (Towill, 1992). The sequence of species in succession is determined solely by their autecological characteristics (Connell & Slatyer, 1977).

The *inhibition pathway* differs from the tolerance pathway in that the pioneer species which invade and secure the available space and suppress or retard the invasions of all other later successional species, for prolonged periods of time (Connell & Slatyer, 1977; Towill, 1992). The pioneer species, which preempt/capture the space, will continue to exclude or inhibit later species, until the former die and release the space (resources). Only then can later colonists become established and eventually reach maturity (Radosevich & Holt, 1984; Radosevich & Osteryoung, 1987). Both the latter two pathways involve amensalistic and competitive interactions and seem to explain crop tree establishment problems in the boreal forest.

Figure 2 illustrates a schematic example of the occupation of space by vegetation following a disturbance (e.g. fire) of an even-aged, unmanaged boreal conifer species (e.g. jack pine), over time. It is similar to that which that described by Radosevich & Conard (1981) and it parallels the relationships between foliar area (or yield) and time described by Begon & Mortimer (1986), Kimmins (1987), Oliver & Larson (1990) and Odum (1993). The five phases described are not necessarily discrete and there is a degree of coexistence of the associated species over time, especially in Phase I.

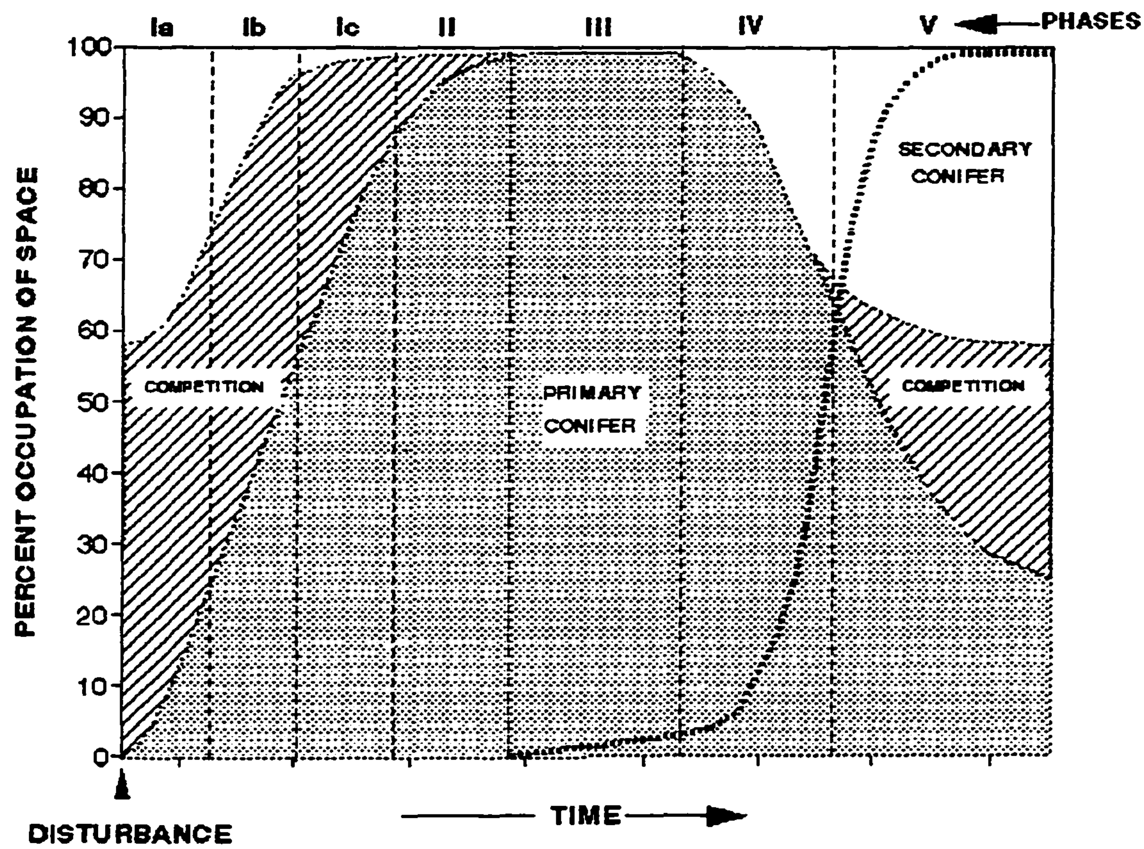

Figure 2. A schematic of the occupation of space by vegetation on an even aged Boreal forest conifer site following disturbance (refer to text).

Phase Ia: Invasion of graminoid, herbaceous and low shrub vegetation such as fireweed, raspberry and sedges (*Carex* (Dill.) L. spp.). These species are very intolerant to shade and are generally inefficient users of space (resources).

Phase Ib: Invasion of high shrub vegetation such as alder (*Alnus* B. Ehrh. spp.), mountain maple (*Acer spicatum* Lam.) and beaked hazel (*Corylus cornuta* Marsh.). The species in Phase **Ia** may coexist with or be out-competed by the more tolerant and efficient users of the space.

Phase Ic: Invasion of tree species such as trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.). Again, these species may coexist with or out-compete the species in Phases **Ia** and **Ib**.

Phase II: The colonizing non-conifer vegetation begins to die and/or becomes inhibited by the primary conifer as it approaches maturity and crown closure.

Phase III: The conifer achieves maturity and occupies the majority of the space in the stand. Other minor but 'efficient' users of space may exist in the understory (e.g. mosses). Shade tolerant conifers may establish at this time (e.g. balsam fir). They tend to 'sit' on the space but can not make use of it. Therefore they survive but remain suppressed. Intraspecific competition is the predominant form of interaction in this phase.

Phase IV: The primary conifer begins to decline. The loss of foliage and mortality of roots releases space. At this point, the space is prone to a new disturbance (especially fire) which would likely return it back to Phase I. In the absence of a disturbance, a secondary conifer (e.g. one which was suppressed in the understory in Phase III) may occupy the space.

Phase V: The primary conifer continues to decline and will eventually surrender all the space to either a) a secondary conifer, b) reinvading non-crop vegetation (Phase I species), or c) a combination both.

Competition Thresholds

It is necessary for silviculturists to understand that a threshold measure of the abundance of non-crop vegetation in or encroaching the same growing space of a crop tree will affect the tree's survival and growth. The point at which crop tree survival and/or growth becomes in jeopardy because of non-crop vegetation is referred to as the *competition threshold*. However, it is difficult to quantify the relationship between non-crop vegetation abundance and crop tree growth (Day, pers. comm., 1994). The competition threshold will vary depending on the critical silvics of both the crop tree and the non-crop vegetation. It will also depend on the type of unfavourable crop tree growth conditions which the non-crop vegetation may be creating (i.e. the degree of competition for essential resources). Wagner (1994) indicates that competition thresholds appear to be different for survival and height growth than for diameter growth. If survival is more important than diameter growth, then moderate levels of non-crop vegetation may be maintained in young forests. Similarly, height growth appears to be sustained under moderate levels of competition. However, if crop tree diameter growth is to be maximized, much lower levels of competition are required. In Ontario, competition thresholds for conifer crop trees are currently being researched by Wagner (1994) and Bell (1994).

RESPONSE OF CONIFERS TO RELEASE FROM COMPETING VEGETATION

A reduction of non-crop vegetation that is competing with crop trees will lead to increased growing space and a 'free-growing' condition that almost always increases survival, vigour and growth (Sutton, 1985; Deloitte & Touche, 1992). Any exceptions to this general trend are rare (Morris *et al.* 1993). A conifer crop, which is released from the influence of other vegetation, has the potential to 'respond' and occupy the new growing space. Intolerant crop tree species such as pines (*Pinus* L. spp.) tend not to respond if they have been suppressed for several years and have experienced 'checked' growth (Day, pers. comm. 1994).

Responses are most commonly observed in diameter/basal area growth and seedling survival. Morris *et al.* (1990) indicate the most consistent response variable for jack pine and black spruce is seedling dry weight. But as this is often an inappropriate measure (because of destructive sampling), seedling root collar diameter is the best substitute because it correlates well with dry weight. Responses may also be observed in one or more of the following tree and/or stand attributes: height growth, and individual tree or stand volume growth; crown length and width; bud size; needle number, colour, length and retentivity; nutrient status, tree vigour and resistance to damaging agents (insects, disease) (Bell, 1991).

Richardson (1993) describes three identified responses of radiata pine volume growth in Australia and New Zealand, over time, to the removal of non-crop vegetation. Figure 3 illustrates each growth response relative to no treatment.

Type I responses result from treatments that have little or no permanent effects on soil characteristics and lead to higher yet parallel volume growth trends in treated relative to untreated stands. This may result from the removal of non-crop vegetation such as grasses, herbs and low shrubs which likely have little long term impact on crop tree growth.

Type II responses result in a change of site productivity or carrying capacity and a divergence of growth curves of treated and untreated stands. This may result from the removal of non-crop vegetation that is more tolerant and has the ability to persist under a closed canopy and compete for water and nutrients. For example, Richardson (1993) indicates that in radiata pine

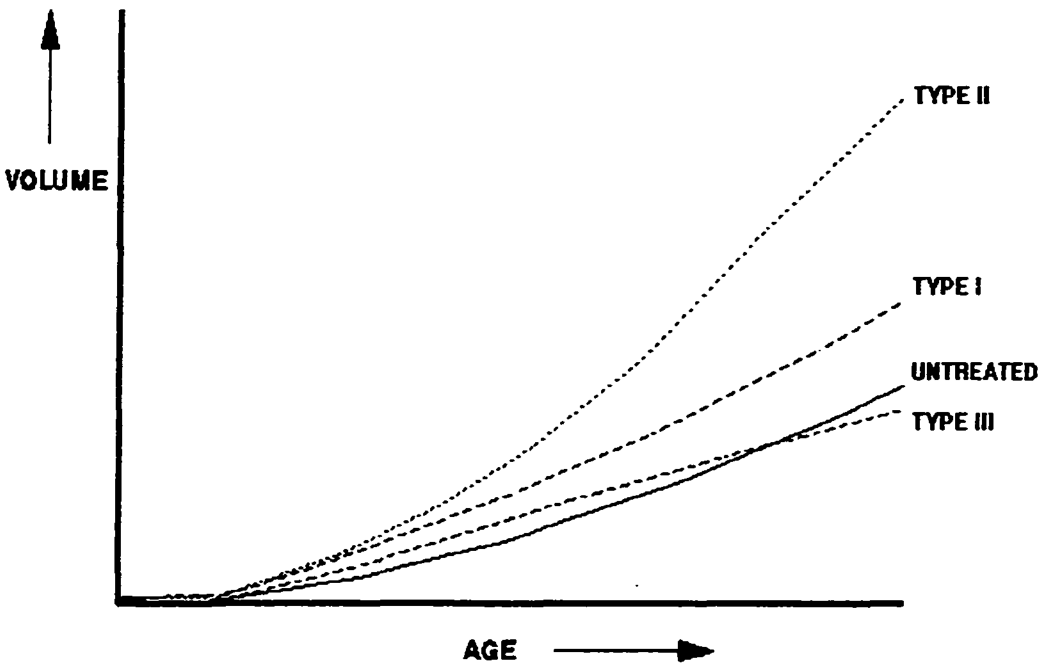

Figure 3. Three possible volume growth responses of radiata pine to removal of non-crop vegetation (refer to text) (adapted from Richardson, 1993).

plantations in Australia and New Zealand, if native bracken fern (*Pteridium esculentum* (Forst. f) Cockayne) is not removed, it can persist in the understory. This can cause "spindle", phosphorous deficient pine stands which are unable to close canopy, and becomes a very serious problem if the plantations are initially established at low densities for sawlog production.

A **Type III** response is soil dependent. Where some competitors occupy a low-nutrient site, such as on sand dunes or aeolian deposits, initial crop tree growth may be reduced relative to stands with vegetation control. However, the competitor species can conserve nutrients which would otherwise be lost from the site through leaching. Although there may be initial growth benefits to the removal of non-crop vegetation, the volume growth curve for such stands may fall below that of a stand in which there was no treatment (Figure 3) (Richardson, 1993).

Table 2 presents numerous references, by conifer species, documenting improved crop tree survival and/or positive growth responses resulting from the reduction of non-crop vegetation. Perala (1982) concluded from a comprehensive literature review, that the release of conifers from undesirable vegetation, in the Upper Great Lakes Region resulted in, on average, 43% greater survival, 120% greater height growth and 84% greater biomass growth than unreleased conifers.

Table 2. References, by conifer species, documenting survival and/or growth benefits resulting from the control of non-crop vegetation.

CONIFER SPECIES	REFERENCE(S)
Jack pine (*Pinus banksiana* Lamb.)	Aschbacher *et al.* (1990) Krishka and Towill (1989) Sutton and Weldon (1993) Sutton *et al.* (1991) Weetman and Fournier (1984)
Loblolly pine (*Pinus taeda* L.)	Busby *et al.* (1993) Creighton *et al.* (1987) Edwards (1994) Haywood (1994) Knowe *et al.* (1985)
Lodgepole pine (*Pinus contorta* Dougl. ex. Loud.)	Blackmore and Corns (1979) LePage and Coates (1993)
Longleaf pine (*Pinus palustris* Mill.)	Creighton *et al.* (1987) Nelson *et al.* (1985)
Ponderosa pine (*Pinus ponderosa* Dougl. ex. Loud.)	Lanini and Radosevich (1986)
Red pine (*Pinus resinosa* Ait.)	Allen and Wentworth (1993) Anonymous (1993) Aschbacher *et al.* (1990) Buckman and Lundgren (1962) Latagne (1989)
Slash pine (*Pinus eliottii* Enlem.)	Creighton *et al.* (1987)
Sugar pine (*Pinus lambertiana* Dougl.)	Lanini and Radosevich (1986)
White pine (*Pinus strobus* L.)	Buckman and Lundgren (1962) Sterrett and Adams (1977)
Black spruce (*Picea mariana* (Mill.) B.S.P.)	Anonymous (1993) Richardson (1982) Wood and von Althen (1993) Wood *et al.* (1990)
Engelmann spruce (*Picea engelmannii* Parry)	Comeau *et al.* (1993)
Norway spruce (*Picea abies* (L.) Karst.)	Anonymous (1993)
Red spruce (*Picea rubens* Sarg.)	Anonymous (1993)
Sitka spruce (*Picea sitchensis* (Bong) Carr.)	Reynolds *et al.* (1993)
White spruce (*Picea glauca* (Moench) Voss)	Ardron *et al.* (1992) Blackmore and Corns (1979) Cain (1988) Wood and Dominy (1988) Wood and von Althen (1993) Yang (1991)
Hybrid spruce (*Picea glauca* X *Picea sitchensis*)	LePage and Coates (1993)
Balsam fir (*Abies balsamea* (L.) Mill)	Maass (1991) MacLean and Morgan (1983) Newton *et al.* (1992b)
White fir (*Abies concolor* (Gord. & Glend,) Lindle. ex Hildebr.)	Conard and Radosevich (1982) Lanini and Radosevich (1986)
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	Dunsworth and Deyoe (n.d)

Buse & Bell (1992) state that increased volume growth from 40 to 100% or more, in the short term, is common. Long term studies (>15 years) suggest that tree growth response after release persists or increases with time, continuing at least until crown closure. However, long term responses would depend on the intensity of treatment and target species of non-crop vegetation (Richardson, 1993). Bell (1991) states that there are two fundamental considerations when manipulating non-crop vegetation. Firstly, no matter how effective a treatment is, it will not be beneficial unless the crop trees have the vigour to respond to the resources made available. Secondly, if the resources are released at rates in excess of the ability of the crop trees to use them, the crop trees will not benefit from the surplus.

JACK PINE AND COMPETING VEGETATION

Jack Pine Response to Interspecific Competition

According to Sims *et al.* (1990), jack pine is a shade-intolerant species requiring full light to survive and achieve optimum growth. Certain herbs and shrubs can provide protection from heat and moisture stress by providing a shady, cool microenvironment. This may be beneficial to the initial survival and establishment of the seedlings (Bell, 1991; Buse & Bell, 1992). The best initial survival of seedlings occurs on microsites with less than four hours of direct sunlight daily (Sims *et al.* 1990). However, the benefits of shade to the early survival are short-lived and it soon becomes detrimental (Bell, 1991). Once the seedlings have established, they should receive full light (Rudolph & Laidly, 1990; Benzie, 1977). Sims *et al.* (1990) describe a detailed survey performed by Bakusis & Hansen (1959) on jack pine forests in Minnesota. On a five-unit "requirement" scale (where 1 = least and 5 = greatest), jack pine ranked 5.0, 1.0 and 1.9 for light, moisture and nutrient requirements, respectively.

Logan (1966) performed a five year study on the effects of four light intensities; 13%, 25%, 45% and 100%, on jack pine seedlings. Total seedling height, shoot dry weight, root dry weight and root collar diameters increased with increasing light intensity and all were maximized in 100% full light. Mean needle lengths were maximized in 25% sunlight and decreased with increasing light intensity. Logan (1966) states that poor root growth observed in low light intensities may well be related to the translocation of photosynthate. It has been observed that shaded white pine seedlings translocate a smaller fraction of photosynthate to the roots than those grown in full light. In addition, decreases in stem growth in low light intensities may be due, in part, to hormone deficiencies. Kozlowski & Peterson (1962) indicate that hormone production may be reduced in the shade and this subsequently delays the initiation of cambial activity in the plant.

Although jack pine is a very drought resistant species, it has been found that intense root competition results in a consequent decrease of available soil moisture, reducing diameter growth prior to the reduction of height growth. Ericaceous shrub species (e.g. blueberry (*Vaccinium* spp. L.)) reduce survival and growth on coarse textured soils through competition for moisture while raspberry and grasses compete for moisture on silty and clayey sites (Buse & Bell, 1992). Early height growth in jack pine plantations varies inversely with the ground occupancy of ericaceous plants (Bell, 1991). Cayford *et al.* (1967) found that competition from trembling aspen and hazel has been responsible for poor survival of jack pine planted on clay soils in Manitoba and Saskatchewan.

Jack pine has a relatively low nutrient requirement (previously indicated as 1.9 on Bakusis & Hansen's (1959) requirement scale from 1 to 5) and is usually found on sites of low nutrient status (Sims *et al.* 1990; Bell, 1991). No information was found with respect to the specific effects of competition for nutrients on jack pine. Examples of other agents which negatively interact with jack pine are presented by Bell (1991). For example, both aster (*Aster* L. spp.) and goldenrod (*Solidago* L. spp.) serve as the alternate hosts for needle rust fungus (*Coleosporium asterum* (Diet.) Syd.) (Hiratsuka, 1987).

Buse *et al.* (1994) concluded, from an intensive survey of the forest industry and of the Ontario Ministry of Natural Resources, that the most important competitor species of jack pine were: *Populus* L. spp., beaked hazel, white birch, *Alnus* B.Ehrh. spp., red maple (*Acer rubrum* L.), pin cherry, raspberry and grasses (not ranked in any order of importance).

Jack Pine Response to Release from Interspecific Competition

Generally, the response of jack pine parallels the positive survival and growth responses to vegetation control observed in other conifers. As previously reported, the requirements of jack pine for moisture and nutrients are relatively low compared to its light requirements.

Jack pine should be released from overtopping non-crop vegetation within a year after planting (Bell, 1991). A 50% or greater reduction in the percent cover of overtopping vegetation is required to increase survival and growth of seedlings. Weetman and Fournier (1984) observed that the elimination of competition for water by ericaceous plants (may have) contributed to positive jack pine growth responses.

Studies by Sutton *et al.* (1991) and Sutton & Weldon (1993) indicated that jack pine survival was not enhanced from chemical site preparation but positive growth responses were maintained through five growing seasons. Buse & Bell (1992) state that removal of non-crop vegetation through chemical site preparation has resulted in stem volume increases of 18% after three years of growth, but they note no difference in height growth, when compared to controls. In contrast, Richardson (1982) did find that jack pine height growth was enhanced, four years after crop tree release treatments, but it was also noted that growth was only improved when the overtopping vegetation was more than twice the height of the crop trees.

TRICLOPYR ESTER AND GLYPHOSATE HERBICIDES

A Profile of RELEASE™ Herbicide[1]

Triclopyr herbicide has both an amine formulation and an ester formulation. In 1991, the ester formulation received federal registration status in Canada, as Release™, for ground application (CPPA, 1992; Campbell, 1991). It received restricted registration for aerial application in 1995 (DowElanco, 1995). Release™, is an emulsifiable liquid form of triclopyr. It has an acid equivalent of 480 g/l of triclopyr, present as a low volatile butoxyethyl ester and is manufactured by DowElanco Canada Ltd. (DowElanco, 1995; Pitt *et al.* 1993).

Release™ is recommended for the control of woody and herbaceous vegetation on forest sites. It is a selective herbicide which is readily absorbed by the foliage of the target plant (CPPA, 1992). It is translocated throughout the shoot and root system, via both symplastic and apoplastic tissues (Pitt *et al.* 1993; Dow Chemical, n.d.), where it accumulates in the meristematic tissues (Weed Science Society of America (WSSA), 1989). Symplastic tissues are defined by the total mass of living cells in the plant. Apoplastic tissues include non-living cell walls, intercellular spaces and xylem elements surrounding the symplastic tissues (Stephenson, 1992). It behaves similar to phenoxy acid herbicides (e.g. 2,4-D) by inducing auxin-type responses in the target plants. This causes rapid, abnormal growth and cell division (Pitt *et al.* 1993; WSSA, 1989), disrupting the food production mechanisms and severely injuring or killing the plant (DowElanco, n.d.). In addition, it can prevent root sprouting of perennial vegetation (WSSA, 1989).

Triclopyr ester is not strongly absorbed in principal soil types but the degree of absorption is dependant on soil pH and organic matter content. Some leaching may occur in soils under high

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[1] The information presented here is not meant to be used as a substitute to the manufacturer's label directives.

rainfall conditions. Triclopyr is degraded by microbes, has a mean half life of 46 days in soil (depending on soil and climatic conditions) and a mean half life in water of 10 hours at 25°C. It has a low order of toxicity to wildlife (WSSA, 1989) but is highly toxic to fish and aquatic plants and invertebrates if applied to water. It is not registered for application to water surfaces (DowElanco, 1995).

Release™, although registered federally, only has provincial registration in British Columbia, Ontario, Quebec and the Atlantic provinces. The types of applications which are permitted are as follows:

- Broadcast foliar application from the air or ground sprayers for site preparation and conifer release;
- Single stem foliar application for site preparation and conifer release; and,
- Basal bark applications, including one-sided low volume spraying, thinline spraying, streamline spraying, dormant stem spraying and cut stump spraying (DowElanco, 1995) (refer to product label). Basal bark applications are not recommended if snow or water cover the area to be treated (Pitt *et al.* 1993; Buse & Bell, 1992).

Buse & Bell (1992) state that triclopyr ester requires a minimum two hour rain-free period following application. As with any herbicide, proper timing of an application can significantly improve results. Herbicide induced injury to conifer crop trees most often occur when applications are made during periods of active growth, low water stress and high photosynthetic activity (Bell, 1991). The application of triclopyr ester for site preparation should occur from early June through to July in Northwestern Ontario. The timing for plantation release should occur from late August to frost, while basal bark treatments may be made year round (Buse & Bell, 1992). Appendix A presents more detailed information with respect to the use of Release™.

A Profile of Vision™ Herbicide[1]

In 1984, glyphosate herbicide received federal registration status in Canada, as Vision™, for both aerial and ground applications (Reynolds *et al.* 1993). Vision™ is a liquid formulation of glyphosate. It has an acid equivalent of 356 g/l, present as the isopropylamine salt of glyphosate and is manufactured by Monsanto Company of Canada (CPPA, 1993).

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[1] The information presented here is not meant to be used as a substitute to the manufacturer's label directives.

Vision™ is recommended for the control of woody and herbaceous vegetation and grasses on forest sites. It is a non-selective herbicide which is readily absorbed by photosynthetically active portions of the target plant. It is generally translocated throughout the target plant in both symplastic and apoplastic tissues (Pitt *et al.* 1993). It inhibits the production of 5-enolpyruvyl shikimic acid-3-phosphate synthase, an essential enzyme in the shikimic acid pathway and in the synthesis of aromatic amino acids and secondary metabolites (Pitt *et al.* 1993; CPPA, 1993; Zwiazek & Blake, 1990). Glyphosate will also prevent root sprouting of perennial vegetation (WSSA, 1989).

Glyphosate is strongly absorbed in principal soil types and the occurrence of leaching is very low. Glyphosate is degraded by soil microbes and has a mean half life less than 60 days in soil (depending on soil conditions and microfloral population types) (WSSA, 1989) and a mean half life in water of 12 hours (CPPA, 1993). Glyphosate has a very low order of toxicity to wildlife and fish (WSSA, 1989).

Vision™ is currently registered in all provinces except Alberta and Saskatchewan. The types of applications which are permitted are as follows:

- Broadcast foliar application from the air or ground sprayers for site preparation and conifer release;
- Single stem foliar application for site preparation and conifer release; and,
- Individual stem injection (CPPA, 1993).

Buse & Bell (1992) state that glyphosate requires a minimum six hour rain-free period following application. The application of glyphosate for site preparation should occur from late June through to July in Northwestern Ontario. Timing for plantation release should occur from mid-August to frost, and stem injection applications from April to mid-December. Appendix B presents more detailed information with respect to the use of Vision™.

A Profile of Touchdown 480™ Herbicide[1]

An experimental glyphosate herbicide called Touchdown 480™ has been tested for forestry use since 1989 (Campbell, 1990), but it has still not obtained federal approval in Canada. This is a liquid formulation of glyphosate that has an acid equivalent of 330 g/l, present as the

[1] The information presented here is not meant to be used as a substitute to the manufacturer's label directives.

trimethylsulphonium salt of glyphosate (Vision™ contains the isopropylamine salt of glyphosate) (Zeneca Agro, 1989). This herbicide is manufactured by Imperial Chemical Industries and is distributed in Canada by CHIPMAN.

The behaviour and mode of action of Touchdown 480™ essentially the same as Vision™ (Pitt *et al.* 1993). Touchdown 480™ is recommended for the control of woody and herbaceous vegetation and grasses on forest sites. It is a non-selective herbicide which is readily absorbed by photosynthetically active portions of the target plant.

There is no occurrence of leaching from soil and this herbicide is rapidly degraded within days or at most a few weeks in the soil. It has a very low order of toxicity to wildlife and fish. Touchdown 480™ requires a minimum six hour rain-free period following application (Zeneca Agro, 1989).

The principal difference between the formulations of Vision™ and Touchdown 480™, other than the difference in glyphosate salts, is that the latter has a built-in glucocide wetting agent. Touchdown 480™ may affect jack pine more adversely than Vision™ because of this adjuvant; not because it is the trimethylsulphonium salt of glyphosate [Partika (pers. comm., 1993)]. Appendix C presents detailed reference information with respect to Touchdown 480™ experimental herbicide.

[Note: Unless otherwise indicated, any reference to glyphosate in the remainder of the literature review pertains to Vision™ (or its identical counterpart Roundup™), not to Touchdown 480™. In addition, any reference to triclopyr in the remainder of this report pertains to the ester formulation, not the amine formulation of triclopyr.]

SUSCEPTIBILITY OF NON-CROP VEGETATION TO TRICLOPYR ESTER AND GLYPHOSATE

Both triclopyr ester and glyphosate herbicides are used for the control of both woody and herbaceous vegetation. Many environmental factors influence foliar applied herbicide absorption, translocation and efficacy. Temperature, photoperiod, relative humidity and plant water stress (Seiler *et al.* 1993). Table 3 compares the susceptibility of selected boreal forest vegetative species to Release™ and Vision™. Except for grasses, sedges and bracken fern, most non-crop species tend to be more susceptible to triclopyr ester than to glyphosate.

Efficacy of Triclopyr Ester

In Canada, published material reporting positive results in vegetation control with triclopyr ester in Canada is minimal. This is because triclopyr has only recently received federal approval for forestry operations. Jotcham (1988**b**) reported successful control of trembling aspen with triclopyr ester when applied with a backpack at a rate of 0.87 kg ae/ha; and 100% red oak (*Quercus rubra* L.) and red maple stem kill at 0.87 and 1.75 kg ae/ha. Ritty & Welker (1984) observed satisfactory control of maple, poplar, oak (*Quercus* L. spp.) and hazel (*Corylus* L. spp.) with applications of triclopyr at rates of 1.68 kg ae/ha and 2.25 kg ae/ha. It was found that the degree of control was directly related to age, size and intensity of the non-crop vegetation.

MacKay *et al.* (1988**a**) report 95% trembling aspen stem kill with aerially applied triclopyr at a rate of 2.2 kg ae/ha. MacKay *et al.* (1988**b**) also observed at least 85% trembling aspen, white birch and pin cherry stem kill with aerially applied triclopyr at 2.5 kg ae/ha. Both these trials occurred near Thunder Bay, Ontario. Other trials with triclopyr in Northern Ontario resulted in: 80% or greater stem kill of trembling aspen, white birch and willow (*Salix* L. spp.) after basal bark applications near Kapuskasing; good control of trembling aspen and pin cherry two years after an aerial application, at a rate of 1.45 kg ae/ha near Fort Frances, and; excellent control of trembling aspen, beaked hazel and mountain maple two years after a ground broadcast application from a Bräcke herbicider, at a rate of 2.9 and 3.87 kg ae/ha near Thunder Bay (Mercier & Leach 1991; Mercier *et al.* 1992; Mercier & Mihajlovich 1992).

Efficacy of Glyphosate

Positive results in vegetation control using glyphosate is well documented. In British Columbia, Pollack *et al.* (1990) observed satisfactory control of willow when glyphosate was applied with backpack sprayers at a rate of 2.1 kg ae/ha. In Manitoba, Ardron *et al.* (1992) observed increased trembling aspen mortality with increasing rates of glyphosate (0.88 to 1.96 kg ae/ha) when releasing white spruce (*Picea glauca* (Moench) Voss) plantations.

In Nova Scotia, Jotcham (1988**a**) observed 90% dieback of raspberry with the backpack application of 2.24 kg ae/ha of glyphosate. Anonymous (1989) observed adequate control of raspberry with an application of glyphosate at 0.61 kg ae/ha and red maple at 0.82 kg ae/ha. Also in Nova Scotia, successful reductions of woody and herbaceous vegetation were observed five to eight years after the application of glyphosate at 1.65 kg ae/ha (Anonymous, 1993).

In New Brunswick, Pitt *et al.* (1992) observed >60% cover reduction of raspberry, pin cherry, elderberry (*Sambucus* L. spp.) and trembling aspen at rates between 0.5 and 1.0 kg ae/ha of glyphosate. Crown cover reductions of 60% for red maple and white birch were achieved with the application of 1.0 kg ae/ha. Pitt *et al.* (1993) observed that both Vision™ and Touchdown 480™ glyphosate herbicides were effective in controlling sugar maple (*Acer saccharum* Marsh.), mountain maple, and yellow birch (*Betula lutea* Michx. f.) at rates above 0.5 kg ae/ha; but were not effective in controlling beaked hazel and striped maple (*Acer pensylvanicum* L.). Touchdown 480 ™ was found to be slightly inferior to Vision™ in the control of mountain maple.

In Maine, Newton *et al.* (1992a) reported effective control of trembling aspen, red maple and raspberry with glyphosate applied at rates of 1.65 and 3.3 kg ae/ha; two and seven years after herbicide application. In Northeastern Ontario, Wood & von Althen (1993) applied glyphosate at a rate of 2.0 kg ae/ha for site preparation and observed a 95% reduction of woody sprouts, shrubs and herbaceous vegetation. In North Central Ontario, Stasiak *et al.* (1991) observed that the growth and vigour of pin cherry and trembling aspen was negatively affected two years after the application of very low rates of glyphosate (0.04 to 0.5 kg ae/ha). Herbicidal activity was measured in the field by monitoring shikimic acid levels in the target plants long before any visual effects could be detected (within two days after herbicide application).

Campbell (1990) stated that glyphosate constituted 81% of all Canadian forest herbicide applications made in 1988, followed by 2,4-D, simazine and hexazinone. Triclopyr was not registered for use at that time.

SUSCEPTIBILITY OF CONIFER CROP TREES TO TRICLOPYR ESTER AND GLYPHOSATE

The effectiveness of herbicides is often limited by their ability to control undesirable vegetation selectively without injuring the conifer crop (Willis *et al.* 1989). Coniferous species generally tolerate herbicides best if they are applied during periods without active apical growth; therefore applications are timed to coincide with conifer 'dormancy'. However, herbicide tolerance varies widely among conifer species (King & Radosevich, 1985). Radosevich *et al.* (1980) observed that the highest level of conifer seedling injury occurred when triclopyr and glyphosate were applied during periods of active growth, low water stress (Zwiazek & Blake, 1990) and high photosynthetic activity. These observations were made on ponderosa pine, Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), sugar pine, Douglas-fir, white fir and red fir (*Abies magnifica* A. Murr.). Similar observations were made by King & Radosevich (1985) on these same species except ponderosa pine.

Table 3. A comparison of the susceptibility of selected boreal forest vegetative species to Release™ and Vision™ (where: 'R' = resistant; 'I-R' = intermediate to resistant; 'I' = intermediate; 'S-I' = susceptible to intermediate; 'S' = susceptible; '-' = no information) (adapted from Buse & Bell, 1992).

VEGETATIVE SPECIES	RELEASE (Triclopyr)	VISION (Glyphosate)
Aster L. spp.	R *	R *
Calamagrostis canadensis (Michx.) Beauv.	R	I
Carex (Dill.) L. spp.	-	S-I
Graminae (E.P., B.H.) spp.	R	S-I
Epilobium angustifolium L.	S	I
Pteridium aquilinum (L.) Kuhn.	I-R	S-I
Acer spicatum Lam.	S	S-I
Alnus B. Ehrh. spp.	S	S-I
Amelanchier Medik. spp.	S	S
Betula papyrifera Marsh.	S	S-I
Cornus stolonifera Michx.	S	I-R
Corylus cornuta Marsh.	S-I	S-I
Ledum groenlandicum Oeder	I-R	R
Populus L. spp.	S	S-I
Prunus L. spp.	S	S
Ribes L. spp.	S	I
Rosa acicularis Lindl.	S	S-I
Rubus L. spp.	S	I
Salix L. spp.	S	I-R
Vaccinium L. spp.	S	S-I

* Note: *Aster* spp. has only been controlled with triclopyr and glyphosate at rates higher than those approved for forestry use (Hollstedt, 1992).

Late fall applications of glyphosate caused some injury to dormant Douglas-fir, white fir and red fir (Radosevich *et al.* 1980). Damage in late fall was also observed by Lund-Hoie (1975) with Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.). In New Zealand, Saville (1989) noted that during periods of active growth, triclopyr applications greater than 0.6 kg ae/ha caused significant growth suppression and malformation of radiata pine seedlings. It was found that release treatments for dormant radiata pine transplants less than 1-year-old should not exceed 1.8 kg ae/ha. Balneaves & Davenhill (1990) observed that the application of triclopyr at rates greater than 0.6 kg ae/ha for releasing radiata pine and Douglas-fir caused apical death, multi-leadering and reduced growth. Anjou & Pendl (1986) indicate that grand fir (*Abies grandis* (Dougl.) Lindl.) in British Columbia could tolerate rates of triclopyr up to 2.9 kg ae/ha.

Boyd *et al.* (1985) indicate that ponderosa pine and lodgepole pine (*Pinus contorta* Dougl.) are very susceptible to foliar applications of triclopyr ester. Warren (1982) observed that a long needled pine such as ponderosa pine was slightly more susceptible to triclopyr at rates of 1.1 to 1.6 kg ae/ha than a short needled pine, such as western white pine (*Pinus monticola* Dougl.), during August/September applications. These observations concur with those of Cole & Newton (1988) and Cole *et al.* (1987). Gnegy & Lichy (1984) observed adverse effects of triclopyr at 1.1 to 1.68 kg ae/ha on loblolly pine growth, but normal growth resumed 2 years after application. Application was made in the third week of September in Virginia. This is contrary to observations made by Fitzerald & Griswold (1984), who observed safe release of dormant loblolly pine with triclopyr applied at rates from 0.56 to 1.68 kg ae/ha in Georgia.

With the exception of jack pine, all major boreal forest conifer crop trees (balsam fir, black spruce, white spruce, red pine and white pine) are resistant to the herbicidal effects of triclopyr and glyphosate. Jack pine is considered intermediate to resistant to both herbicides. However, *resistance is dependent on the proper timing and rates of application* (Buse & Bell, 1992).

Jack pine has the potential for lammas or late season shoot growth. In addition, it has a very thin needle cuticle (Bell, 1991) and the needle stoma are not as well covered by waxy diaphrams, as compared to other conifers [Lehala *et al.* 1972; Day (pers. comm. 1994)]. Willis *et al.* (1989) found that foliar injury to jack pine was highest following field applications of glyphosate and triclopyr in July. Triclopyr injured jack pine more so than did glyphosate in both field and growth chamber studies. Increased wax deposition on the needles over the growing season increased jack pine tolerance to both herbicides. However, Willis *et al.* (1989) observed that, regardless of application date, triclopyr always caused some injury to jack pine. This parallels observations made by Paley & Radosevich (1984) who found that ponderosa pine was damaged by triclopyr regardless of application date.

The Release™ (triclopyr ester) product label cautions that the probability of injury to jack pine is greater when the herbicide application is made in the same year as planting. It is indicated that seedlings planted for at least two years prior to application are less likely to show symptoms of injury. (DowElanco, 1995). Similarly, the Vision™(glyphosate) product label indicates that conifers should be established for more than one year before crop tree release (Monsanto, 1992).

MINIMUM TIME INTERVALS BETWEEN CHEMICAL SITE PREPARATION WITH TRICLOPYR ESTER AND PLANTATION ESTABLISHMENT

Herbicides are rarely used to kill non-crop vegetation outright but to suppress it for a short period of time to provide crop trees with favourable establishment and growing conditions (Malik & Vanden Born, 1986). Control treatments more often result in a partial reduction in overall biomass coupled with a shift in the dominant plant species (Morris *et al.* 1993). Consequently, there is a need to reestablish crop trees prior to the reinvasion of non-crop vegetation in order to maximize the competition-free period.

A herbicide may persist on a site following chemical site preparation while it degrades. For example, 2,4-D has a half life of three to four weeks in warm moist soil (CPPA, 1994). Such a persistence may have a detrimental effect on conifer crops planted to soon after the application. In addition, herbicides applied concurrent with planting may result in detrimental nutrient immobilization, and decomposing plant residues may have also have a detrimental chemical effect on the planted trees. Such undesirable effects may only be eliminated by applying the herbicide well in advance of planting (Bell, 1991). The knowledge of the minimum time interval between herbicide application and outplanting conifer crop trees is crucial. The Release™(triclopyr ester) product label indicates that the planting of conifers should be delayed until the year following chemical site preparation (DowElanco, 1995).

Table 4 presents results of several studies regarding the minimal time interval between chemical site preparation with triclopyr ester and planting conifer seedlingsThe rates of triclopyr applied in these studies varied from 2.24 to 3.85 kg ae/ha. Generally, research indicates that spruces (*Picea* A. Dietr. spp.) require a minimum of 7 days to one month between chemical site preparation and safe outplanting; while pines (*Pinus* L. spp.) require a minimum of 22 days to a month between chemical site preparation with triclopyr and outplanting.

Table 4. Observed minimum time intervals between chemical site preparation with triclopyr ester and the planting of conifer seedlings.

CONIFER SPECIES	TIME INTERVAL	LOCATION	REFERENCE(S)
Jack pine (*Pinus banksiana* Lamb.)	one month > 7 days 24 days 33 days	Michigan Nova Scotia New Brunswick N.E. Ontario	Becker *et al.* (1990) Jotcham (1992)b MacKay *et al.* (1988)d MacKay *et al.* (1988)e
Red pine (*Pinus resinosa* Ait.)	one month 22 days	Michigan Nova Scotia	Becker *et al.* (1990) MacKay *et al.* (1988)c
European larch (*Larix decidua* Mill.)	one month	Michigan	Becker *et al.* (1990)
Norway spruce (*Picea abies* (L.) Karst.)	22 days	Nova Scotia	MacKay *et al.* (1988)c
White spruce (*Picea glauca* (Moench) Voss)	7 days	Nova Scotia	Jotcham (1992)b
Black spruce (*Picea mariana* (Mill.) B.S.P.)	7 days 22 days 24 days 33 days	Nova Scotia Nova Scotia New Brunswick N.E. Ontario	Jotcham (1992)b MacKay *et al.* (1988)c MacKay *et al.* (1988)d MacKay *et al.* (1988)e
Balsam fir (*Abies balsamea* (L.) Mill)	7 days	Nova Scotia	Jotcham (1992)b

MacKay *et al.* (1988e) chemically site prepared a site in Northeastern Ontario with triclopyr ester at two rates: 2.88 and 3.84 kg ae/ha. It was observed that both black spruce and jack pine seedlings planted 33 days after the applications exhibited little or no injury. However, only two planting times were evaluated: 1 hour after application and 33 days after application. There were no plantings during the interim period.

THE USE OF HERBICIDE MIXTURES

Most selective herbicides are limited in their ability to successfully control all undesirable vegetation that might be encountered on a given area (Walstad *et al.* 1987). In addition, it is generally not economically desirable and/or logistically feasible to make multiple herbicide applications in the same rotation. Hence, there is interest in the development and registration of a product containing two or more herbicides to maximize non-crop vegetation control in a single application.

Herbicide combinations or mixtures can: a) widen the spectrum of non-crop vegetation control greater than that obtained from a single herbicide, and b) control different species of vegetation with a single application (Bohmont, 1983; Walstad *et al.* 1987). There is currently no product registered in Canada for forestry use that contains a combination of two or more herbicides (CPPA, 1992). However, they are common in the United States.

Herbicide mixtures which have been researched for silvicultural activities include: picloram[1] and triclopyr (Fitzgerald & Griswold, 1984; Shiver *et al.* 1990; Balneaves & Davenhill, 1990); picloram and glyphosate (Yeiser, 1991); glyphosate and imazapyr[2] (Yeiser, 1991; Maass, 1991); triclopyr and 2,4-D (Warren, 1982) and triclopyr and imazapyr (Maass, 1991).

Triclopyr Ester and Glyphosate Mixtures

McCormack *et al.* (1982) applied a mixtures of triclopyr ester and glyphosate, both at 0.28 kg ae/ha and also at 0.56 kg ae/ha, over a variable range of site conditions. The mixtures showed excellent potential for site preparation and release activities with small quantities of herbicide. Yeiser (1991) observed after August applications of several herbicides alone and in mixture that triclopyr and glyphosate at 3.38 and 2.45 kg ae/ha respectively, provided optimum brownout of broadleaves and pines in Arkansas.

In Nova Scotia, Jotcham (1988**a**) observed 100% control of raspberry with triclopyr and glyphosate in mixture at rates of 0.87 kg ae/ha and 0.28 kg ae/ha, respectively. Jotcham (1988**b**) reported significant control of red oak and red maple of triclopyr and glyphosate mixtures (rates ranged from 0.44 to 1.82 kg ae/ha and 0.28 to 1.12 kg ae/ha, respectively) relative to glyphosate alone (at 1.12 kg ae/ha). Jotcham (1992**a**) also reported safe release of black spruce and red spruce (*Picea rubens* Sarg.) after budset (after the third week in July), with a triclopyr and glyphosate mixture of 1.20 kg ae/ha and 0.89 kg ae/ha, respectively.

In Northwestern Ontario, MacKay *et al.* (1988**a**) observed that late August aerial application of triclopyr and glyphosate, both at rates of 1.1 kg ae/ha, provided 93%, 94% and 100% control of trembling aspen, speckled alder (*Almus rugosa* (DuRoi) Spreng.) and willow, respectively, two years after treatment. However, it was noted in this study by Helewa (1988) that this mixture did induce some needle burn in the black spruce crop trees, while triclopyr ester, when applied alone, did not.

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[1] Picloram: 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid

[2] Imazapyr: (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid

FIELD STUDY #1

MINIMUM TIME INTERVAL BETWEEN CHEMICAL SITE PREPARATION WITH TRICLOPYR ESTER AND PLANTING JACK PINE CONTAINER STOCK

METHODOLOGY

Location

The trial was conducted in a boreal forest setting approximately 60 kilometres (km) west of Thunder Bay, Ontario [Lat. 48° 24' N; Long. 90° 04' W]. The field plots were established in a cutover adjacent to the Ontario Ministry of Natural Resources 'Mattawin Seed Orchard', east of the Mattawin River. Appendix D illustrates the location of the study area.

Site Description

The site was a recently harvested jack pine stand, on a flat, rapidly drained, coarse sandy outwash plain (Vegetation Type 29 according to the Forest Ecosystem Classification for Northwestern Ontario (Sims *et al.* n.d.)). In 1990, a root rake was used to remove all the slash and most of the shallow humus to expose mineral soil on 60 to 70 percent (%) of the area. This site was considered to be ideal for the study as it was a typical site for jack pine growth and the majority of non-crop vegetation was removed with the site preparation treatment. This allowed for observation of the herbicide effects on the seedlings without the influence of other competing vegetation.

Seedling Stock

Overwinter cold stored jack pine container stock, grown in Trimroot 165 Ventblocks ™ was obtained from A&R Greenhouses of Thunder Bay, Ontario. The Trimroot 165 Ventblocks have cavities with a volume of only 49 millilitres (ml). Therefore the mean seedling was small, with a weight of approximately 1000 milligrams (mg). The seedlings were carefully heeled-in on the planting site approximately one week prior to the first time of planting. Heeling-in was done to ensure that all the stock would be in as uniform morphological and physiological condition as possible at each planting time. If the seedlings had been kept in cold storage until just prior to each planting, they would not likely have been in good physical condition; especially for the later planting times.

Experimental Design

A randomized complete block design (RCBD) composed of thirty 6 x 10 metre (m) [60 m^2] plots was surveyed and staked in the field in early July, 1992 (Figure 4). Three rows of five seedling [15 seedlings] were planted on the appropriate plots at 2 x 2 m spacing at each time of planting. The design also included the same number of plots for black spruce, which were randomly placed in amongst the jack pine plots (Figure 4). The treatments are explained below.

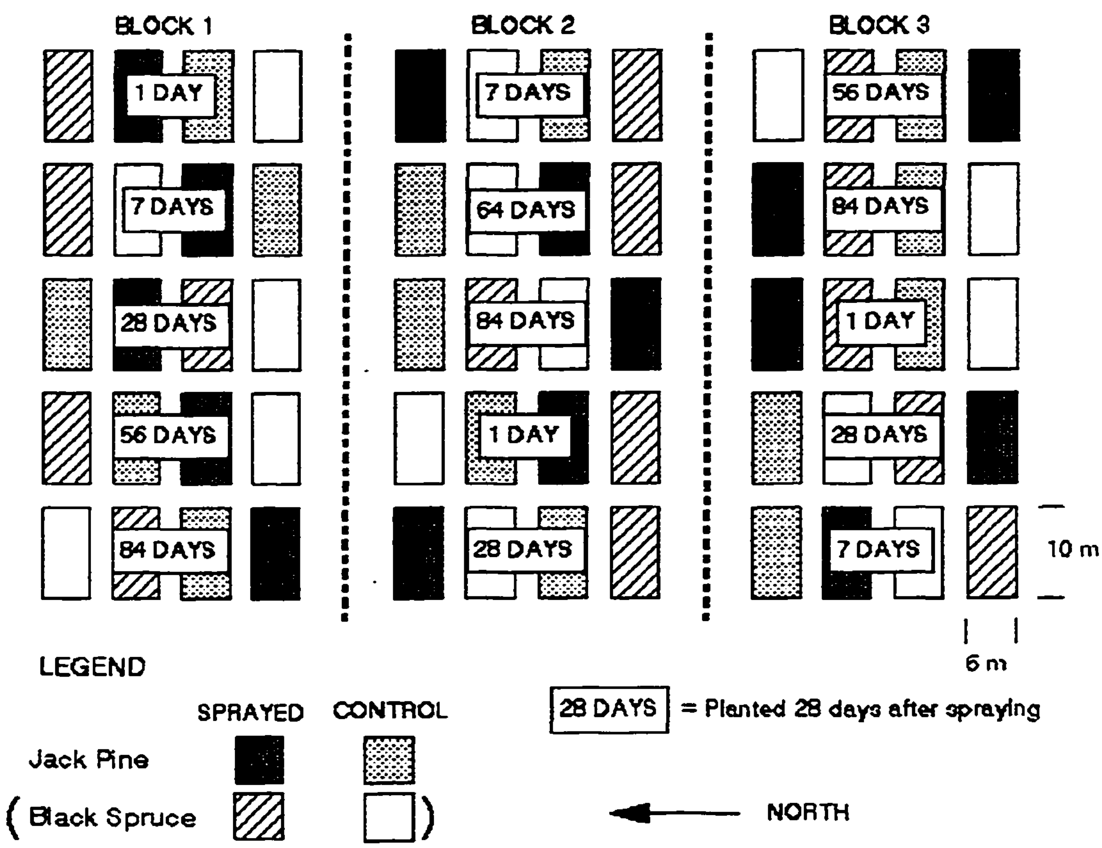

Figure 4. The randomized complete block design established in the boreal forest for field study #1, approximately 60 kilometres west of Thunder Bay, Ontario.

Treatments

There were two sets of treatments applied to the jack pine seedlings: the first was a set of herbicide treatments and the second was a set of planting time treatments.

1) The <u>Herbicide Treatments</u> were as follows:

a) Control (0.0 kg ae/ha of triclopyr ester)
b) Sprayed 3.84 kg ae/ha (8 l/ha) of triclopyr ester (maximum recommended rate)

2) The <u>Planting Time Treatments</u> (days after herbicide application/date) were as follows:

a) 1 day/July 21st, 1992.
b) 7 days/July 27th, 1992.
c) 28 days/August 18th, 1992.
d) 56 days/September 15th, 1992.
e) 84 days/October 13th, 1992.

Linear Model

The linear model for this RCBD study was as follows:

$$Y_{ijkl} = \mu + B_i + \delta_{(i)j} + H_k + BH_{ik} + T_l + BT_{il} + HT_{kl} + BHT_{ikl} + \epsilon_{(ijkl)}$$

<u>where</u>: $i = 1,2,3;\ j = 1;\ k = 1,2;\ l = 1,2,3,4,5$

Y_{ijkl} = the measured seedling response resulting from the interaction of the k^{th} herbicide treatment with the l^{th} time treatment of the i^{th} block;
μ = the overall mean;
B_i = the fixed effect of the i^{th} block;
$\delta_{(i)j}$ = the random effect of the j^{th} randomization of the time and herbicide treatments within the i^{th} block. The $\delta_{(i)j}$'s are assumed to be IID $(0,\sigma^2)$ [identically and independently distributed according to the normal probability density function with a zero mean and variance σ^2 (Brown, 1992)].
H_k = the fixed effect of the k^{th} herbicide treatment.
BH_{ik} = the interaction effect of the i^{th} block and the k^{th} herbicide treatment.
T_l = the fixed effect of the l^{th} time treatment.
BT_{ik} = the interaction effect of the i^{th} block and the k^{th} time treatment.
BHT_{ikl} = the interaction effect of the i^{th} block with the k^{th} herbicide treatment and the l^{th} time treatment.
$\epsilon_{(ijkl)}$ = the random effect of the k^{th} herbicide treatment and the l^{th} time treatment within the j^{th} randomization within the i^{th} block. The $\epsilon_{(ijkl)}$'s are assumed to be IID $(0,\sigma^2)$ [identically and independently distributed according to the normal probability density function with a zero mean and variance σ^2 (Brown, 1992)].

Expected Mean Squares (EMS)

Table 5 presents the expected mean squares (EMS) and associated degrees of freedom for the linear model. The test statistics and reference distributions for the null hypothesis are also presented. The EMS notation follows Anderson & MacLean (1974).

Table 5. The expected mean squares (EMS) and associated degrees of freedom for the linear model; including the test statistics and reference distributions for the null hypothesis.

VARIABLE	EMS	DF	HYPOTHESIS	TEST STATISTIC	REF. DIST.
B_i	$\sigma^2 + 10\sigma_\delta^2 + 10\phi(B)$	2	$\phi(B) = 0$	no test	
$\delta_{(i)j}$	$\sigma^2 + 10\sigma_\delta^2$	0	$\sigma_\delta^2 = 0$	no test	
H_k	$\sigma^2 + 15\phi(H)$	1	$\phi(H) = 0$	EMS(H)/EMS(BH)	$F(1,2)$
BH_{ik}	$\sigma^2 + 5\phi(BH)$	2	$\phi(BH) = 0$	EMS(BH)/EMS(BHT)	$F(2,8)$
T_l	$\sigma^2 + 6\phi(T)$	4	$\phi(T) = 0$	EMS(T)/EMS(BT)	$F(4,8)$
BT_{il}	$\sigma^2 + 2\phi(BT)$	8	$\phi(BT) = 0$	EMS(BT)/EMS(BHT)	$F(8,8)$
HT_{kl}	$\sigma^2 + 3\phi(HT)$	4	$\phi(HT) = 0$	EMS(HT)/EMS(BHT)	$F(4,8)$
BHT_{ikl}	$\sigma^2 + \phi(BHT)$	8	$\phi(BHT) = 0$	no test	
$\epsilon_{(ijkl)}$	σ^2	0			

Herbicide Application

The herbicide was applied at walking speed by personnel carrying a Research and Development (R&D) pressurized backpack sprayer, fitted with a 1.42 m short boom held at waist height. The boom was fitted with four #8002 flat fan nozzles. The 3.8 kg ae/ha (8 l/ha) of triclopyr was diluted in 150 litres (l) of water per hectare and applied at a pressure of 275 kPa (40 psi). The herbicide was applied on July 20th, 1992; a clear day without rainfall or significant wind. There was 9.2 millimetres (mm) of rainfall reported the day before application (July 19th) and 0.6 mm of rainfall the day after (July 21st) at Thunder Bay Airport (Environment Canada, 1992). It must be noted that the study area was located inland from Lake Superior and Thunder Bay. Hence, meteorological information, especially temperature, may not be accurate for the study area.

Crop Tree Assessment & Data Analysis

The following measurements were made on all seedlings at time of planting (i.e. on each planting date in 1992): 1) basal calliper (BC) in mm, and 2) total height (T-Ht) in centimetres (cm) from ground to the base of the terminal bud. BC was measured at ground level using machinist's callipers and T-Ht was measured with a retractable carpenter's measuring tape.

In late September, 1993, the following measurements were made on all seedlings: 1) BC in mm, 2) T-Ht in cm and 3) needle length in mm (i.e. of a randomly selected needle of the youngest needles in the leading shoot). The BC measurements were taken using callipers with digital readout; the T-Ht measurements were taken using a carpenter's tape; and the needle lengths were measured using a machinist's steel ruler. The physical condition of each seedling was visually assessed, encoded and recorded; primarily on the basis of entire seedling needle condition. The physical condition codes used are presented in Table 6. The author suspects that a physical condition code > 2.5 probably would result in mortality or 'checked' growth.

Table 6. Codes used to describe the physical condition of the jack pine seedlings based on visual assessment. [Note: Seedlings with condition codes 1 - 3 were considered to be 'alive', and those with code 4 were considered to be 'dead'.]

Code Number	Physical Condition
1	Foliage healthy (green); <20% brown or defoliated
2	21 to 60% brown or defoliated
3	61 to 99% brown or defoliated
4	100% brown or defoliated; buds dead and inner bark dry

Seedling performance from time of herbicide application in 1992 to the fall of 1993 was evaluated by computing the following means (per plot):

1) Percent survival of all planted seedlings;
2) Physical condition of all seedlings;
3) Needle length (mm) of the surviving seedlings;
4) Volume Increment/ha in cubic centimetres (cm^3) of surviving seedlings (calculated using Formula 1);

$$\text{Vol. Inc./ha} = \frac{(BC \div 2)^2 \times \pi}{3} \times (\text{T-Ht inc.}) \times K \qquad (1)$$

where: BC = Basal Calliper increment (1992 to 1993) (cm)
T-Ht inc. = Total Height increment (1992 to 1993) (cm)

K = conversion factor = (10000 m^2/ha) ÷ 60 m^2 x no. live trees/plot

Analysis of variance (ANOVA) (Steel & Torrie, 1981) was used to determine any significant treatment effects on the jack pine seedling performance. Tukey's Honestly Significance Difference (HSD) Multiple Range test was used to determine the statistical differences between ranked planting time treatment means at $p = 0.05$. [Note: Percent survival was transformed to angles using arcsin(proportion)$^{1/2}$ (Snedecor & Cochran, 1967) for the statistical analysis because of the non-normality of percentage data.] Paired t-tests were used to determine significant differences between herbicide treatment means (control and sprayed) for each planting time.

The physical condition code data was an ordinal type of measurement. Generally, it is not advised to use multiple range tests for significance, such as Tukey's - HSD, for ordinal data unless it appears to have a normal distribution or unless it comes from large sample sizes (Freese, 1962; Freese, 1967). Exploratory analysis and the Bartlett-Box F test for homogeneity of variance indicated that the data was normally distributed. All data was organized using a Quattro Pro 4.0™ spreadsheet and all statistical analyses were performed using SPSS/PC+™.

RESULTS

Results of Crop Tree Assessment & Data Analysis

Appendix E presents a summary of the probabilities of obtaining a larger F-ratio for the herbicide and planting time treatments and the interaction effects, determined from the analysis of variance (ANOVA), for the mean seedling response variables.

Mean Percent Survival

Figure 5 presents the mean percent survival of the jack pine seedlings for each herbicide and planting time treatment after one growing season. The means presented here are from raw data, while statistical analysis was performed on transformed data (see Methodology).

The ANOVA indicated that there were highly significant differences in survival between the herbicide treatments and between the planting time treatments. In addition, the effects of the two-way interactions between: block and herbicide treatment; block and planting time, and; herbicide treatment and planting time, were all highly significant at $p = 0.05$.

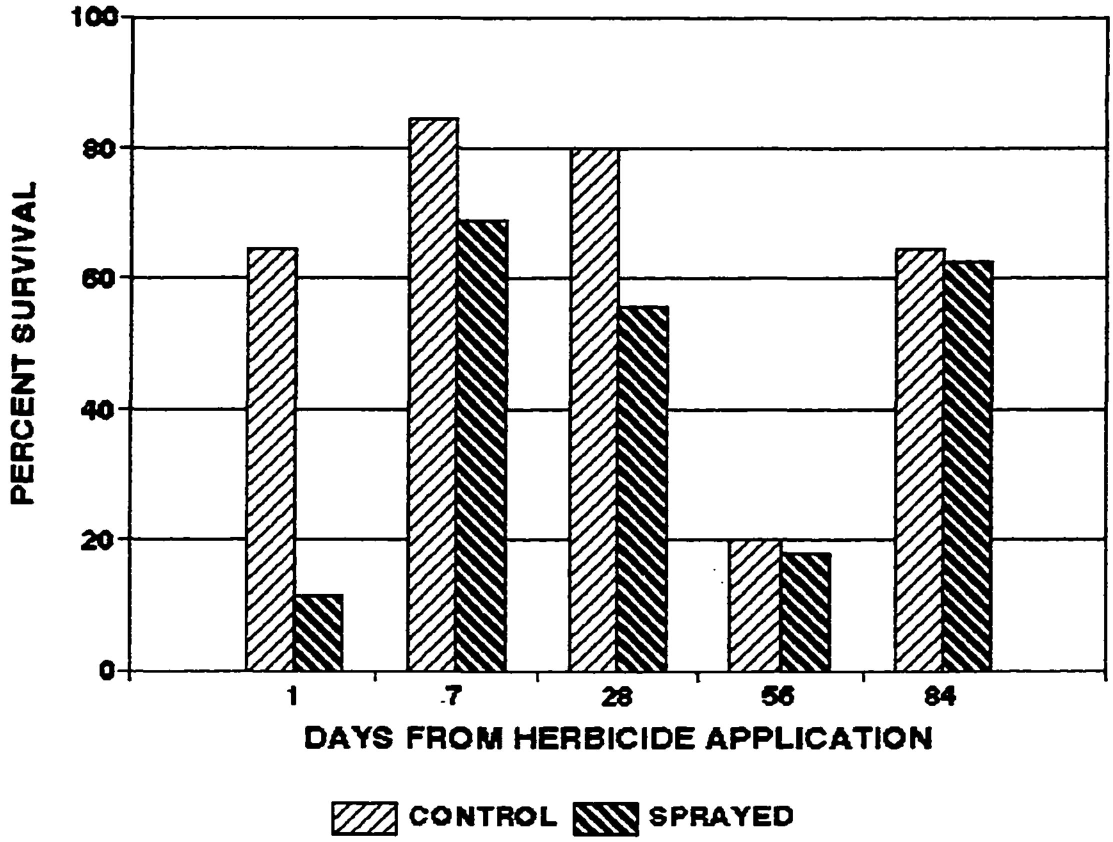

Figure 5. The mean percent survival rates of the jack pine seedlings for each herbicide and planting time treatment after one growing season.

The Tukey's - HSD multiple range test indicated that there were significant differences in seedling survival between the planting times. The mean percent survival of seedlings planted 7 days after treatment was significantly higher than those observed at 1 and 56 days. The survival of seedlings planted at 28 and 84 days after spraying were also significantly different from that observed of seedlings planted 56 days after herbicide application.

The paired t-tests indicate that there were no significant differences between control and sprayed plots at any of the planting times. However, the difference in seedling survival between the control and sprayed plots, planted 1 day after spraying, was significant at $p = 0.07$.

Results in Figure 5 suggest a trend of decreasing differences in seedling survival between control and sprayed plots as post-application planting time increases. Although there were no statistically significant differences in mean percent seedling survival between the control and sprayed plots at 1, 7 and 28 days, the differences that were observed could well be of significance to the silviculturist.

Mean Physical Condition

Figure presents the mean condition code of the jack pine seedlings for each herbicide and planting time treatment after one growing season. As the code increases from 1.0 to 4.0, seedling physical condition decreases (refer to Table 6 in Methodology).

The ANOVA indicated that the two-way interaction effect of block and herbicide treatment was significant. The herbicide treatment effects; the planting time treatment effects; the interaction effects of block and planting time, and those of herbicide and planting time treatments, were all highly significant at $p = 0.05$. The Tukey's - HSD multiple range test indicated that seedlings planted 7 days after herbicide application were in significantly better physical condition than those planted 1 day after spraying.

The paired t-tests indicated that there was no significant differences in mean seedling physical condition between the control and sprayed plots at each planting time. The largest difference in condition code between seedlings in the control and sprayed plots, which occurred at the first planting time, would have been significant at $p = 0.06$.

With the exception of planting time at day 56, the seedling condition code approximated 2.5 in all the control plots and the seedlings were in better or equal physical condition than seedlings planted into sprayed plots (Figure 6). The mean seedling planted into sprayed plots 1 day after herbicide application was dead (code 4).

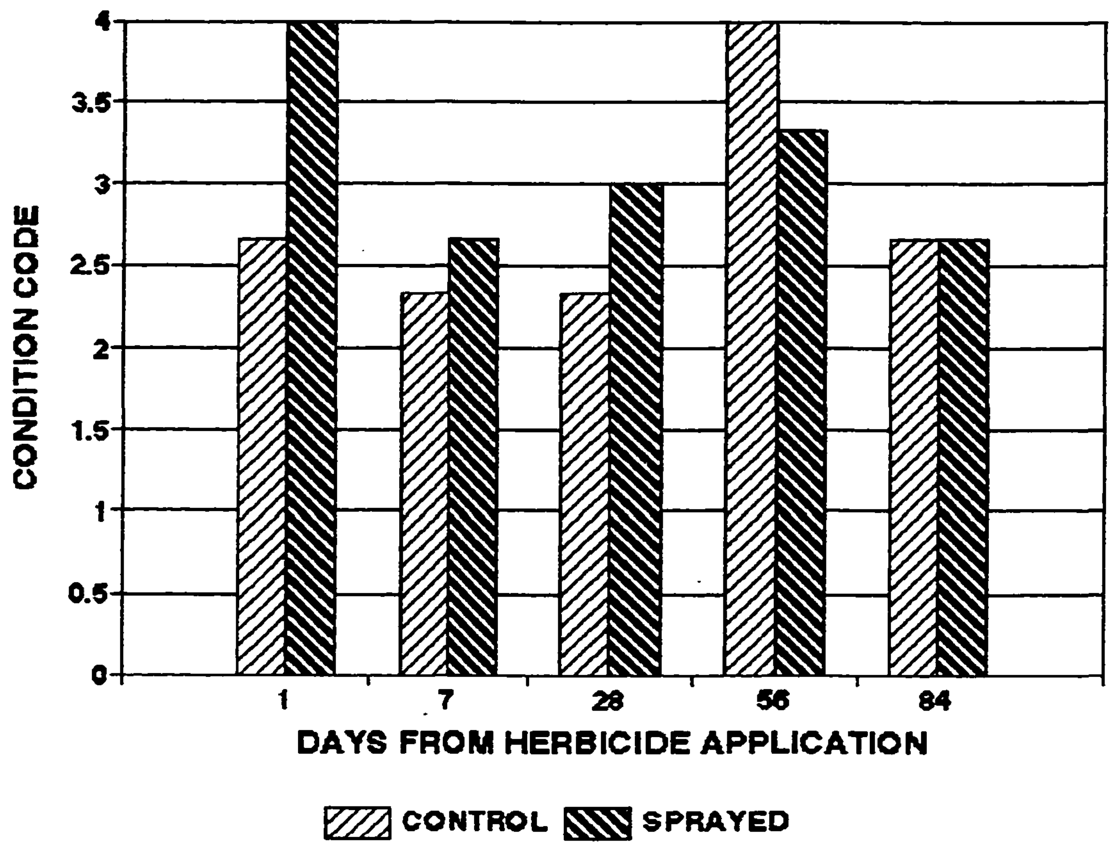

Figure 6. The mean physical condition codes of the jack pine seedlings for each herbicide and planting time treatment after one growing season.

Mean Needle Length

Figure 7 presents the mean needle length (in mm) of the jack pine seedlings for each herbicide and planting time treatment after one growing season. The ANOVA indicated that only the planting time treatments had significant effects on mean needle length. Herbicide treatment effects and all the interaction effects were not significant at $p = 0.05$. The Tukey's - HSD multiple range test indicated that there were no significant differences in mean needle lengths of seedlings observed between the five planting times. This did not concur with the results of the ANOVA, likely because of the inclusion of block effects in the range testing procedure when using SPSS/PC+.

The paired t-tests indicated that there were no significant differences in mean needle lengths between the control and sprayed plots at each planting time. The largest difference in needle length was observed at the first planting time, where the needles of the control seedlings were

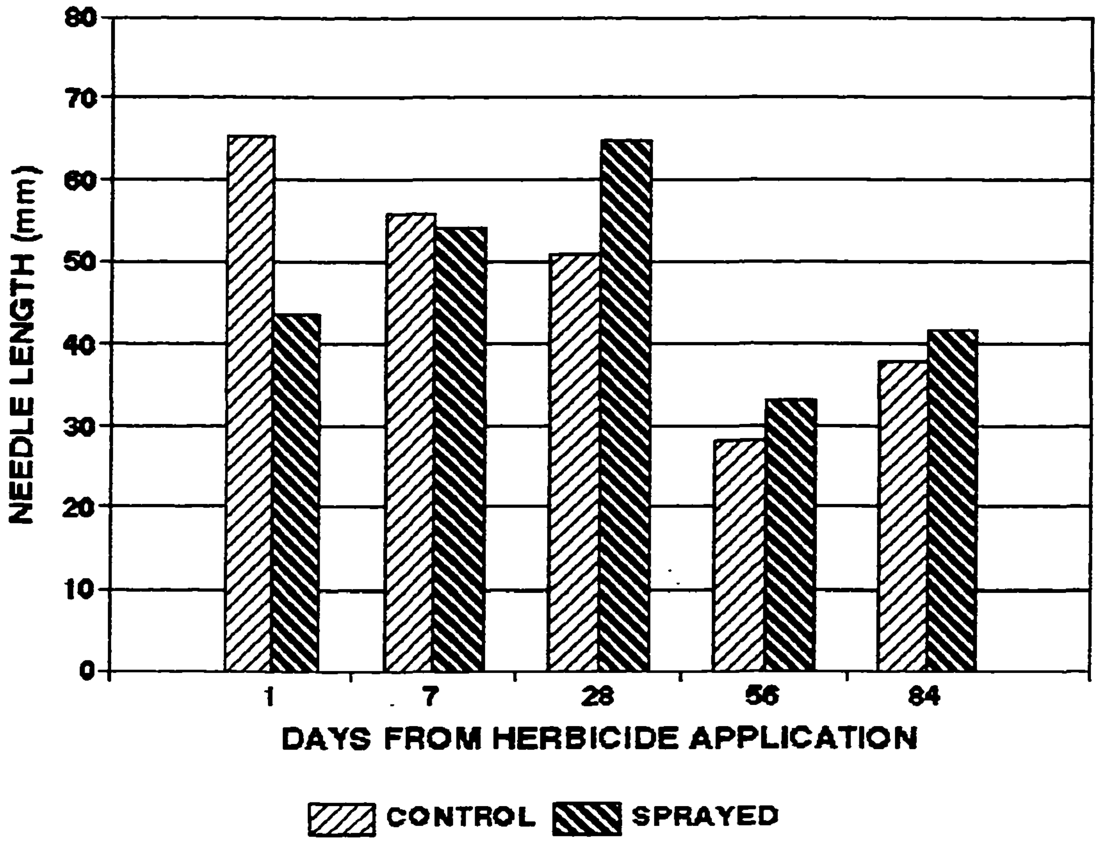

Figure 7. The mean needle lengths (in mm) of the jack pine seedlings for each herbicide and planting time treatment after one growing season.

approximately 22 mm longer than those of seedlings in the sprayed plots. The needle lengths observed in the control plots generally decreased, and those observed in the sprayed plots increased, as planting time from herbicide treatment increased (Figure 7). Mean needle length did not appear to be in any way related to seedling survival (Figure 5).

Volume Increment/ha

Figure 8 presents the mean volume increment/ha in (cm^3) of the jack pine seedlings for each herbicide and planting time treatment after one growing season. The addition of a constant of (+ 400) to each mean was necessary for graphical presentation because of negative volume increments/ha. Seedling volume was calculated as a function of height. As the leaders of many seedlings died, seedling heights were subsequently measured to the base of the terminal bud of the next tallest, secondary, live branch.

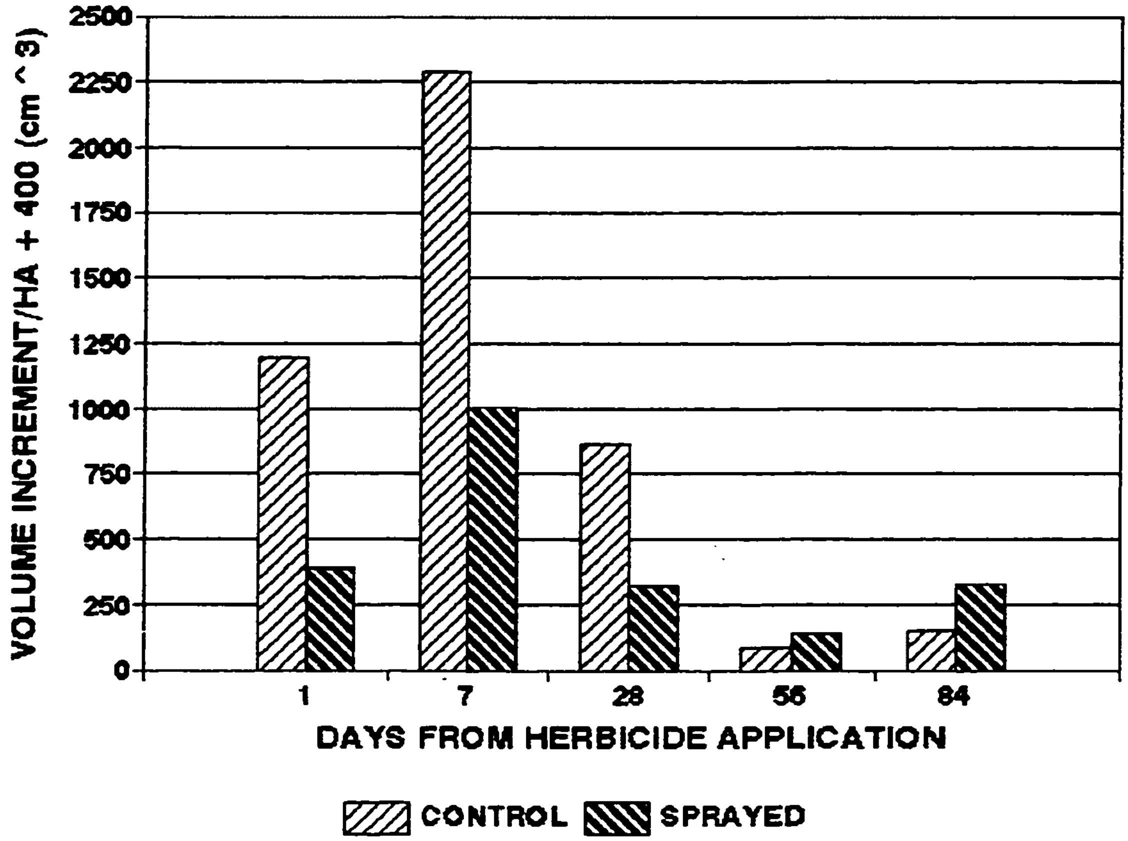

Figure 8. The mean volume increments/ha + 400 cm^3 of the jack pine seedlings for each herbicide and planting time treatment after one growing season.

The ANOVA indicated that the herbicide treatments had significant and the planting time treatments had highly significant effects on volume increment/ha. There was a significant interaction effect of block by planting time treatment on volume increment/ha at $p = 0.05$. The Tukey's - HSD multiple range test indicated that the mean volume increment/ha of the seedlings planted 7 days after spray was significantly higher than those planted at 56 and 84 days after herbicide application. In addition, the mean increments/ha of seedlings planted at 1 and 28 days were also significantly higher than that of seedlings planted at 56 days.

The paired t-tests indicate that there were no significant differences in mean volume increment/ha between the control and sprayed plots at each planting time. It was observed that at 1, 7 and 28 days, the mean volume increments/ha in the controls were more than twice those observed in their respective sprayed counterparts (Figure 8). The sprayed plots at 56 and 84 days had higher mean volume increments/ha than the respective control plots.

DISCUSSION

Label directives for Release™ (triclopyr ester) recommend an application rate of 3 to 8 l/ha (1.44 to 3.84 kg ae/ha) for broadcast foliar chemical site preparation. The label also recommends that the planting of conifer seedlings should be delayed for one year following the application (DowElanco, n.d.). In this study, triclopyr ester was applied at the maximum recommended rate of 8 l/ha (3.84 kg ae/ha). Under the soil and climatic conditions of this study, the results suggest that a period of one year between herbicide application and planting jack pine is not necessary.

After one growing season, comparisons of mean jack pine percent survival, physical condition, needle length and volume increment/ha between control and sprayed plots showed no statistically significant differences at each planting time. However, this could be a function of the experimental design not having not having sufficient power of the test. However, if the field forester wishes to maximize the survival and performance of the crop, the results did show that differences were **silviculturally significant**.

Mean seedling survival was consistently poorer on the sprayed plots than on the controls for each planting time treatment (Figure 5). The greatest difference between the control and sprayed plots was observed with the seedlings planted 1 day after herbicide application; 64% vs 11%, respectively. The planting of the jack pine 7 and 28 days after herbicide application still resulted in 15 and 22% poorer survival, respectively, on the sprayed than on the controls. However, planting 56 and 84 days after application resulted in very small differences in survival between controls and sprayed plots (only 2%).

Mean seedling physical condition was consistently poorer in the sprayed plots than in the control plots at 1, 7 and 28 days (Figure 6). The assessment of physical condition only allows for an 'educated guess' of the future survival and growth of the seedlings. The mean seedling planted 1 day after application into herbicide treated plots died (reflected in mean survival). Only the seedlings in the control plots which were planted 1, 7 and 28 days after herbicide treatment, and those which were planted into the control and sprayed plots at 84 days, were in a physical condition that approximated the tolerance limit set by the author. As with survival, the greatest difference in physical condition resulted from planting 1 day after application.

Mean needle lengths of the jack pine seedlings were not significantly different between control plots and sprayed plots at each planting time (Figure 7). It can be construed that shorter needles would result in generally poorer seedling health and efficiency in photosynthesis and growth

(Kramer & Kozlowski, 1979). Only when seedlings were planted 1 day after herbicide application was there a large difference in needle length. At this time, needles were approximately 33% longer in the control plots than those observed in the sprayed plots. It is speculated that triclopyr induced needle damage in this study occurred because the seedlings somehow came into direct contact with the herbicide. Planting 7 days after spraying resulted in little difference in needle length between control and sprayed plots. It must be noted that the mean needle length of the seedlings was measured from the youngest needles in the leading shoot, while physical condition was assessed on the condition of all the needles (Table 6).

The volume increments/ha 1, 7 and 28 days after application in the sprayed plots were consistently less than half that observed in the respective control plots (Figure 8). This is a similar trend to that observed in seedling survival. Volume increment/ha was calculated using the number of live seedlings after one growing season; hence, increment was directly related to percent survival. An interesting observation at 56 and 84 days was that, although survival was lower in the sprayed plots than in the control plots (Figure 5), the volume increment/ha was higher on the sprayed plots than on the control plots (Figure 8). There was no definitive explanation for this observation.

Overall, the measured responses of seedlings planted into both the control and sprayed plots 56 days after herbicide application were all low/poor. The exact reason for this is not known. Environment Canada in Thunder Bay, Ontario, reported that, immediately following the planting of the seedlings on September 15th 1992, there were three days of rainfall followed by 7 days without precipitation. The mean high and low temperatures for the remainder of September was 15°C and 4°C, respectively. There were 5 days with frost after September 15th, and 17 days with frost in October 1992 (Environment Canada, 1992). It is suspected that seasonal changes were a contributing factor causing poor mean seedling survival and physical condition. It must be noted that temperature and precipitation observations at Thunder Bay, which are directly influenced by Lake Superior, may not be representative of those which occurred at the study site (the site may have experienced colder temperatures).

The containerized seedlings transplanted 56 and 84 days after spraying could have been described as being bareroot seedlings. They had been heeled-in on the site approximately two months prior to the 56 day post-spray planting. By this time, root development was well beyond the surrounds of the containerized root plugs. The seedlings had set bud by September 15th, 1992, and there was no evidence of lammas growth. However, seedlings will continue to respire and develop roots until complete dormancy [Van Damme (pers. comm. 1994)]. Active root growth generally ceases when the soil temperature drops below 5°C [Day (pers. comm. 1994)]. Therefore, roots were likely still in a period of slow but active growth at time of transplanting and many fine roots may have been lost in the transplanting process. Sutton (1982) explains that when fall lifting and planting bareroot stock, there is an interruption in the physiological dormancy process, and that seedlings become prone to frost heaving before the establishment of root systems. These are major causes of disappointing fall planting results. It was observed that with extended and late season planting of 2+0 bareroot jack pine in the boreal forest, survival declined rapidly when planting after the end of July.

The results obtained for the 56 and 84 day planting times following application were not reliable. However, in 1992, DowElanco Inc. insisted that these late plantings be attempted. It would be desirable to repeat this study at the beginning rather than at the end of the planting season, which starts approximately in first week of May in Northwestern Ontario, as soon as the soil has thawed (Sutton, 1982). This would eliminate potential negative effects of late season plantings, cold temperatures and frost heaving. However, because of the similar results obtained in both control and sprayed plots for the 56 and 84 day planting times, it is likely that 56 days is more than an adequate length of time between herbicide application and planting jack pine.

There are three possible pathways in which the herbicide could have affected the planted seedlings. Firstly, there may have been sufficient herbicide in the upper layers of soil 1, 7 and 28 days after application, which could have been absorbed by roots and/or stem bases. Although triclopyr ester is not a soil active herbicide, it might be absorbed from the soil if it was in direct contact with the seedling. Triclopyr ester readily binds with organic matter restricting its movement in the soil or on the soil surface (DowElanco, n.d.). However, the study site, being a dry, coarse sandy outwash plain, had little organic matter prior to harvest. The mechanical site preparation treatment with a root rake exposed 60 to 70% of the mineral soil, into which the seedlings were planted. Without organic matter to bind the herbicide, coupled with a possible substantial reduction of soil microbes to break it down (WSSA, 1989), the herbicide may have been mobile and slow to degrade.

Secondly, it is speculated that there was little reduction of herbicide from the site because there was very little vegetation to intercept and absorb it at time of application. Hence, the 8 l/ha (3.84 kg ae/ha) of triclopyr ester was, more or less, applied directly to the soil surface. At time of application, the only major species of non-crop vegetation which was beginning to invade the site was Canada blue-joint grass; which is resistant to triclopyr ester (Buse and Bell, 1992). In addition, any residual herbicide on the grass could have come into contact with the seedlings at time of planting.

Thirdly, it is possible that there was enough triclopyr ester vapour, especially one day after application that could have been absorbed via the needles of the jack pine seedlings.

Although this type of forest site was requested by DowElanco Canada Inc., it may have not been an ideal one for this study. The previous mechanical site preparation removed the duff, organic matter and herbicide intercepting non-crop vegetation. However, it was possible to observe the effects of the herbicide on the crop without the influence of non-crop vegetation. If mechanical and chemical site preparation techniques are used, it is recommended that either the chemical application precedes mechanical scarification or a mechanical treatment which mixes the upper layers of soil with the lower ones be used, so that there could be a better restriction of triclopyr ester movement in the soil. The recommendations made here pertain only to sites similar to the one used for this study.

On the basis of seedling survival, physical condition codes, needle length and volume increment/ha, **it is not recommended that jack pine containerized seedlings be planted within 28 days of the application of 8 l/ha (3.84 kg ae/ha) of triclopyr ester**. More robust statistical tests on different site types are required to substantiate this cautious recommendation. It is important to note that the highest recommended rate of the herbicide was applied in this study (3.84 kg ae/ha). This conclusion is similar to that made by MacKay *et al.* (1988e), who also applied the maximum recommended herbicide rate, and observed that a 33 day time interval was required before planting jack pine in Northeastern Ontario. However, MacKay *et al.* (1988e) planted seedlings one hour after application and 33 days after application. There was no planting during the interim period.

It may be speculated that shorter time intervals between herbicide application and crop tree establishment may accompany the use of lower herbicide rates. Field testing of this hypothesis in Northwestern Ontario would be required before such a conclusion could be made. Becker *et al.* (1990) in Michigan observed that a minimum time interval of one month was still required with the application of triclopyr at 4.6 l/ha (2.2 kg ae/ha) before planting jack pine.

Had this study been conducted earlier in the season, it would have been more feasible to bring container stock directly from cold storage for each planting time. This would more closely simulate operational planting procedures. However, due to the lateness of the planting dates in this study, container stock had to be removed from storage and heeled-in on site because it can not be maintained in good physiological condition in cold storage over 8 - 9 months (Day, pers. comm., 1995).

The results of this study indicate that the planting of jack pine containerized seedlings can occur *at least* 28 days after the application of Release™ for chemical site preparation, in Northwestern Ontario. It is strongly recommended that a minimum time interval of one full month be used to ensure seedling safety on sites with high mineral soil exposure. The herbicide should applied in late May or early June after the majority of non-crop vegetation flush (leaf-out) has occurred. Moist sites could be planted one month after application. However, on drier sites, a late summer planting (mid to late August) could be performed following summer drought periods, which normally occur in late June through early August. This would allow an adequate two month time interval between herbicide application and planting jack pine container stock.

CONCLUSIONS AND RECOMMENDATIONS

The objective of this field study was to provide additional baseline information about the use of triclopyr ester for chemical site preparation and outplanting jack pine. Several weaknesses in the methodology make it difficult to directly apply the results obtained to operational settings. However, the observations and experiences gained from this study have lead to the following conclusions and recommendations that deserve further study.

- Planting jack pine 1, 7 and 28 days after the application of 8 l/ha (3.84 kg ae/ha) of Release™ (triclopyr ester) resulted in consistently poorer seedling survival, physical condition and volume increment/ha than untreated controls.

- Applying triclopyr ester did not significantly affect the mean needle length of the post-application planted jack pine seedlings. However, seedlings planted 1 day after herbicide application had needles which were only 67% the length of the control seedling needles, one year after application.

- On the basis of seedling survival, physical condition, needle length and volume increment/ha, it is not recommended to plant containerized jack pine seedlings within 28 days of applying 8 l/ha (3.84 kg ae/ha) of Release™. A minimum time interval of at least one month is recommended.

- The results obtained for the 56 and 84 days post-spray plantings were not reliable owing to planting late in the growing season and the poor establishment conditions.

- It is speculated that the nature of the mechanical site preparation prior to trial establishment and the lack of herbicide interceptive vegetation allowed for unexpected herbicide movement in the soil and slow decomposition of triclopyr ester.

- It would be desirable to repeat this study on other sites that better represent operational sites requiring chemical site preparation. These sites should have more abundant vegetative cover, less mineral soil exposure and the herbicide should be applied at the beginning rather than at the end of the planting season; which starts approximately the first week in May in Northwestern Ontario.

FIELD STUDY #2

EFFICACY OF TRICLOPYR-GLYPHOSATE HERBICIDE TANK MIXTURES FOR JACK PINE RELEASE

METHODOLOGY

Location

The trial was conducted in a boreal forest setting approximately 50 km west of Thunder Bay, Ontario, in Adrian Township [Lat. 48° 28' N, and Long. 89° 48' W]. Appendix F illustrates location of the study area.

Site Description

The site was an upland boreal mixedwood, on rolling ground moraine over bedrock, prior to being harvested in 1991. The soil was dry to moist well-drained (Vegetation Type 8 according to the Forest Ecosystem Classification for Northwestern Ontario (Sims *et al.* n.d.)). It was scarified with shark-fin barrels in 1991 to expose mineral soil on 10 to 20% of the area. The cutover was planted with jack pine container stock, grown in Ventblocks[1], at approximately 2 x 2.5 m spacing in 1992. The site had a moderate amount of slash and was rapidly being colonized by non-crop vegetation; the most abundant being trembling aspen, white birch, beaked hazel, mountain maple, *Prunus* L. spp., *Rubus* L. spp., bush honeysuckle (*Diervilla lonicera* Mill.) and *Aster* L. spp.).

Experimental Design

Based on DowElanco Canada Inc.'s experimental design, a randomized complete block design (RCBD) was used for this trial. Three blocks, each composed of twenty-three 4 x 10 m [40 m^2] plots, were surveyed and staked in the field in mid-August, 1992, one week before treatment application. Figure 9 shows the placement of each treatment in the experimental design. Each plot contained 7 to 10 jack pine seedlings, and each seedling was marked with a 0.4 m hoop pin and numbered for future reference.

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1 The size of the seedlings at time of planting is not known. However observations of seedling root plugs suggest that the seedlings were grown in Trimroot 165 Ventblocks™.

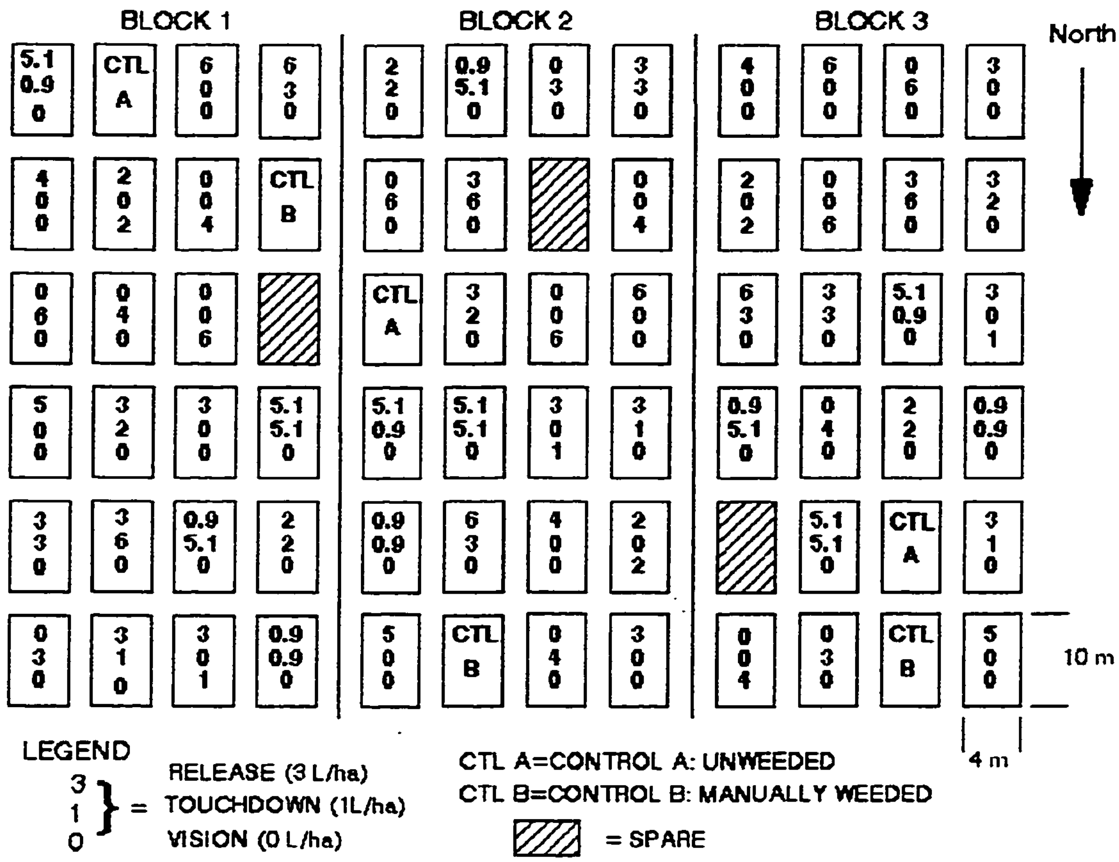

Figure 9. The randomized complete block design established in the boreal forest for field study #2, approximately 50 kilometres west of Thunder Bay, Ontario. Herbicide rates are in l/ha.

Treatments

The ranges of application rates of the herbicides evaluated were:

a) Release™ 0 to 6 l/ha (0.0 to 2.88 kg ae/ha)
b) Touchdown 480™ 0 to 6 l/ha (0.0 to 1.98 kg ae/ha)
c) Vision™ 0 to 6 l/ha (0.0 to 2.14 kg ae/ha)

Table 7 lists the 23 treatments used in this study: 21 herbicide treatments; one untreated control (Control A) and one manually weeded control (Control B). The manual weeding treatment involved the removal of both stems and roots of all non-crop vegetation and a mixing of the soil (as a result of the root removal). Figure 10 presents graphically the conversion of treatment rates from l/ha to kg ae/ha for each of the three herbicides used.

The 'odd' treatment combinations (e.g. 0.9 l/ha RELEASE - 0.9 l/ha TOUCHDOWN - 0 l/ha VISION) were a result of an initial central composite experimental design (Anderson & MacLean (1974); Mead (1988). This type of design is particularly suitable for determining optimum rates of herbicides in mixture, because it generates a 'response surface', based on regression analysis, that permits the interpolation of results. A RCBD usually does not have enough observations to generate such a response surface. However, the results were analyzed using the RCBD because it was found that there was an insufficient number of treatments to generate a smooth 'response surface', to accurately interpolate herbicide rates; and because there was a poor representation of treatments with Vision™ in the initial design.

Table 7. The twenty-three release treatment in l/ha (kg ae/ha). Treatment 1 = unweeded control A; Treatment 2 = manually weeded control B.

Treatment	Release	Touchdown	Vision
1	0	0	0
2	0	0	0
3	0	0	4 (1.42)
4	0	0	6 (2.14)
5	0	3 (0.99)	0
6	0	4 (1.32)	0
7	0	6 (1.98)	0
8	3 (1.44)	0	0
9	4 (1.42)	0	0
10	5 (2.40)	0	0
11	6 (2.88)	0	0
12	0.9 (0.43)	0.9 (0.30)	0
13	0.9 (0.43)	5.1 (1.68)	0
14	2 (0.96)	0	2 (0.71)
15	3 (1.44)	0	1 (0.36)
16	2 (0.96)	2 (0.66)	0
17	3 (1.44)	1 (0.33)	0
18	3 (1.44)	2 (0.66)	0
19	3 (1.44)	3 (0.99)	0
20	3 (1.44)	6 (1.98)	0
21	5.1 (2.45)	0.9 (0.30)	0
22	5.1 (2.45)	5.1 (1.68)	0
23	6 (2.88)	3 (0.99)	0

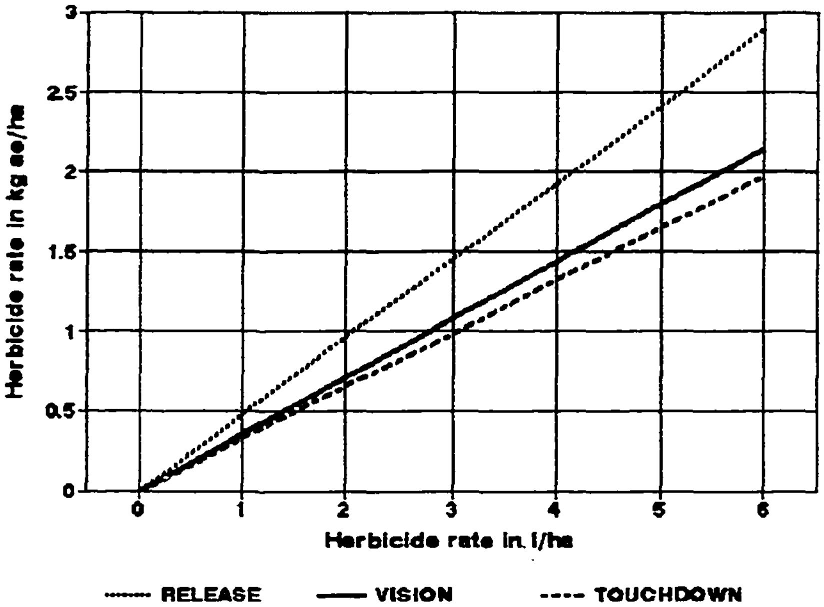

Figure 10. Conversion of herbicide rates from l/ha to kg ae/ha.

Linear Model

The linear model for this RCBD study was as follows:

$$Y_{ijk} = \mu + B_i + \delta_{(i)j} + H_k + BH_{ik} + \epsilon_{(ijk)}$$

where: $i = 1,2,3;\ j = 1;\ k = 1,2,..,23.$

Y_{ijk} = the measured non-crop vegetation or seedling response resulting from the k^{th} herbicide treatment of the i^{th} block;

μ = the overall mean;

B_i = the fixed effect of the i^{th} block;

$\delta_{(i)j}$ = the random effect of the j^{th} randomization of the herbicide treatments within the i^{th} block. The $\delta_{(i)j}$'s are assumed to be IID $(0,\sigma^2)$ [identically and independently distributed according to the normal probability density function with a zero mean and variance σ^2 (Brown, 1992)].

H_k = the fixed effect of the k^{th} herbicide treatment.

BH_{ik} = the interaction effect of the i^{th} block and the k^{th} herbicide treatment.

$\epsilon_{(ijk)}$ = the random effect of the k^{th} herbicide treatment within the j^{th} randomization within the i^{th} block. The $\epsilon_{(ijk)}$'s are assumed to be IID $(0,\sigma^2)$ [identically and independently distributed according to the normal probability density function with a zero mean and variance σ^2 (Brown, 1992)].

Expected Mean Squares (EMS)

Table 8 presents the expected mean squares (EMS) and associated degrees of freedom for the linear model. The test statistics and reference distributions for the null hypothesis are also presented. The EMS notation follows Anderson & MacLean (1974).

Table 8. The expected mean squares (EMS) and associated degrees of freedom for the linear model; including the test statistics and reference distributions for the null hypothesis.

VARIABLE	EMS	DF	HYPOTHESIS	TEST STATISTIC	REF. DIST.
B_i	$\sigma^2 + 23\sigma_\delta^2 + 23\phi(B)$	2	$\phi(B) = 0$	no test	
$\delta_{(i)}$	$\sigma^2 + 23\sigma_\delta^2$	0	$\sigma_\delta^2 = 0$	no test	
H_k	$\sigma^2 + 3\phi(H)$	22	$\phi(H) = 0$	EMS(H)/EMS(BH)	F(22,44)
BH_{ik}	$\sigma^2 + \phi(BH)$	44	$\phi(BH) = 0$	no test	
$\epsilon_{(ijk)}$	σ^2	0			

Herbicide Application

The herbicide tank mixtures were applied, at walking speed, by personnel carrying an R&D pressurized backpack sprayer; fitted with a 1.42 m R&D boom and held at waist height. The boom was fitted with four #8002 flat fan nozzles. The herbicide was diluted in 200 l of water per hectare and applied at a pressure of 275 kPa (40 psi). In order to facilitate the use of the R&D spray boom, it was necessary to reduce the height of the shrubs (mainly trembling aspen, beaked hazel and mountain maple) to 1 m on each of the treatment plots [at the request of DowElanco Canada Inc.]. This treatment is very unusual for operational vegetation control in the boreal forest. This procedure may not allow the application of the experimental results to operational settings because of: a) the reduced foliar area of shrubs (less herbicide absorptive surface), and; b) the potential increase in vegetative reproduction in response to stem cutting.

The herbicides treatments were applied over a period of 3 days; the 26th, 27th and 28th of August, 1992. Environment Canada recorded no precipitation during this period at Thunder Bay Airport nor was there any at the study area. There was 11.3 mm of rain on August 29th. The mean temperature during the period of herbicide application was 11.9°C (Environment Canada, 1992). It must be noted that the study area was located inland from Lake Superior and Thunder Bay. Hence, meteorological information, especially temperature, may not be accurate for the study area.

Owing to a late season start, time did not permit a pre-treatment assessment of the non-crop vegetation other than a general visual assessment (see Site Description). [Note: A pre-treatment assessment was not requested by DowElanco Inc..]

Non-Crop Vegetation Assessment & Data Analysis

Within each treatment plot, two 4 m^2 (1.13 m radius) vegetation (VEG) plots were used to assess the non-crop vegetation in late July, 1993; one growing season after treatment application. Randomly selected seedlings were used as centre points for the VEG plots; with the restriction that the plots fall completely within the boundaries of the treatment plots.

In each VEG plot, the non-crop vegetation (trees/shrubs, herbs, graminoids and bryophytes) was tallied by species. In addition, for each species, the total percent cover (in 5% classes) and the mean height in cm was measured. These measurements were used to calculate a VEGETATION INDEX (VI) as described by Towill & Archibald (1991). A treatment resulting in a high vegetation index has *relatively* more non-crop vegetation than a treatment resulting in a lower vegetation index. An index was calculated for each species using Formula 2.

$$\text{Species VI} = (\%\ \text{cover}) \times (\text{mean height (cm)}) \qquad \textbf{(2)}$$

where: VI = vegetation index

The vegetation index for a particular VEG plot equalled the cumulative total of all the species' indices calculated for that plot. The mean of the two VEG plot indices was calculated to obtain the vegetation index for each treatment plot (Formula 3).

$$\text{Treatment plot VI} = \frac{([\text{VEG plot \#1}]\text{VI} + [\text{VEG plot \#2}]\text{VI})}{2} \qquad \textbf{(3)}$$

where: VI = vegetation index

Five major vegetation types were identified: total vegetation, shrubs, herbs, graminoids and bracken fern. The mean vegetation indices of these major vegetation types and of individual important species were analyzed using analysis of variance (ANOVA) (Steel & Torrie, 1981). Any significant differences in the effectiveness of the herbicide treatments in controlling non-crop vegetation, relative to the controls, were then identified. The Tukey's - Honestly Significant Difference (HSD) Multiple Range Test was used to identify any significant differences between ranked treatment means at $p = 0.05$. All data was organized using a Quattro Pro 4.0 ™ spreadsheet and all statistical analyses were performed using SPSS/PC+™.

Mean indices were calculated for herbicide treatments grouped on the basis of a treatment rate concentration gradient (0, 1-3 and 4-6 l/ha), to determine if any trends in vegetation control existed.

Crop Tree Assessment & Data Analysis

The following measurements were taken on all seedlings at the time of herbicide application in 1992: 1) basal calliper (BC) in mm, and 2) total-height (T-Ht) in centimetres (cm) from the ground to the base of the terminal bud. Seedling BC was measured at ground level using machinist's callipers and T-Ht was measured with a retractable carpenter's measuring tape.

In early October, 1993, the following measurements were made on all seedlings: 1) BC in mm, 2) T-Ht in cm and 3) needle length in mm (i.e. of a randomly selected needle of the youngest needles in the leading shoot). The BC measurements were taken using callipers with digital readout; the T-Ht measurements were taken using a carpenter's tape; and the needle lengths were measured using a machinist's steel ruler. The physical condition of each seedling was visually assessed, encoded and recorded (codes used are presented in Table 6). A tolerance limit of 2.5 was set because a physical condition code > 2.5 probably would result in mortality or 'checked' growth.

Seedling performance from time of herbicide application in 1992 to the fall of 1993 was evaluated by computing the following means (per plot):

1) Percent survival of all planted seedlings;
2) Physical condition of all seedlings;
3) Needle length (mm) of the surviving seedlings;
4) Volume increment/ha in cubic centimetres (cm^3) of surviving seedlings (calculated using Formula 4);

$$\text{Vol. Inc./ha} = \frac{(BC \div 2)^2 \times \pi}{3} \times (\text{T-Ht inc.}) \times K \qquad (4)$$

<u>where</u>: BC = basal calliper increment (1992 to 1993) (cm)
T-Ht inc. = total height increment (1992 to 1993) (cm)

K = conversion factor = (10000 m^2/ha)÷ 40 m^2 x no. live trees/plot

The crop tree data were analyzed using ANOVA. Tukey's - HSD Multiple Range Test was used to determine the statistical differences between ranked treatment means at $p = 0.05$. [Note: Percent survival was transformed to angles using arcsin(proportion)$^{1/2}$ (Snedecor & Cochran, 1967) for the statistical analysis because of the non-normality of percentage data.]

The physical condition code data was an ordinal type of measurement. Generally, it is not advised to use multiple range tests for significance, such as Tukey's - HSD, for ordinal data unless it appears to have a normal distribution or unless it comes from large sample sizes (Freese, 1962; Freese, 1967). Exploratory analysis and the Bartlett-Box F test for homogeneity of variance indicated that the data was normally distributed. Data was organized using a Quattro Pro 4.0™ spreadsheet and all statistical analyses were performed using SPSS/PC+™.

Mean seedling responses were calculated for herbicide treatments grouped along a treatment rate concentration gradient (0, 1-3 and 4-6 l/ha), to determine if any trends in seedling performance existed. To further synthesize the data, the mean of each seedling response variable between herbicide treatments which resulted in above 70% seedling survival and those which resulted in below 70% seedling survival was calculated. Seedling responses resulting from the two control treatments were not included in this calculation.

To determine the optimum treatments which resulted in 'safe' and satisfactory control of each of the major vegetation types, it was found necessary to set tolerance limits on seedling survival and physical condition code following each treatment. When conducting conifer release treatments with herbicides, the survival and health of the crop trees are of greatest concern. That is, if non-crop vegetation is not effectively controlled, there are still other alternatives available. However, if the herbicide applied damages or destroys the crop, then the implications are much more serious. In this context, the choice herbicide or herbicide mixture must be based primarily on the effects on the planted crop, and secondly on the efficacy with which it controls undesirable vegetation. Hence, the author set the tolerance limits on seedling survival and physical condition code, and then recommended potential herbicide mixtures on the basis of observed and statistical evidence. An acceptable treatment should not cause more than 30% mortality and/or cause physical condition codes to exceed 2.5. These tolerance limits, although arbitrarily chosen, should be similar to the expectations and tolerance limits of the field forester.

RESULTS

Results of Non-Crop Vegetation Assessment & Data Analysis

Tables 9 and 10 present a listing of all tree/shrub and herbaceous plant species observed, respectively, on the site one year after treatment application. Those listed in **bold** were the species (or groups of species) which were of most interest to DowElanco Canada Inc.. Trembling aspen and white birch were the only two tree species encountered, but as the vegetation in each plot was cut to approximately 1 m in height prior to treatment (see Methodology), these two species were tallied as shrubs. In addition, two cherry and two raspberry species, although tallied separately, were grouped as *Prunus* L. spp. and *Rubus* L. spp., respectfully, for statistical analysis and results presentation. Canada blue-joint grass (*Calamagrostis canadensis* (Michx.) Beauv.), sedges (*Carex* (Dill.) L. spp.) and bracken fern were also observed on the site. Mosses, other ferns and fern allies were not tallied.

Herbicide rates in the results are expressed in l/ha but they are expressed in both l/ha and kg ae/ha in the discussion. See Table 7 or Figure 10 for equivalent application rates in l/ha and kg ae/ha.

The analysis of variance (ANOVA) indicated that, one year after treatment application, there was a significant treatment effect on total vegetation index and a highly significant effect on shrub vegetation index. The remainder vegetation was not significantly affected by the herbicide treatments. Appendix G summarizes the results of the ANOVA.

Table 11 lists the mean total vegetation indices, ranked in increasing order (Ranked Mean Total Veg Index), that were observed one year after each of the twenty-three treatments. The corresponding mean shrub, herb, graminoid and bracken fern vegetation indices are also presented. For the ranked mean total vegetation index and the mean shrub vegetation index, letters are used to show the mean indices which were significantly different from each other, as identified by Tukey's - HSD multiple range test (at $p = 0.05$). Three statistical groups were identified; a, ab and b. Treatment #1 (unweeded control) and #2 (manually weeded control) are listed in *italics* and marked with an asterisk '*'.

Table 9. A listing of all shrub species tallied on the site. Those listed in **bold** were the species (or species groups) of most interest to DowElanco Canada Inc..

SHRUB SPECIES	
Trembling aspen	*Populus tremuloides* Michx.
Mountain maple	*Acer spicatum* Lam.
Beaked hazel	*Corylus cornuta* Marsh.
***Prunus* L. spp.**	
Choke cherry	*P. virginiana* L.fil.
Pin cherry	*P. pensylvanica* L.fil.
Bush honeysuckle	*Diervilla lonicera* Mill.
***Rubus* L. spp.**	
Wild raspberry	*R. idaeus* var *strigosus* (Michx.) Maxim.
Dwarf raspberry	*R. pubescens* Raf.
White birch	*Betula papyrifera* Marsh.
Amelanchier Medik. spp.	
Mountain juneberry	*A. bartramiana* (Tausch) Roem.
Red-twigged serviceberry	*A. sanguinea* (Pursh) DC.
Prickly wild rose	*Rosa acicularis* Lindl.
Velvet leaf blueberry	*Vaccinium myrtilloides* Michx.
Green alder	*Alnus crispa* (Ait.) Pursh
Canada fly honeysuckle	*Lonicera canadensis* Bartr.

Table 10. A listing of all herb species tallied on the site. Those listed in **bold** were the species of most interest to DowElanco Canada Inc..

HERB SPECIES	
***Aster* L. spp.**	*A. macrophyllus* L.; *A. ciliolatus* Lindl.
Fireweed	*Epilobium angustifolium* L.
Rose twisted stalk	*Streptopus roseus* Michx.
Wild sarsaparilla	*Aralia nudicaulis* L.
Pale vetchling	*Lathyrus ochroleucus* Hook.
Blue bead lily	*Clintonia borealis* (Ait.) Raf.
Spreading dogbane	*Apocynum androsaemifolium* L.
False buckwheat	*Polygonum scandens* L.
Wood anemone	*Anemone quinquefolia* L.
Bicknell's cranesbill	*Geranium bicknellii* Britt.

Appendix H presents graphically the mean vegetation indices for each vegetation type by individual treatment. The results for individual species or species groups which were of most interest to DowElanco Canada Inc. are also presented. Results of Tukey's - HSD testing at p = 0.05 are given where significant differences between mean indices existed one year after treatment.

Table 11. The twenty-three treatments ranked according to mean total vegetation index (in increasing order) and the corresponding mean vegetation indices for the remaining vegetation types; one year after each treatment. Treatment #1 (no control) and #2 (manual control) are listed in *italics* and marked with an asterisk. Rel - Tdn - Vis refers to: Release - Touchdown 480 - Vision. Letters denote significant differences identified by Tukey's - HSD multiple range tests.

Treatment No.	Herbicide Mixtures Rel - Tdn -Vis (in l/ha)	Ranked Mean Total Veg Index	Mean Shrub Veg Index	Mean Herb Veg Index	Mean Graminoid Veg Index	Mean Fern Veg Index
5	0 3 0	1349 a	409 ab	870	77	0
20	3 6 0	1388 a	253 ab	984	169	4
6	0 4 0	1450 a	156 a	1180	93	25
22	5.1 5.1 0	1458 a	641 ab	704	83	54
4	0 0 6	1503 a	287 ab	1085	56	81
17	3 1 0	1619 a	400 ab	282	342	74
8	3 0 0	1740 a	323 ab	919	433	75
3	0 0 4	1745 a	576 ab	1098	40	38
14	2 0 2	1945 a	432 ab	936	138	456
19	3 3 0	2010 a	457 ab	1365	208	0
7	0 6 0	2030 a	467 ab	1330	117	125
18	3 2 0	2034 a	896 ab	981	110	67
* *2*	*0 0 0*	*2183 a*	*317 ab*	*1526*	*206*	*138*
13	0.9 5.1 0	2354 a	994 ab	1158	56	160
15	3 0 1	2776 a	742 ab	1668	258	125
11	6 0 0	2800 ab	688 ab	1281	469	375
10	5 0 0	2817 ab	603 ab	1717	392	118
12	0.9 0.9 0	2829 ab	1168 ab	1440	235	0
9	4 0 0	2843 ab	1409 ab	1093	296	56
21	5.1 0.9 0	3284 ab	825 ab	2180	69	234
23	6 3 0	3490 ab	1609 ab	1566	96	254
16	2 2 0	4205 ab	2293 ab	1767	146	17
* *1*	*0 0 0*	*5321 b*	*3203 b*	*2140*	*227*	*54*

Mean vegetation indices for each vegetation type were calculated for the herbicide treatments, and presented graphically, on the basis of a grouped herbicide rate concentration gradient: 0 l/ha, 1-3 l/ha and 4-6 l/ha. This was done to determine if any **general** trends in vegetation control existed.

It must be noted that when comparing treatments with Touchdown 480™ to those with Vision™, similar concentrations in litres/ha of do not represent the same acid equivalent concentrations in grams/litre (330 g ae/l and 356 g ae/l, respectively). Appendix I presents the calculated means grouped along the herbicide concentration gradient in tabular form.

Mean Total Vegetation Index

The ANOVA indicated that there were significant differences between the mean total vegetation indices. The Tukey's - HSD Multiple Range Test indicated that the resultant mean index in Control A (no vegetation control) was significantly different from the majority of the herbicide treatments and from the manually weeded control (Control B) (Table 11). Relative to no vegetation control, treatment #5 (0-3-0) was the most effective in reducing the mean total vegetation index while treatment #16 (2-2-0) was the poorest.

Figure 11 presents the mean total vegetation indices grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). It shows that, with the exception of the application of Release™ mixed with Touchdown 480™, both at rates ≥ 4 l/ha, no herbicide mixtures were as effective in reducing the mean total vegetation indices as were glyphosate treatments applied alone. However, all the herbicide treatments and manual weeding did substantially reduce the mean index relative to no vegetation control (Control A). Application rates of Release™ ≥ 4 l/ha were not as effective as that at 3 l/ha.

The application of triclopyr ester appears to be associated with less control of vegetation. However, despite this organization of the treatments into a concentration gradient, few strong patterns emerge, possibly a result of the experimental problems in the methodology (i.e. the cutting of the shrubs and the lack of a pre-treatment vegetation assessment).(0, 1-3 and 4-6 l/ha). It shows a similar trend to that observed with mean total vegetation index (Figure 11).

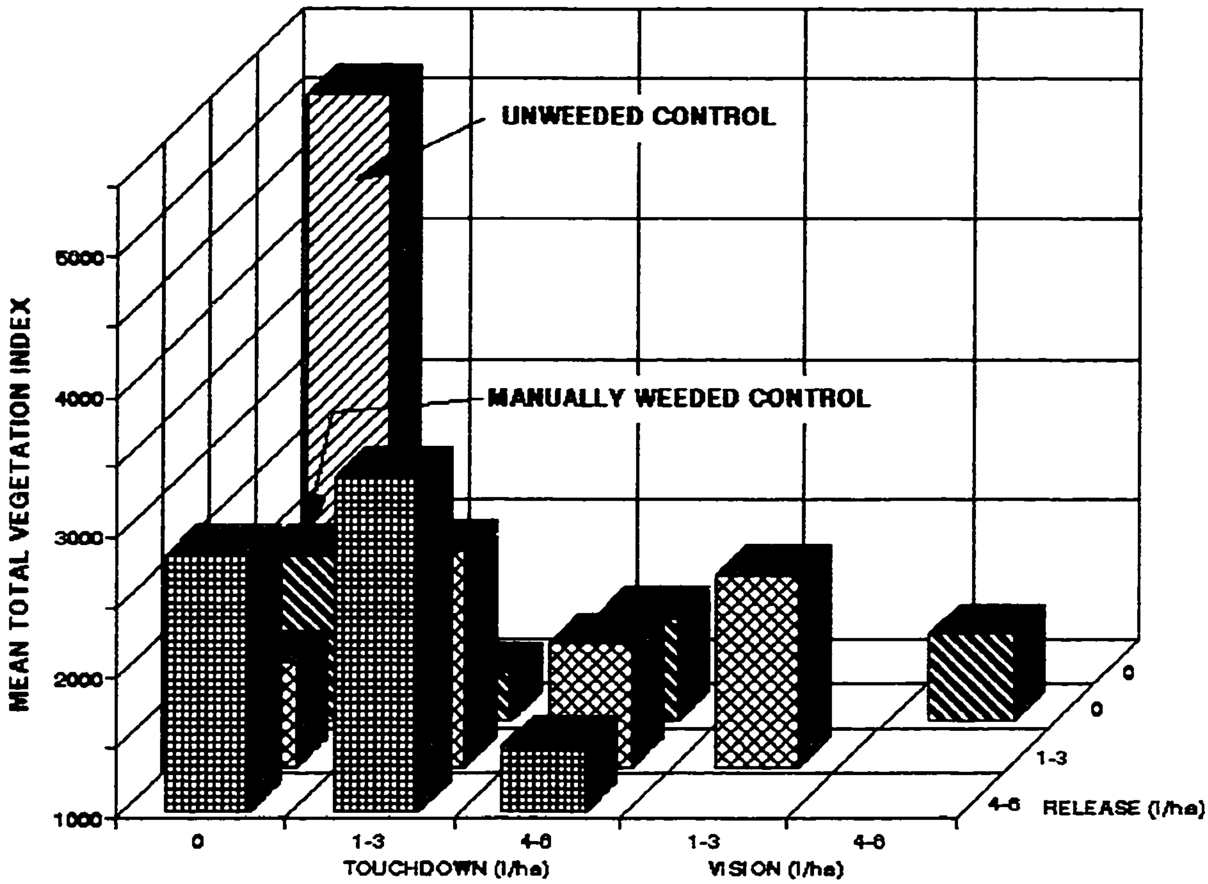

Figure 11. The mean total vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11).

Mean Shrub Vegetation Index

The ANOVA indicated that there were highly significant differences between the mean shrub vegetation indices. Tukey's - HSD Multiple Range Test indicated that the lowest mean shrub vegetation index resulted from treatment #6 (0-4-0) and was significantly different from Control A (no vegetation control) (Table 11). As with mean total vegetation index, herbicide treatment #16 (2-2-0) resulted in the poorest vegetation control.

Figure 12 presents the mean shrub vegetation indices grouped by herbicide treatment rates Mixtures of Release™ with either Touchdown 480™ or Vision™ did not reduce the mean shrub indices as much as did either glyphosate herbicide applied alone. However, all the herbicide treatments and the manual weeding did substantially reduce the mean shrub index relative to no vegetation control (Control A). Again, application rates of triclopyr ester ≥ 4 l/ha were not as effective as that at 3 l/ha.

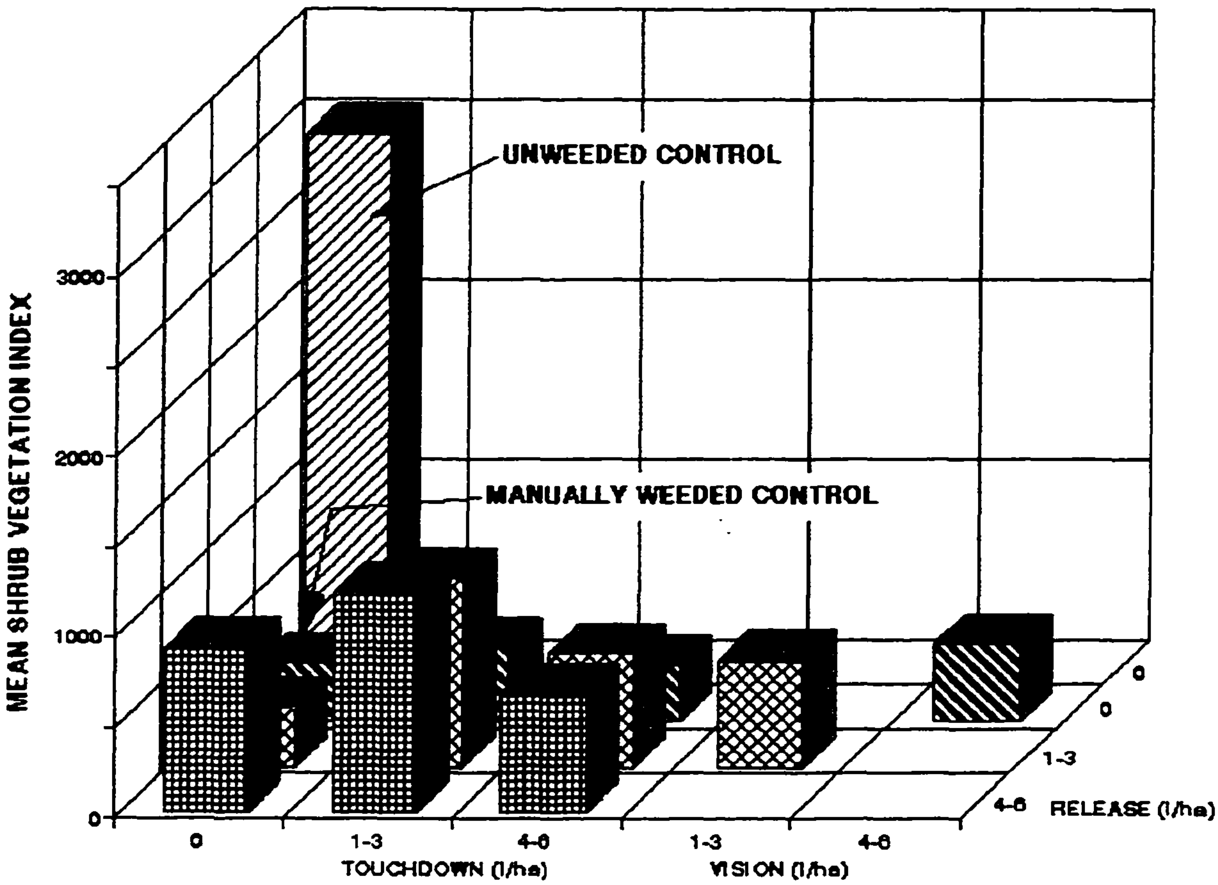

Figure 12. The mean shrub vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11).

Mean Herb Vegetation Index

There were no significant differences between the mean herb vegetation indices resulting from the treatments. However, many of the treatments did substantially reduce the mean index relative to no vegetation control. The best herbaceous plant control resulted from treatment #17 (3-1-0) while the poorest resulted, again, from treatment #16 (2-2-0) (Table 11). This suggests that the poor vegetation control resulting from treatment #16 may have been simply anomalous or the herbicide mixture may not have been properly applied. A lower rate herbicide mixture, treatment #12 (0.9-0.9-0), had consistently better control of total, shrub and herb vegetation than treatment #16 (Table 11).

Figure 13 presents the mean herb vegetation indices grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). It shows that treatments with Release™ applied in mixture with Touchdown 480™, both at rates ≥ 4 l/ha, were the most effective in reducing the mean herb vegetation indices. Although all the herbicide treatments and the manual weeding were effective to some degree in reducing the mean indices, there was no distinguishable trend observed in the magnitude of the efficacy. Again, application rates of triclopyr ester alone ≥ 4 l/ha were not as effective as that at 3 l/ha (Figure 13).

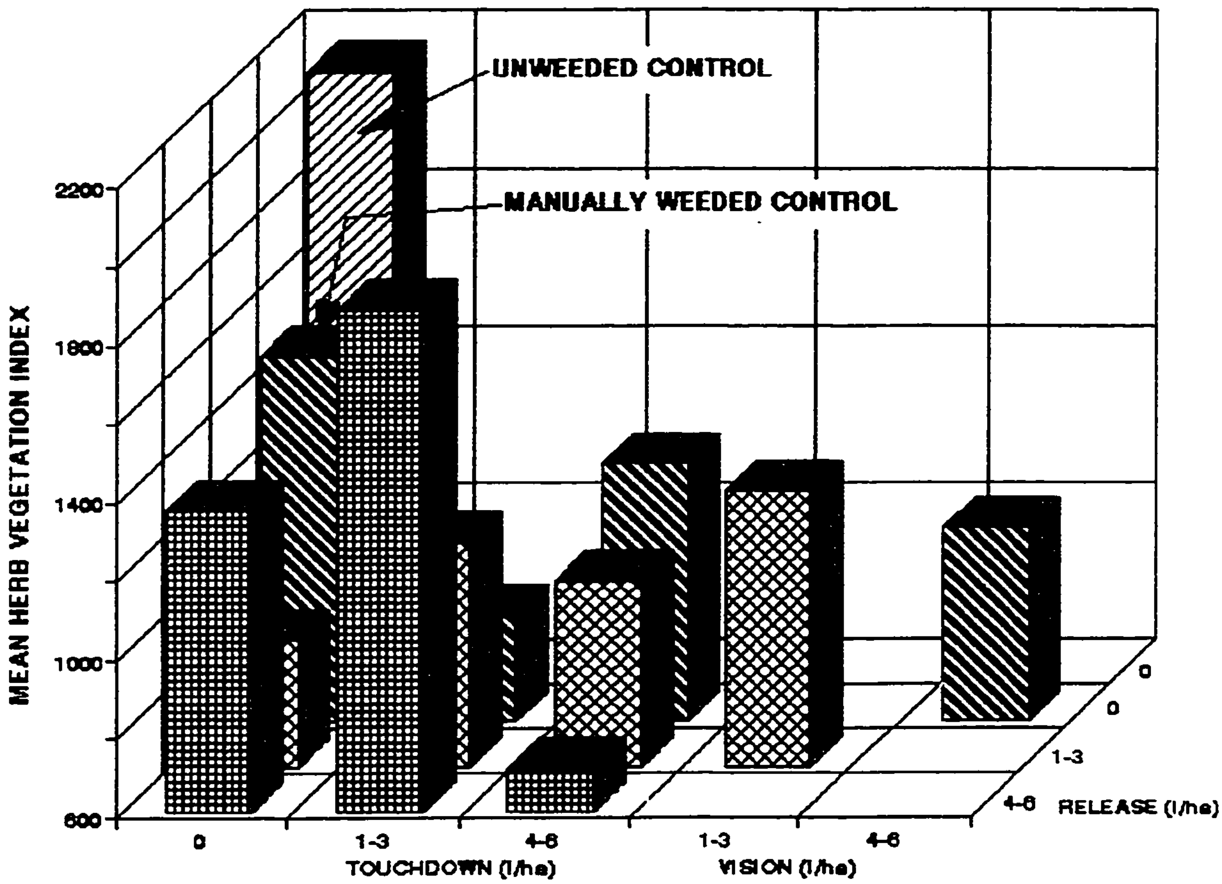

Figure 13. The mean herb vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11).

Mean Graminoid Vegetation Index

There were no significant differences between the mean graminoid vegetation indices resulting from the treatments. Several of the treatments resulted in higher mean graminoid indices relative to no vegetation control. The best graminoid control resulted from treatment #3 (0-0-4) while the poorest resulted from treatment #11 (6-0-0) (Table 11). Figure 14 presents the mean graminoid vegetation indices grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). 1-3 and 4-6 l/ha).

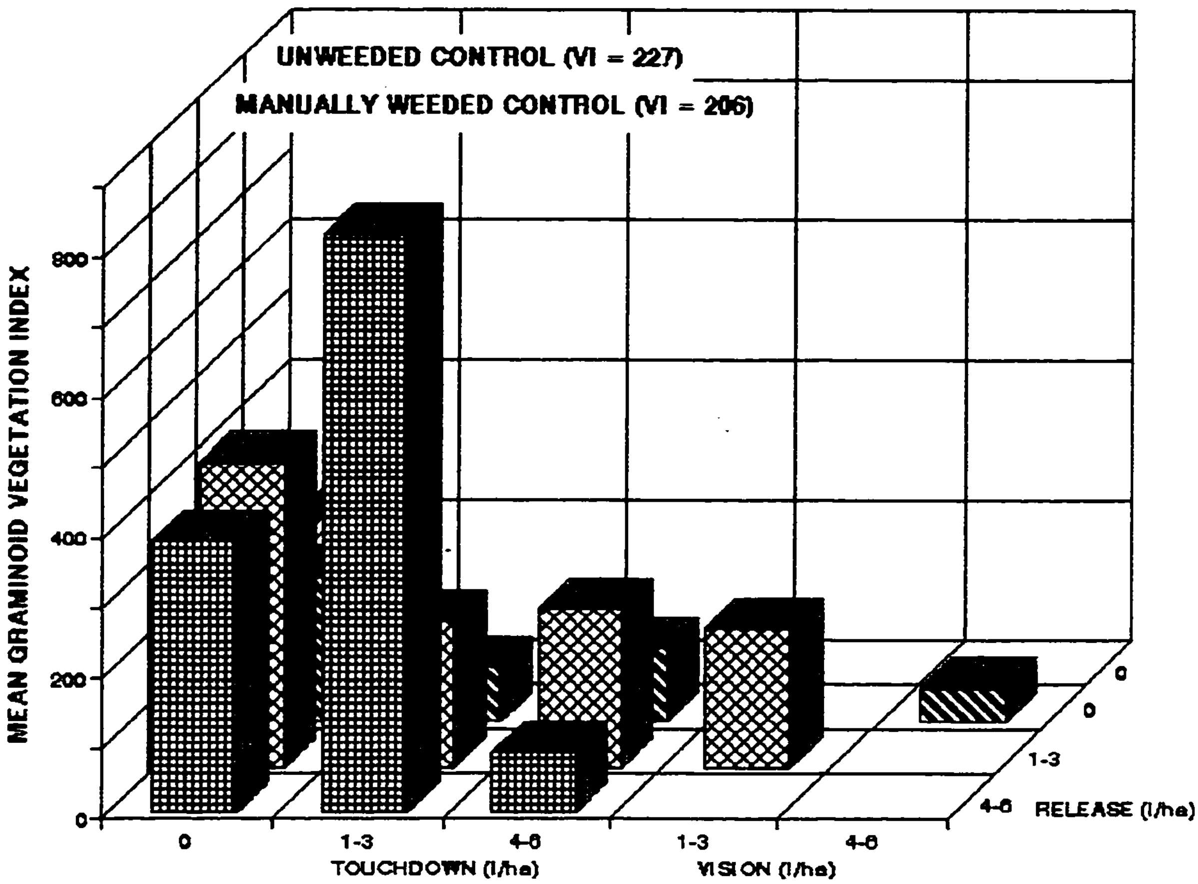

Figure 14. The mean graminoid vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11).

It shows that, with the exception of mixtures Release™ and Touchdown 480™ both applied at rates ≥ 4 l/ha, none of the herbicide mixtures nor those of Release™ applied alone were as effective as either glyphosate herbicide applied alone. Vision™ treatments applied at rates ≥ 4 l/ha were the most effective in reducing the mean graminoid vegetation index relative to no vegetation control (Figure 14).

Mean Bracken Fern Vegetation Index

There were no significant differences between the mean bracken fern vegetation indices resulting from the treatments. Three treatments resulted in 100% control of bracken fern while the poorest control resulted from treatment #14 (2-0-2) (Table 11).

Figure 15 presents the mean bracken fern vegetation indices grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). It shows that, with two exceptions, all treatments generally increased the mean index of bracken fern relative to no vegetation control (Control A). The exceptions included the one treatment with Touchdown 480™ applied alone at a rate of 3 l/ha and the mixtures of Release™ and Touchdown 480™ both applied at rates ≤ 3 l/ha (Figure 15).

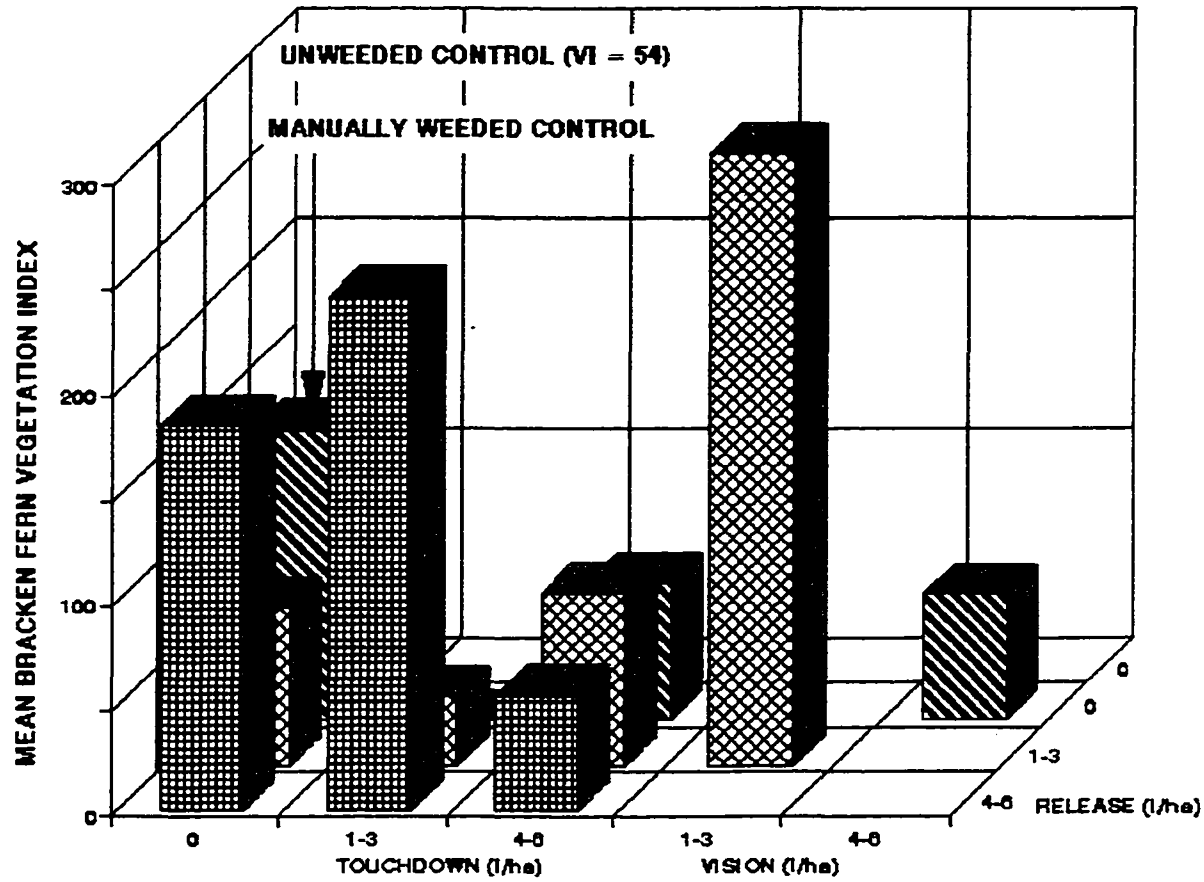

Figure 15. The mean bracken fern vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11).

Results of Jack Pine Crop Tree Assessment & Data Analysis

The analysis of variance (ANOVA) indicated that, one year after treatment application, the herbicide treatments had a significant effect on survival and needle length. Physical condition and volume increment was not significantly affected by the herbicide treatments. Appendix J summarizes the results of the ANOVA.

Table 12 lists the mean seedling percent survival rates, ranked in decreasing order (Ranked Mean % Survival), that were observed one year after each of the twenty-three herbicide treatments. Statistical analysis was performed on the transformed survival data, however the raw data is presented. The corresponding physical condition codes, needle lengths and volume increments are also presented. An overall mean for each seedling response variable is presented (in **bold**) for the treatments which were in the '*above 70% survival group*' (A70G) and for those which were in the '*below 70% survival group*' (B70G). The unweeded control (treatment #1) and the manually weeded control (treatment #2) are not included in the overall mean of the A70G and B70G. The two control treatments are listed in *italics* and marked with an asterisk '*'.

Appendix K presents the results graphically for: mean percent survival rates; mean physical condition codes, mean needle lengths and mean volume increments/ha, of the jack pine seedlings, one year after each treatment.

Means for each seedling response variable were calculated for the herbicide treatments, and presented graphically, on the basis of a grouped herbicide rate concentration gradient: 0 l/ha, 1-3 l/ha and 4-6 l/ha. This was done to determine if any **general** trends in seedling response existed. It must be noted that when comparing treatments with Touchdown 480™ to those with Vision™, similar concentrations in litres/ha of do not represent similar acid equivalent concentrations in grams/litre (330 g ae/l and 356 g ae/l, respectively). Appendix L presents the calculated means grouped along the herbicide concentration gradient in tabular form.

Mean Percent Survival

The ANOVA indicated that there were significant differences between mean seedling survival. However, the Tukey's - HSD multiple range test did not distinguish which treatments means were significantly different. This may be due to the inclusion of block effects in the range testing procedure when using SPSS/PC+.

As presented in Table 12, 100% seedling survival was observed, one year after treatment application, as a result of manual weeding (Control B) and of treatment #12 (0.9-0.9-0). Poorest survival was observed with treatments #20 (3-6-0) and #21 (5.1-0.9-0); 32% and 34%, respectively. The A70G survival mean was much higher than the B70G survival mean; 81% vs 51%, respectively.

Table 12. The twenty-three treatments ranked according to mean percent survival (in decreasing order) and the corresponding mean physical condition code, mean needle length and mean volume increment/ha; one year after each treatment. Treatment #1 (no control) and #2 (manual control) are listed in *italics* and marked with an asterisk. Rel - Tdn - Vis refers to: Release - Touchdown 480 - Vision.

Treatment No.	Herbicide Mixtures Rel - Tdn -Vis (in l/ha)	Ranked Mean % Survival	Mean Condition Code	Mean Needle Length (mm)	Mean Vol. Increment (cm^3/ha)
* *2*	*0 0 0*	*100.00*	*1.00*	*79*	*753*
12	0.9 0.9 0	100.00	1.33	74	355
14	2 0 2	93.33	1.67	76	334
4	0 0 6	86.33	1.67	64	193
17	3 1 0	79.33	2.33	65	201
15	3 0 1	75.00	2.00	64	127
16	2 2 0	75.00	2.00	71	219
8	3 0 0	73.33	2.00	75	339
5	0 3 0	73.00	2.00	52	88
10	5 0 0	71.00	2.33	62	71
MEAN		**80.70**	**1.92**	**67**	**214**
	SURVIVAL	**CUTOFF**	**OF 70**	**PERCENT**	
* *1*	*0 0 0*	*67.00*	*2.00*	*68*	*141*
11	6 0 0	62.00	2.33	56	164
9	4 0 0	61.33	2.67	75	378
3	0 0 4	61.00	1.67	56	70
18	3 2 0	61.00	2.67	70	102
13	0.9 5.1 0	57.67	3.00	33	22
6	0 4 0	54.00	2.67	38	34
7	0 6 0	54.00	2.67	52	47
19	3 3 0	49.33	2.67	53	85
22	5.1 5.1 0	42.00	3.00	57	24
23	6 3 0	41.33	3.00	59	304
21	5.1 0.9 0	33.67	3.00	56	76
20	3 6 0	32.00	3.33	28	37
MEAN		**50.80**	**2.70**	**53**	**112**

Figure 16 presents the mean seedling survival rates grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha).

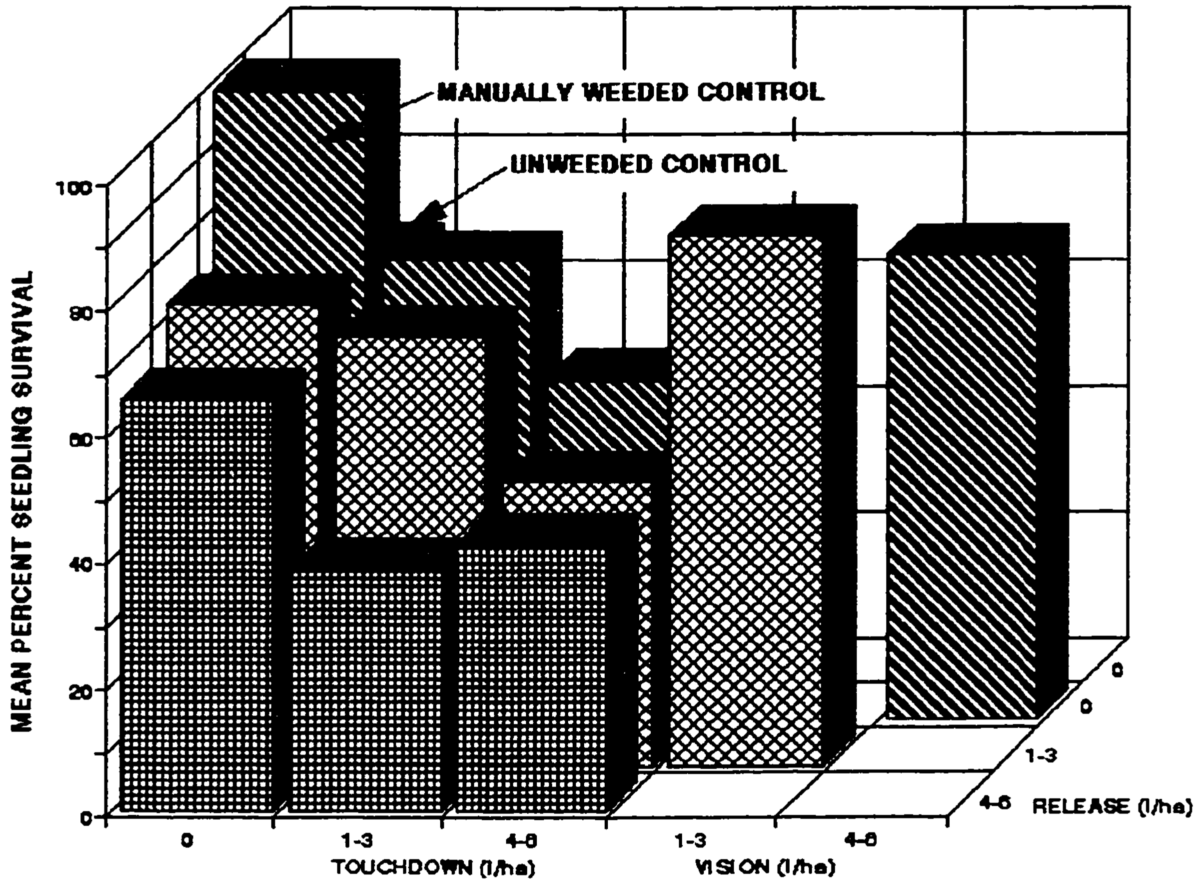

Figure 16. The mean seedling percent survival grouped by herbicide rate (0,1-3 and 4-6 l/ha) (adapted from Table 12).

It shows that all mixtures of Release™ and Touchdown 480™ an resulted in seedling survival rates below the 70% acceptable survival cut-off. In addition, applying either Touchdown 480™ or Release™ alone at rates ≥ 4 l/ha was detrimental to seedling survival. No vegetation control (Control A) resulted in only 67% survival as opposed to the 100% survival observed in the manually weeded control. Although not well represented, treatments with Vision™ both alone and in mixture with Release

Mean Physical Condition

The ANOVA indicated that there were no statistically significant differences in seedling physical condition. As presented in Table 12, seedlings in the best physical condition one year after treatment application were those in the manually weeded control followed by those in treatment #12 (0.9-0.9-0). Seedlings in the poorest physical condition were those observed in treatments #20 (3-6-0); #21 (5.1-0.9-0); #23 (6-3-0); #22 (5.1-5.1-0) and #13 (0.9-5.1-0) (all had codes ≥ 3.00). As with seedling survival, the A70G mean physical condition code was better than that of the B70G; 1.9 vs 2.7, respectively. Figure 17 presents the mean physical condition codes grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha).

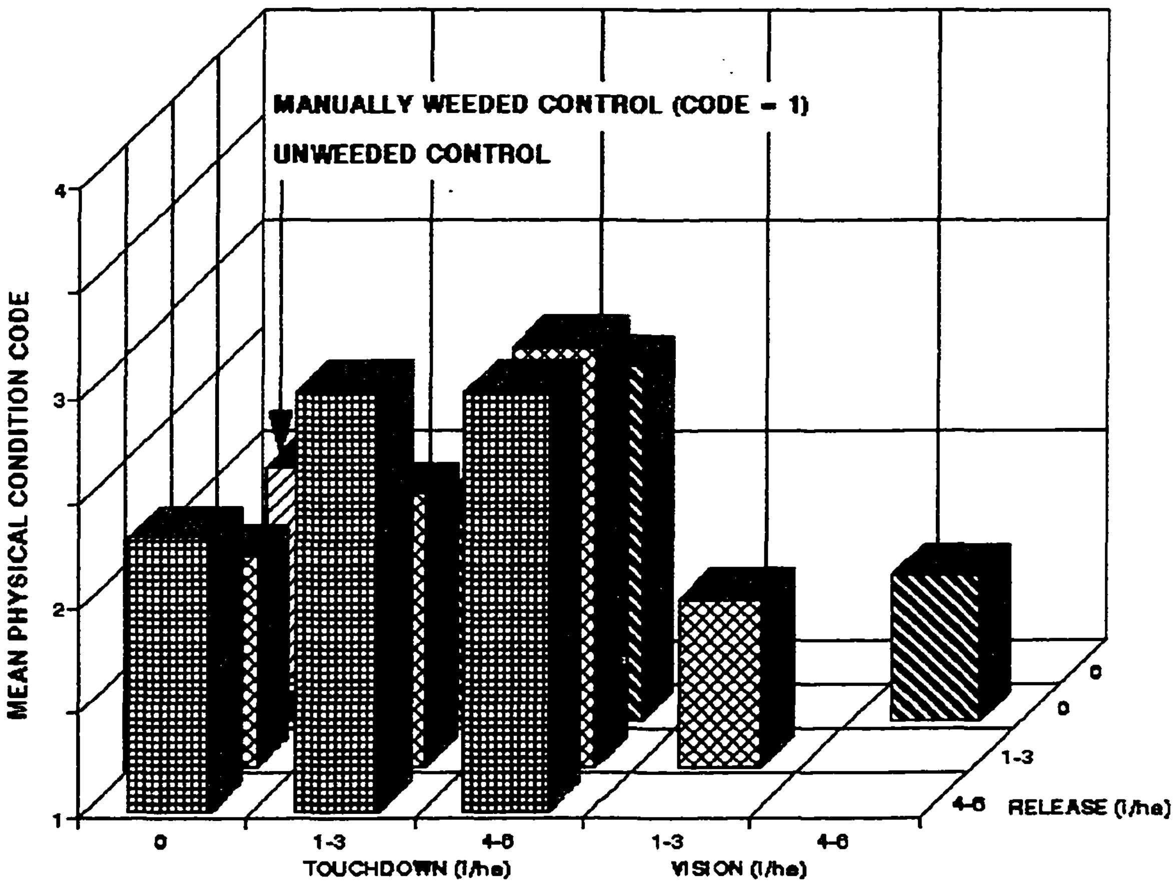

Figure 17. The mean seedling physical condition codes grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12).

It shows that: mixtures of Release™ and Touchdown 480™ applied at rates ≥ 4 l/ha (of each herbicide) and; the application of Touchdown 480™ alone at rates ≥ 4 l/ha; all resulted in mean physical condition codes greater than the acceptable 2.5 limit set by the author. Vision™ applied alone and in mixture with Release™ resulted in better seedling physical condition than did either no vegetation control, or Release™ or Touchdown 480™ applied alone.

Mean Needle Length

As with mean percent survival, there were significant differences between mean needle lengths. However the Tukey's - HSD test may not have identified any perhaps because of the inclusion of block effects in the range testing procedure when using SPSS/PC+. As presented in Table 12, the greatest mean needle lengths were observed on seedlings in the manually weeded control (79 mm), followed by those in treatment #14 (2-0-2) (76 mm). The A70G mean needle length was 67 mm while that of the B70G was only 53 mm.

Figure 18 presents the mean needle lengths (in mm) grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). It shows that needles of seedlings growing with no vegetation control treatment were 11 mm shorter than those in the manually weeded control. The general trend was that mean needle lengths decreased as herbicide application rates, both alone and in mixture, increased. All but one of the herbicide treatments with Touchdown 480™ resulted in mean needle lengths less than those which resulted from treatments with Vision™.

Mean Volume Increment/ha

The ANOVA indicated that there were no statistically significant differences in mean volume increment/ha. However, seedling growth responses to vegetation control treatments are generally not evident after one growing season, and volume increment/ha was directly dependant on seedling survival.

As presented in Table 12, the manually weeded control had the highest mean volume increment/ha; likely because the seedlings were able to achieve full growth potential and there was 100% survival. With the exception of treatment #9 (4-0-0), the volume increment/ha of manually weeded seedlings were twice that observed with the remaining herbicide treatments and more than 5 times that observed in the unweeded control. Poorest volume increment/ha occurred in treatments which were observed to have either poor survival or physical condition codes ≥ 3.0 (with the exception of treatment #23 (6-3-0)). The A70G mean volume increment/ha was almost twice the B70G mean; 214 and 122 cm^3/ha, respectively (Table 12).

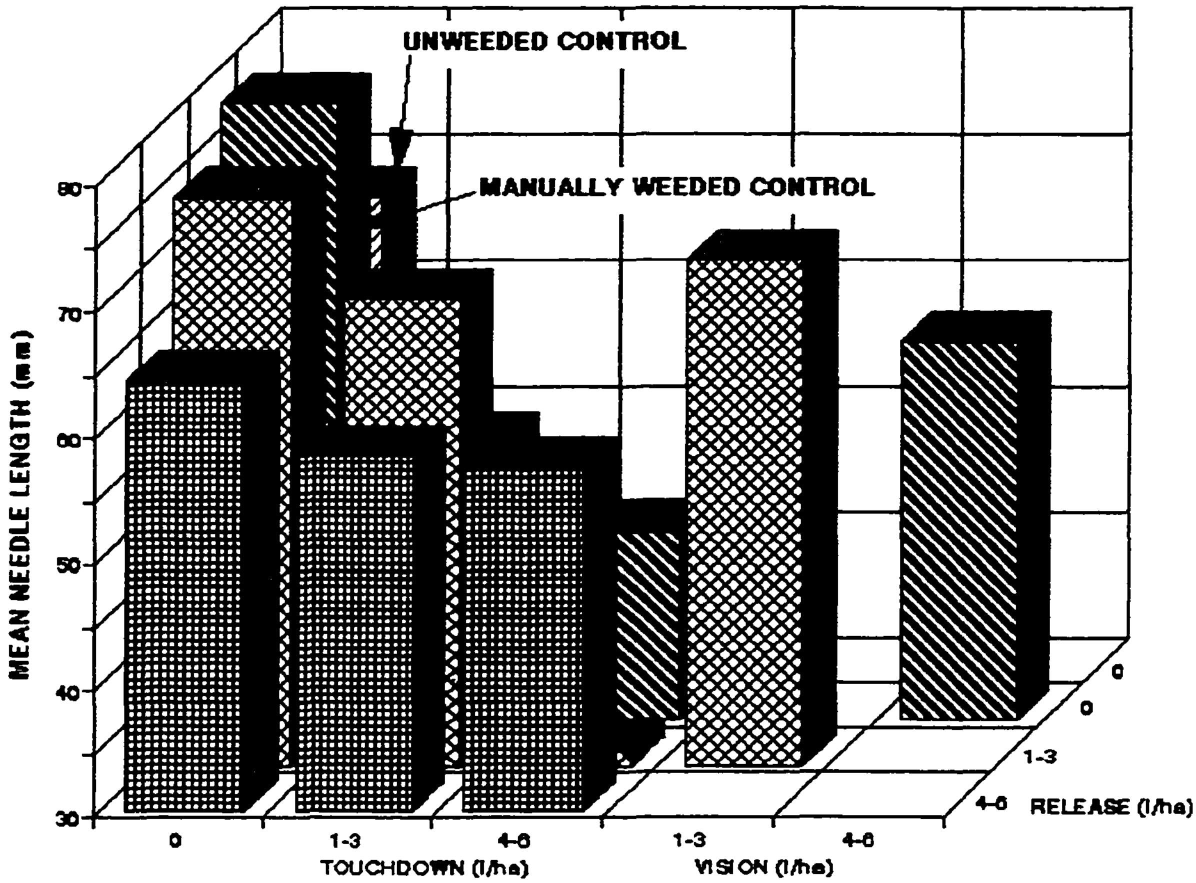

Figure 18. The mean seedling needle lengths (in mm) grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12).

Figure 19 presents the mean volume increments/ha (in cm^3/ha) grouped by herbicide treatment rates (0, 1-3 and 4-6 l/ha). It shows that increasing rates of herbicide, alone and in mixture generally resulted in decreasing volume increments/ha. The application of Touchdown 480 ™alone and in mixture with Release™ at rates ≥ 4 l/ha was detrimental to seedling survival and this was, consequently, reflected in the low volume increments/ha.

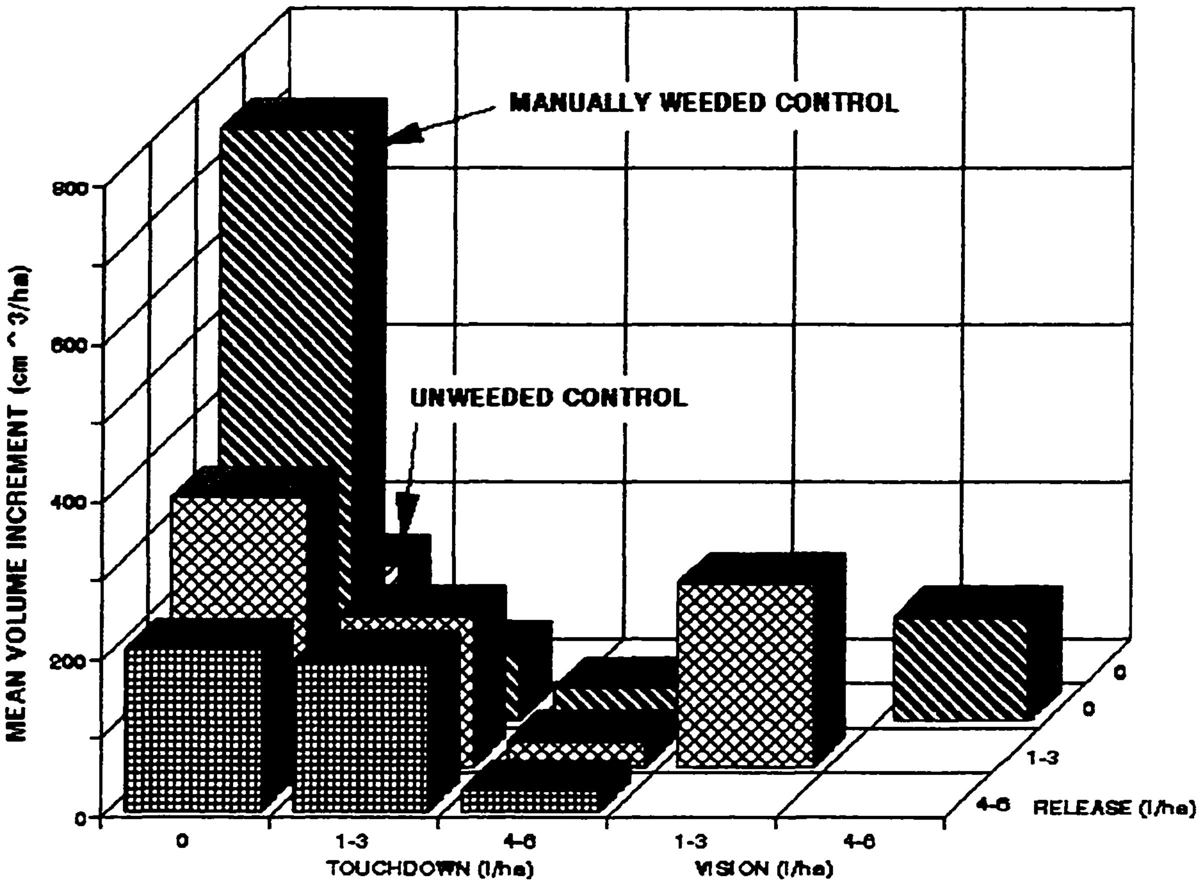

Figure 19. The mean seedling volume increments (in cm^3/ha) grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12).

DISCUSSION

Non-Crop Vegetation Response

Assessments of non-crop vegetation control with herbicides after one growing season are generally not reflective of the full extent of long-term control. Long-term herbicidal effects on non-crop vegetation do not reach a maximum until about two years after treatment for glyphosate (Carruthers & Towill, 1988) and triclopyr ester (Deloitte & Touche, 1992). Nevertheless, there were distinguishable short-term effects of the 23 treatments on non-crop vegetation observed one year after application.

The majority of herbicide treatments significantly reduced the mean total vegetation index relative to no control. Optimal control was achieved with the application of 3 l/ha (0.99 kg ae/ha) of Touchdown 480™ while the poorest control was observed with the application of Release™ with Touchdown 480™, both at 2 l/ha (0.96 and 0.66 kg ae/ha, respectively) (Table 11). The application of triclopyr at any rate with rates of glyphosate ≤ 3 l/ha tended to be the least effective (Figure 11). *All glyphosate treatments applied alone resulted in the best total vegetation control, as did the mixture of Release™ with Touchdown 480™, both at 5.1 l/ha (2.45 and 1.68 kg ae/ha, respectively)* (Figure 11).

The examination of the vegetation indices of the individual vegetation types provides a clearer picture of the treatment results. The application of 4 l/ha (1.32 kg ae/ha) of Touchdown 480™ resulted in the most significant control of all shrubs (Table 11). All the glyphosate treatments applied alone, the manual weeding treatment, and the application of triclopyr alone at 3 l/ha (1.44 kg ae/ha), were the most effective (Figure 12). Beaked hazel was the most difficult shrub species to control (see Appendix H). Treatments with triclopyr alone did not reduce the mean beaked hazel index as effectively as did glyphosate alone, particularly those with Vision™. This concurs with results by Pitt *et al.* (1993), who found in New Brunswick, that crown cover reductions of beaked hazel and other major shrubs were more consistent with glyphosate than with triclopyr.

One year after treatment, there were no distinguishable trends in control of trembling aspen, mountain maple, *Prunus* spp., bush honeysuckle and *Rubus* spp. (see Appendix H). All treatments except the application of Release™ with Touchdown 480™, both at 2 l/ha (0.96 and 0.66 kg ae/ha, respectively) reduced the mean shrub index to half that observed in the unweeded control (Table 11). *However, in general, herbicide tank mixtures offered no advantage over single herbicides for the control of shrubs one year after treatment.*

There were no significant differences between treatments in the control of herbs. Few treatments reduced the mean herb vegetation indices to less than half observed on the unweeded control. Greatest reductions were achieved with mixtures of Release™ and Touchdown 480™ at rates ≥ 4 l/ha (1.92 and 1.32 kg ae/ha, respectively) (Figure 13). *Aster* spp. and fireweed were the most dominant herb species on the site one year after treatment application.

Hollstedt (1992) states that the control of large-leaved aster (*Aster macrophyllus* L.) with glyphosate is not possible using application rates approved for forestry use in Ontario; and that triclopyr ester will not control *Aster* spp., except at extremely high rates. Freedman *et al.* (1993) explain that many individuals of some perennial species of ground vegetation survive herbicide treatment because of reduced exposure caused by the physical shielding by taller, overtopping vegetation. These surviving plants would subsequently experience relatively free growth for several seasons, because of a temporary decrease in the intensity of overtopping shrub-sized plants. Both *Aster* spp. and fireweed are prolific seeders and regenerate easily on exposed mineral soil. They are also stimulated to vegetatively reproduce when their root systems are fragmented by mechanical site preparation (Buse & Bell, 1992). Freedman *et al.* (1993) observed that these and other herbaceous species were often more abundant for several years after spraying herbicide than before.

There were no significant differences between treatments in the control of graminoids. Vision™ applied at rates ≥ 4 l/ha (1.42 kg ae/ha) was the most effective in controlling Canada blue-joint grass and *Carex* spp. but glyphosate treatments in general reduced graminoid vegetation indices relative to the unweeded control (Figure 14). Triclopyr was ineffective in the control of graminoids. It is known that Canada blue-joint grass is resistant to triclopyr but it is not known about the effect of triclopyr on *Carex* spp. (Buse & Bell, 1992). From the results of this study it appears that *Carex* spp. is also resistant to triclopyr at rates as high as 6 l/ha (2.88 kg ae/ha). Mixtures of triclopyr with Touchdown 480™ were less effective than mixtures of triclopyr with Vision™. The abundance of graminoids in many of the treatments may be a result of the mechanical site preparation, because both grass and sedges are stimulated by the fragmentation of roots and rhizomes (Buse & Bell, 1992).

As with graminoids, there were no significant reductions of bracken fern with any of the treatments. It is known that bracken fern is resistant to triclopyr (Buse, 1992; Buse & Bell, 1992) therefore any reductions probably resulted from the application of glyphosate. The lowest bracken fern indices resulted from treatments with Touchdown 480™ at 3 l/ha (0.99 kg ae/ha) alone and in mixture with Release™ at rates ≤ 3 l/ha (1.44 kg ae/ha) (Figure 15).

The manual weeding treatment was effective in reducing the total mean vegetation indices to less than half that observed in the unweeded control. The greatest impact was on the shrubs, but it had little effect on herbs, graminoids and it promoted the growth of bracken fern. The manual weeding treatment involved the removal of both stems and roots of all non-crop vegetation and a mixing of the soil (as a result of root removal). It is interesting to compare other treatment results to those of a manual weeding treatment, but it has little bearing on the overall results. This method of manual weeding would not a feasible vegetation control alternative for releasing Northwestern Ontario conifer plantations and its effects are probably very short term (1-2 years).

There were three circumstances that potentially influenced the observed vegetation responses in this study.

Firstly, the site was an upland Boreal mixedwood prior to harvest in 1991 that was then mechanically site prepared with shark-fin barrels in the same year. The release treatments were applied only one year later in 1992. In 1993, it was observed that most of the non-crop vegetation on the site were species which were capable of some form of vegetative reproduction. All the major tree/shrub species were likely stimulated to vegetatively reproduce following the mechanical breakup of roots/rhizomes (with the exception pin cherry which reproduces prolifically by seed and buried seed) (Buse & Bell, 1992). The major herb species, namely *Aster* spp. and fireweed, will also reproduce in abundance following the breakup of rhizomes and the exposure of mineral soil; as will Canada blue-joint grass, *Carex* spp. and bracken fern (Buse & Bell, 1992).

The full effects of the mechanical site preparation on the asexual reproduction capabilities of the vegetation were probably still not realized at the time of herbicide treatment application. The chemical release treatments should have been applied at least two years after the mechanical site preparation to ensure more thorough vegetative reproduction control.

Secondly, there was no pre-treatment assessment of the non-crop vegetation other than a general visual assessment of the invading species (a function of financial and administrative difficulties in August 1992). Hence, there was no record of the changes in vegetation abundance/type which may have occurred between 1992 and 1993. Subsequently, assessments and statistical analyses could only be made which reflected the conditions observed in July 1993 relative to the controls; and not what vegetation *changes* that may actually have occurred on each treatment plot. Pre-treatment assessments of non-crop vegetation would have allowed for covariate statistical analyses. This type of analyses would determine if, for example, a low vegetation index of a species was the result of the herbicide treatment or simply because the species had a low index prior to treatment.

Thirdly, all non-crop vegetation was reduced in height to 1 metre in order to facilitate the use of a Research and Development (R&D) hand-held spray boom (at the request of DowElanco Canada Inc.). This spray boom was one which would not normally be used to apply herbicide operationally for forestry purposes. It is speculated that by reducing the height of species such as trembling aspen, mountain maple, and beaked hazel may have had two key effects on the results. Firstly, there was a reduction of the foliar area of the major target tree and shrub species; subsequently reducing the potential for the herbicide treatments to be effectively absorbed by the target plants. Secondly, there would have been a stimulation of root suckering (in the case of trembling aspen) and root collar or stem sprouting (in the case of mountain maple and beaked hazel). The cutting of the stems above one metre was a poor and unsubstantiated decision for this herbicide trial, since the use of the special R&D spray boom was not the focus of the study.

Jack Pine Crop Tree Response

The effects of the treatments on seedling survival, physical condition and needle length were measures of health and vigour one year after application. Volume growth responses tend not to be observed after one year. In fact, growth responses can not usually be assessed until at least two years after the release treatment because the growth potential of a seedling in one year is determined by the its growth and budset in the previous year. Herbicides applied for conifer release are usually applied after budset. Consequently, a reduction in non-crop vegetation would have little impact on seedling growth the year following application.

Seedling survival was the highest (100%) with manual weeding and with the application of Release™ with Touchdown 480™, both at 0.9 l/ha (0.43 and 0.30 kg ae/ha, respectively) (Table 12). In general, mixtures of Release™ with Touchdown 480™ at any rate resulted in survival rates less than 70%. This was also observed with either the application of Release™ alone at rates ≥ 4 l/ha (1.92 kg ae/ha) or Touchdown 480™ alone at rates ≥ 4 l/ha (1.32 kg ae/ha) (Figure 16). Label directives for triclopyr ester cautions that the probability of injury to jack pine seedlings is greatest when application is made in the same year as planting (DowElanco, 1995). Partika (pers. comm., 1993) indicated that the glucocide wetting agent used in Touchdown 480™ may be detrimental to jack pine seedlings. This information appears to coincide with the survival results obtained in this study. Of all the herbicide treatments, Vision™ applied alone or in mixture with Release™ resulted in the highest seedling survival rate.

There were no significant differences in seedling physical condition one year after treatment. As with mean percent survival, seedlings which were in best physical condition were those with manual weeding and with the application of Release™ with Touchdown 480™, both at 0.9 l/ha (0.43 and 0.30 kg ae/ha, respectively) (Table 12). In general, herbicide mixtures of Release™ with Touchdown 480™, where either one or both herbicides exceeded 4 l/ha (1.92 and 1.32 kg ae/ha, respectively), the seedling physical condition was poor (Figure 17). Overall, with exception of the manually weeded control, the application of Vision™ alone or in mixture with Release™ resulted in better seedling physical condition than all other herbicide treatments and the unweeded control.

The exact implications of reduced needle lengths from herbicide application is not known. However, reduced needle length results in reduced needle surface area capable of producing photosynthate (Kramer & Kozlowski, 1979). This subsequently impacts on the vigour and growth of the seedlings. Mean needle length of seedlings was highest in the manually weeded control (79 mm). The second highest mean needle length was observed after the application of ReleaseTM and Vision™, both at 2 l/ha (0.96 and 0.71 kg ae/ha, respectively). The shortest mean needle length was observed after the application of 3 l/ha (1.44 kg ae/ha) of Release™ mixed with 6 l/ha (1.98 kg ae/ha) of Touchdown 480™ (28 mm) (Table 12).

Applications of Release™ at rates ≥ 4 l/ha (1.92 kg ae/ha); Vision™ at rates ≥ 4 l/ha (1.42 kg ae/ha); or Touchdown 480™ at any rate alone or in mixture, resulted in shorter jack pine needles than the unweeded control (Figure 18). These results appear to coincide with the label warnings for Release™ and Vision™. Touchdown 480™ also appeared to cause detrimental effects to needle growth.

Substantial volume increment per hectare was observed in the manually weeded control relative to the unweeded control (Table 12). This volume growth coincides with the highest observed survival rate, the best physical condition and the longest needles of the manually weeded seedlings. It can be speculated that these seedlings achieved full growth potential. The application of triclopyr ester both alone and in mixture with glyphosate at rates ≤ 3 l/ha (Touchdown 480™ - 0.99 kg ae/ha; Vision™ - 1.1 kg ae/ha) resulted in higher volume increments/ha than the unweeded control or the glyphosate treatments alone (Figure 19). The application of Touchdown 480™ greatly reduced growth, likely because of reduced survival and needle lengths. As volume increment responses can not be accurately assessed one year after treatment, no meaningful conclusions can be drawn.

The application of triclopyr ester at rates ≥ 4 l/ha (1.92 kg ae/ha) was detrimental to seedling survival, physical condition, needle length and volume increment. These observations coincide with those made on other *Pinus* spp.. Saville (1989), who reported that release treatments for dormant radiata pine should not exceed 3.75 l/ha (1.8 kg ae/ha). Boyd *et al.* (1985) indicate that fall foliar applications of triclopyr ester caused severe damage to lodgepole pine at a rate of 3.5 l/ha (1.67 kg ae/ha). Willis *et al.* (1989) noted that jack pine was susceptible to injury from application of triclopyr ester at a rate of 3.1 l/ha (1.5 kg ae/ha). It was found that jack pine was more tolerant to glyphosate than to triclopyr ester.

Willis *et al.* (1989) explain that tolerance to triclopyr ester and glyphosate varies depending on the amount of epicuticular wax on the needles. As the needle matures after budbreak, the stoma become occluded with wax, while the surrounding needle surface becomes only sparsely coated with wax. The thin needle cuticle of jack pine may allow for the absorption of triclopyr and glyphosate

(Lehala *et al.* 1972). It has been determined that regardless of dormancy, triclopyr always induces some damage; while jack pine seedlings are more resistant to glyphosate (Willis *et al.* 1989). Inadequate information regarding Touchdown 480™ makes it difficult to compare its effects on vegetation and on seedlings to those of Vision™.

The label directives for Release™ explicitly indicate that the probability of injury to jack pine seedlings is greater when the application is made in the same year as planting (refer to Appendix A). The seedlings in this field study were planted in the spring of 1992 and the herbicide treatments were applied in late August of the same year. The label also indicates that needle damage to jack pine may be unacceptable with applications above 4 l/ha (1.92 kg ae/ha) (DowElanco, 1995). The label directives for Vision™ indicates that it too should only be applied to conifers which have been established for more than one year and that the target vegetation **should not be disturbed** prior to application (Monsanto, 1992).

The herbicide treatments should not have been made in the same year as planting. This likely would have alleviated many of the negative effects on seedling survival, physical condition and needle length. If the treatments were applied at least two seasons after planting, perhaps then some of them would not have been so detrimental to the seedlings and they likely would have been more effective in controlling the vegetative reproduction of non-crop species.

Summary of Recommended Herbicide Treatments for Jack Pine Release

Five herbicide treatments were chosen which resulted in the least damage to the crop and provided the most control of boreal non-crop vegetation one year after treatment. These herbicide treatments are recommended only for the release of jack pine seedlings *in the same year of planting*. Other post-planting treatments might prove suitable if applied after more than one year.

The herbicide treatments which reduced the total vegetation index to less than 35% of that observed in the unweeded control (Table 13), and which met the crop damage tolerance levels, were:

1) 3.0 l/ha (0.99 kg ae/ha) of Touchdown 480™
2) 6.0 l/ha (2.14 kg ae/ha) of Vision™
3) 3.0 l/ha (1.44 kg ae/ha) of Release™ mixed with 1.0 l/ha (0.33 kg ae/ha) of Touchdown 480TM
4) 3.0 l/ha (1.44 kg ae/ha) of Release™
5) 2.0 l/ha (0.96 kg ae/ha) of Release™ mixed with 2.0 l/ha (0.71 kg ae/ha) of Vision™

Touchdown 480™ is currently not registered for use in Canadian forest vegetation management. Release™ can not be used for the control of graminoids or bracken fern; two types of non-crop vegetation which often occur on boreal mixedwood sites similar to the one in this study. Subsequently, Vision™ applied alone or in mixture with Release™ remains the only two feasible herbicide treatment options for jack pine release activities, in the same year as planting.

In general, the herbicide mixtures tested offered no advantage over herbicides applied alone for jack pine plantation release because of the detrimental effects induced on the crop. The poor representation of Vision™ in the mixtures did not allow for a comprehensive evaluation of its potential.

CONCLUSIONS AND RECOMMENDATIONS

The objective of this field study was to provide additional baseline information about the use of triclopyr ester for jack pine plantation release. As with the first field trial, several weaknesses in the methodology make it difficult to directly apply the results obtained to operational settings. However, the observations and experiences gained from this study have lead to the following conclusions and recommendations that deserve further scientific study and operational testing.

- The results of this study apply to a mixedwood site in Northwestern Ontario. The site selected for the study was rich and very diverse in species composition.

- Jack pine crop tree survival, physical condition and needle length were greatly affected by the composition of the herbicide treatments. The application of triclopyr ester at rates ≥ 4 l/ha (1.92 kg ae/ha) was detrimental to seedling survival, physical condition, needle length and volume increment. The seedlings were very sensitive to the application of Touchdown 480™ at rates ≥ 4 l/ha (1.32 kg ae/ha).

- There was no significant seedling volume increment/ha response one year after the application of the twenty-three treatments. It is expected that there will be considerable change in the effects of the treatments over the next few years. The most important effect will likely be observed in seedling growth response.

- The manually weeded control (Control B) was an ideal treatment which resulted in: 1) excellent vegetation control, 2) 100% jack pine seedling survival, and 3) maximum volume increment/ha. The method of both stem and root removal of all non-crop vegetation coupled with a mixing of the soil would not be a feasible alternative for releasing established conifers in the boreal forest. It is speculated that vegetation control with this treatment would be very short term.

- The unweeded control (Control A) had: 1) the highest vegetation index, 2) poor survival after the first growing season, and 3) very low seedling volume increment/ha, relative to the manually weeded control and some of the herbicide treatments.

- The five recommended herbicide treatments which were found to be the most effective in reducing the total vegetation indices and which were the least detrimental to the jack pine crop trees were as follows:

  1) 3.0 l/ha (0.99 kg ae/ha) of Touchdown 480™
  2) 6.0 l/ha (2.14 kg ae/ha) of Vision™
  3) 3.0 l/ha (1.44 kg ae/ha) of Release™ mixed with 1.0 l/ha (0.33 kg ae/ha) of Touchdown 480™
  4) 3.0 l/ha (1.44 kg ae/ha) of Release™
  5) 2.0 l/ha (0.96 kg ae/ha) of Release™ mixed with 2.0 l/ha (0.71 kg ae/ha) of Vision™

- Because Release™ did not effectively control graminoids or bracken fern on this boreal forest site, and because Touchdown 480™ is not currently registered for use in forest vegetation management, herbicide treatments of Vision™ applied alone or in mixture with Release™ appear to be the only two available options, at this time, for similar site and vegetation conditions.

- Similar trials should be conducted on an operational scale to verify the results obtained. Such trials should be designed to evaluate mixtures of Release™ and Vision™ as they were not well represented in this study. In addition, the difficulties encountered in the methodology of this field study should be avoided so that results could be better applied to operational settings.

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APPENDIX A

DETAILED INFORMATION WITH RESPECT TO THE USE OF RELEASE™ (TRICLOPYR ESTER)

DowElanco

Release*

Silvicultural Herbicide

For the control of undesirable woody plants and annual and perennial broadleaved weeds in forest and woodland management sites.

COMMERCIAL

CAUTION **POISON**

READ THE LABEL BEFORE USING. KEEP OUT OF REACH OF CHILDREN.
POTENTIAL SKIN SENSITIZER.
GUARANTEE: triclopyr ....480 g acid equivalent/L
(present as butoxyethyl ester)
REGISTRATION NUMBER 22093
PEST CONTROL PRODUCTS ACT
Net Contents: 10 L & 110 L Returnable Container

OPERATOR USE PRECAUTIONS

HARMFUL IF SWALLOWED.
MAY CAUSE SKIN IRRITATION.
MAY BE HARMFUL IF ABSORBED THROUGH SKIN.
POTENTIAL SKIN SENSITIZER.

Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Avoid breathing vapour or spray mist. Where frequent inhalation of spray mist cannot be avoided, occupational exposure to pesticides can be reduced by use of an air purifying respirator equipped with organic vapor cartridges. Avoid contact with treated foliage and other contaminated surfaces while wet. When spraying, follow a "walk in, spray out" pattern to avoid contact with treated brush. Take precautions to avoid spray drift. Direct spray outward and away from self. Avoid overhead spraying. Select spray nozzle types and pressures to minimize drift potential.

Practice good personal hygiene. At all times when handling herbicide concentrate or applying the dilute mixture, plan events in such a way as to minimize personal exposure. Locate wash stations with an adequate supply of fresh water on work vehicles. Wash thoroughly with soap and water after handling and before eating or smoking. Bathe or take a hot shower after work using plenty of soap.

To minimize exposure when handling and applying Release Silvicultural Herbicide:

- Read and follow directions in the Protective Equipment Requirements and Operator Use Precautions sections on the label.
- Applicators should receive training on how to minimize personal exposure while applying high volume stem-foliage applied herbicides, including the "walk-in/spray-out" technique and on how to minimize contact with treated foliage.
- Applicators should be supervised to ensure that all label directions and proper application techniques are followed.

DowElanco Canada Inc. • 17705 Leslie Street
Newmarket, Ontario L3Y 3E3 (905) 836-0436

*Trademark of DowElanco
DowElanco Canada Inc. is a licensed user.

PHYSICAL OR CHEMICAL HAZARDS

COMBUSTIBLE. Do not use or store near heat or open flame.

ENVIRONMENTAL HAZARDS

This product is highly toxic to fish, aquatic plants and aquatic invertebrates and is not labelled for application to water surfaces. Keep out of lakes, ponds and streams. Do not contaminate water by cleaning of equipment or disposal of wastes.

FIRST AID

If swallowed: Do not induce vomiting. Call a physician or contact a poison control centre and/or transport to emergency facility immediately.
If in eyes: Irrigate immediately with flowing water for fifteen minutes.
If on skin: Wash off in flowing water or shower.
If inhaled: Remove to fresh air if effects occur. Consult a physician or a poison control centre.

TOXICOLOGICAL INFORMATION

The decision of whether to induce vomiting or not should be made by an attending physician. If lavage is performed, suggest endotracheal and/or esophageal control. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach. This product contains petroleum distillates. No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

For further information consult the MATERIAL SAFETY DATA SHEET.

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offense under THE PEST CONTROL PRODUCTS ACT to use a control product under unsafe conditions.

NOTICE TO BUYER: Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

Do not ship or store with food, feeds, drugs or clothing.

GENERAL USE PRECAUTIONS

Do not apply this product in a manner inconsistent with the label.

Do not apply Release Silvicultural Herbicide directly to, or otherwise permit it to come into direct contact with desirable crops or other desirable broadleaf plants or non-target species and do not permit spray mists containing Release Silvicultural Herbicide to drift onto them.

Sensitive terrestrial and aquatic habitat must be protected (refer to Ground Application and/or Aerial Application sections on buffer zone requirements and spray drift control recommendations).

AVOID SPRAY DRIFT: Apply only when there is little or no hazard from spray drift. Small quantities of the spray which may not be visible, may seriously injure susceptible plants and damage sensitive non-target habitat. A method must be used to detect air movement, lapse conditions, or temperature inversions (stable air) such as the use of a spotter plane, balloons or a continuous smoke column at or near the spray site or a smoke generator on the spray equipment. If the smoke develops into layers or indicates a potential for hazardous spray drift, DO NOT SPRAY.

GENERAL INFORMATION

Release Silvicultural Herbicide is recommended for the control of undesirable woody plants and annual and perennial broadleaved weeds in forest and woodland management sites. Applications may be made for woodland site preparation prior to natural or artificial regeneration of coniferous crop trees, for conifer release in plantations and established stands and for forest roadside vegetation control. Among the woody plants controlled are:

alder, red	maple, red
alder, speckled	maple, sugar***
ash, white	oak, red
aspen, trembling	poplar, balsam
birch, white**	raspberry
cherry, pin	salal****
maple, bigleaf***	willow

** White birch is best controlled through the use of any one of the foliar application methods.

*** Sugar maple and bigleaf maple are best controlled through the use of any one of the basal bark application methods.

**** For control of salal, refer to the Directions For Use - Broadcast Foliar section.

PROTECTIVE EQUIPMENT REQUIREMENTS

HANDLING CONCENTRATE: When handling concentrate, wear goggles or faceshield, chemically resistant gloves (nitrile or neoprene), clean coveralls over normal work clothes, impermeable head covering and chemical resistant boots (rubber) during all mixing/loading activities. Remove clothing contaminated with concentrate promptly and wash before re-use. Exercise care in removal of contaminated clothing to avoid secondary skin contact. Segregate contaminated articles and launder separately from other clothing using a double rinse. Leather articles such as boots, belts or watchbands should be destroyed if contaminated by concentrate.

APPLYING DILUTE SPRAY SOLUTION: When spraying dilute solution and during equipment maintenance and repair, wear clean coveralls over normal working clothes, impermeable head covering, chemical resistant gloves (nitrile or neoprene) and chemical resistant footwear such as rubber boots.

DIRECTIONS FOR USE: Ground Applications

WOODLAND MANAGEMENT SITES
(500 hectares or less)

Release Silvicultural Herbicide is not registered for application to water surfaces including lakes, ponds and streams and is highly toxic to fish, aquatic plants and aquatic invertebrates. Do not overspray such areas. In order to reduce the hazards to drift to non-target plants, aquatic species or sensitive habitat, ensure that appropriate buffer zones are maintained and refer to the section "Spray Drift Control".

Spray Drift Control: The potential for spray drift can be reduced by applying a coarse spray using large droplet producing nozzle tips; by the use of the Radiarc® or Nalco-Trol® or an equivalent drift control system or additive; by keeping the spray boom as low as possible; by using a spray pressure no greater than is required to obtain a proper spray pattern for adequate plant coverage; and by applying when the wind velocity is low. If a spray thickening agent is used, follow all use directions and precautions on the product label. When using a power sprayer and handgun, direct sprays no higher than the tops of the target plants.

BROADCAST FOLIAR APPLICATIONS

General Information and Mixing Instructions

Apply Release Silvicultural Herbicide mixed with water to make at least 100 litres per hectare of total delivery volume. In all cases, use equipment that will assure uniform coverage of the foliage of the plants to be controlled. An application system or additive should be used to prevent off-target spray particle drift. Nozzles or additives that produce larger droplets may require higher volumes of total delivery volume per hectare to obtain uniform coverage of the treated vegetation (See Directions for Use, Spray Drift Control).

Site Preparation

To control raspberry and woody species apply 3 to 8 L per hectare of Release Silvicultural Herbicide in at least 100 L of total delivery volume. Use of a rate in the upper end of the recommended range is suggested for control of basal sprouting and root suckering species and for tall, dense brush. Applications should be made following full leaf-out, but before autumn colouration. Conifer planting should be delayed until the following year.

Conifer Release

To release conifers, including white spruce, black spruce, and jack pine from raspberry and deciduous woody species, apply 3 to 6 L per hectare of Release Silvicultural Herbicide with water in at least 100 L of total delivery volume. Use of a rate in the upper end of the recommended range is suggested for control of basal sprouting and root suckering species and for tall, dense brush. Applications should be made in late summer, after conifers have hardened off (buds firm and sharp to the touch) and deciduous species are in full leaf, but prior to autumn colouration. Jack pine needle damage at rates greater than 4 L per hectare may be unacceptable. To minimize jack pine injury, applications should not be made while the jack pine trees are in the lammas or secondary growth stage. The probability of injury is greater when application is made in the same year as planting.

Salal Control

To provide control of salal, apply 8 L per hectare of Release Silvicultural Herbicide in an oil carrier (diesel, kerosene or mineral) and at least 100 litres of total delivery volume. Applications should be made to avoid spraying any desirable conifers.

LOW VOLUME FOLIAR APPLICATIONS

General Information and Mixing Instructions

For conifer release and site preparation, use this technique with knapsack or backpack sprayers equipped with flat fan or solid cone nozzles. For site preparation, power sprayers and handguns may also be used. Do not apply the product with mist blowers.

Site Preparation

Mix 1 to 5 L of Release Silvicultural Herbicide in enough water to make 100 L of spray solution. Use of a rate in the upper end of the recommended range is suggested for control of basal sprouting and root suckering species and for tall, dense brush. Direct the spray solution to thoroughly wet the foliage of the target plants but not to the point of runoff. Apply after full leaf-out, but before autumn colouration. Conifer planting should be delayed until the following year.

Conifer Release

Mix 1 to 5 L of Release Silvicultural Herbicide with water to make 100 L of spray solution. Use of a rate in the upper end of the recommended range is suggested for control of basal sprouting and root suckering species and for tall, dense brush. Direct the spray solution to thoroughly wet the foliage of the target plants but not to the point of runoff. Apply after full leaf-out, but before autumn colouration. Avoid spraying the conifers, especially if application occurs before hardening off (buds firm and sharp to the touch) or if they are in lammas growth stage (jack pine).

BASAL BARK APPLICATIONS

General Information and Mixing Instructions

For site preparation, regeneration release, or thinning, use Release Silvicultural Herbicide in oil mixtures prepared and applied as described below. Use a diluent such as diesel fuel, kerosene, or mineral oil. Add Release Silvicultural Herbicide to the required amount of oil in the mixing tank and mix thoroughly. When mixing with oils commercially formulated for basal bark herbicide applications, read and follow the use directions and precautions on the product label prepared by the oil's manufacturer.

Use the higher spray mixture concentration of Release Silvicultural Herbicide when treating basal sprouting and root suckering species or when applying during the dormant season. Use low nozzle pressure to minimize spattering of spray solution off the target stem.

Conventional Volume

To control woody plants with stems less than 15 cm in basal diameter, mix 1 to 5 L of Release Silvicultural Herbicide in enough oil to make 100 L of spray mixture. Apply with backpack or knapsack sprayer using a flat fan or solid cone nozzle. Spray the basal parts of each stem from a height of 50 cm down to the root collar. Thorough wetting of the indicated area is necessary for good control. Spray until runoff at the ground line is noticeable. Old or rough bark requires more spray than smooth young bark. Apply at any time, including the winter months, except when snow or water prevent spraying to the ground line.

One Sided Low Volume

To control woody plants with stems less than 15 cm in basal diameter, mix 20 to 30 L of Release Silvicultural Herbicide in enough oil to make 100 L of spray mixture. Apply with a backpack or knapsack sprayer using a flat fan or solid cone nozzle. Spray the basal parts of at least one side of each stem to thoroughly wet the lower 30 cm, including the root collar area, but not to the point of runoff. Apply at any time, including the winter months, except when snow or water prevent spraying to the ground line.

Thinline

To control woody plants with stems less than 15 cm in basal diameter, apply undiluted Release Silvicultural Herbicide in a thin stream to all sides of the lower parts of each stem. The stream should be directed horizontally to apply a narrow band of Release Silvicultural Herbicide around the entire circumference of each stem about 15 cm above the ground. From 2 to 15 mL of chemical will be required for treatment of single stems and from 25 to 100 mL to treat clumps of stems. A straight stream nozzle and an applicator metered or calibrated to deliver the small amounts of herbicide required should be used. Apply at any time, including the winter months, except when snow or water prevent spraying at the desired height above ground level.

Streamline

To control woody plants, mix 20 to 30 L of Release Silvicultural Herbicide in enough oil to make 100 litres of spray mixture. Apply with a backpack or knapsack sprayer using a flat fan or a solid cone nozzle. Apply sufficient spray to one side of stems less than 8 cm in basal diameter to form a band that is 5 cm in width. When the optimum amount of spray mixture is applied, the treated zone should widen to encircle the stem within approximately 30 minutes. Treat both sides of stems which are 8 to 12 cm in basal diameter. Direct the spray at a point on the stem that is approximately 30 to 50 cm above ground level. Optimal results are achieved when applications are made to young vigorously growing stems which have not developed the thicker bark characteristic of slower growing, understory trees in older stands. Apply at any time, including the winter months, except when snow or water prevent spraying at the desired height above ground level.

Cut Stump Treatment

To control resprouting of cut stumps of woody species, mix 20 to 30 L of Release Silvicultural Herbicide in enough oil to make 100 L of spray mixture. Apply with a backpack or knapsack sprayer using a flat fan or a solid cone nozzle. Thoroughly wet the outer portion of the cut surface adjacent to the cambium and the sides of the stumps, including the root collar area, but not to the point of runoff. Apply at any time, including the winter months, except when snow or water prevent spraying to the ground line. Care must be taken to ensure treatment of all cut stems within a clump.

RESTRICTED USE

AERIAL APPLICATION FOR FOREST MANAGEMENT AREAS (GREATER THAN 500 HECTARES) AND WOODLAND MANAGEMENT AREAS (500 HECTARES OR LESS): This includes site preparation prior to planting crop trees and release of crop trees following planting or in natural regeneration sites.

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offense under the PEST CONTROL PRODUCTS ACT to use a control product under unsafe conditions.

NATURE OF RESTRICTION: This product is to be used only in the manner authorized; consult provincial pesiticide regulatory authorities about use permits.

ENVIRONMENTAL HAZARDS

This product is highly toxic to fish, aquatic plants and aquatic invertebrates and is not labelled for application to water surfaces. Keep out of lakes, ponds and streams. Do not contaminate water by cleaning of equipment or disposal of wastes.

Aerial application must only be done on the basis of provincial use permit. Buffer zones will be specified to protect the sensitive areas as identified in the Environmental Hazards section of this label.

Among the species controlled are:

alder, red	maple, red
alder, speckled	maple sugar***
ash, white	oak, red
aspen, trembling	poplar, balsam
birch, white**	raspberry
cherry, pin	willow
maple, bigleaf***	

**White birch is best controlled through the use of any one of the foliar application methods.

***Sugar maple and bigleaf maple are best controlled through the use of any one of the basal bark application methods.

DIRECTIONS FOR USE: Aerial Application

Release Silvicultural herbicide may be applied by either fixed or rotary wing aircraft. Delivery systems suggested for use in applying Release Silvicultural Herbicide by air include: booms equipped with coarse droplet producing conventional disc and core nozzles (such as the D8-46 or D10-46), the Microfoil® boom or the Thru-Valve® boom. Ensure uniform and adequate coverage is achieved and that equipment has been accurately calibrated. Use higher application rates and volumes when plants are dense or under drought conditions.

Plantation or Natural Stand Release

To release crop trees such as black spruce and white spruce from raspberry and deciduous competition, apply 3.0 to 6.0 L of Release Silvicultural Herbicide with water in a minimum of 30 L of total spray solution per hectare. The higher rates are suggested for control of basal sprouting or root suckering species and for tall, dense brush.

Application should be made in late summer, after conifers have hardened off (buds firm and sharp to the touch); and when deciduous species are in full leaf prior to autumn colouration.

To release jack pine, use 3.0 to 4.0 L per hectare of Release Silvicultural Herbicide. Jack pine injury including needle damage, leader atrophy and scattered mortality may occur at application rates above 4.0 L per hectare or if seedlings are not completely dormant. Do not apply Release Silvicultural herbicide to release jack pine stands unless such injury can be tolerated. The potential for jack pine injury can be reduced by ensuring that trees are not in lammas or secondary growth stage. Healthy, vigorous jack pine seedlings in the ground for at least two years prior to application, are less likely to show symptoms of injury.

Site Preparation

Apply 3 to 8 L of Release Silvicultural Herbicide with water in a minimum of 30 L of total spray solution per hectare. The higher rates are suggested for control of basal sprouting or root suckering species, and for tall, dense brush. Applications should be made after full leaf out of target species, but prior to autumn colouration. Any coniferous silvicultural species may be planted in the season following treatment.

USE PRECAUTIONS

Release Silvicultural Herbicide is not registered for application to water surfaces including lakes, ponds and streams and is highly toxic to fish, aquatic plants and aquatic invertebrates. Do not overspray such areas. In order to reduce the hazard of drift to sensitive areas as identified in the Environment Hazards section of the label ensure that appropriate buffer zones are maintained and refer to the section "Spray Drift Control."

Use only closed mixing/loading systems for aerial application.

Spray Drift Control

Apply only when there is little or no hazard of spray drift since small quantities of product may injure susceptible crops and damage non-target habitat.

1. Do not apply Release Silvicultural Herbicide when wind velocity direction pose a risk of spray drift.
2. Aerial applications should be made as close to the ground as possible while maintaining adequate coverage.
3. For helicopter application use pressures at the lower end of the range recommended by the nozzle manufacturer. For fixed wing application use pressures at the higher end of the range recommended by the nozzle manufacturer.
4. Use a boom length less than 75% of the wing span or rotor length.
5. Coarse spray droplets are less prone to drift, therefore avoid spray dispersal systems and settings that produce a large proportion of fine droplets in the spray pattern. Delivery systems suggested for use in applying Release Silvicultural herbicide by air include: booms equipped with coarse droplet producing conventional disc and core nozzles (such as the D8-46 or D10-46), straight stream coreless nozzles (such as D6 or D8), and the Microfoil or Thru Valve boom. Conventional disc and core nozzles should be oriented straight back or at an angle of less than 30° down.
6. Do not apply by air when an air temperature inversion exists. Such condition is characterized by little or no wind and an air temperature near the ground that is lower than at higher levels. A method must be used to detect air movement, lapse conditions, or temperature inversions, such as the use of balloons, a spotter plane or a continuous smoke column at or near the site.

STORAGE

Do not contaminate water, food or feed by storage or disposal. Store above -2°C, or agitate container before use.

DISPOSAL

NON-RETURNABLE CONTAINERS

1. Rinse the emptied container thoroughly and add the rinsings to the spray mixture in the tank.
2. Follow provincial instructions for any required additional cleaning of the container prior to its disposal.
3. Make the empty container unsuitable for further use.
4. Dispose of the container in accordance with provincial requirements.
5. For information on the disposal of unused, unwanted product and the cleanup of spills contact the regional office of Environmental Protection, Environment Canada.

RETURNABLE CONTAINERS

1. Empty container thoroughly. Do not attempt to rinse or open the container.
2. Follow Manufacturer's instructions for any required additional cleaning of the container prior to its return.
3. Do not destroy container.
4. Make the empty container suitable for pick-up and return according to Manufacturer's instructions.
5. For information on the disposal of unused, unwanted product and the cleanup of spills, contact the regional office of Environmental Protection, Environment Canada.

Radiarc® and Thru-Valve® are trademarks of Waldrum Specialties Inc.
Nalco-Trol® is a trademark of Alchem Inc.
Microfoil® is a trademark of Union Carbide Corp.

APPENDIX B

DETAILED INFORMATION WITH RESPECT TO THE USE OF VISION™ (GLYPHOSATE)

VISION

SILVICULTURAL HERBICIDE by Monsanto

COMMERCIAL

CAUTION IRRITANT

Water soluble herbicide for silvicultural sites

REGISTRATION NO. 19899 PEST CONTROL PRODUCTS ACT

GUARANTEE: Glyphosate 356 g/L present as isopropylamine salt

READ THE LABEL BEFORE USING.

1992 897 10-004 23

(FRANÇAIS AU VERSO)

AVOID CONTACT WITH FOLIAGE, GREEN STEMS, OR FRUIT OF NON-TARGET CROPS, DESIRABLE PLANTS AND TREES, SINCE DAMAGE TO THESE PLANTS MAY RESULT.

PRECAUTION!
Keep out of reach of children.
MAY CAUSE EYE IRRITATION.
HARMFUL IF SWALLOWED.
Avoid contact with eyes or prolonged contact with skin.

FIRST AID: If in eyes, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician. If on skin, immediately flush with plenty of water. Remove contaminated clothing. Wash clothing before re-use. If swallowed, this product will cause gastro-intestinal irritation. Immediately dilute by swallowing water or milk. Call a physician.

Read NOTICE before buying or using. If notice terms are not acceptable, return at once unopened.

Canadian Patent 936,865
Not for reformulation or repackaging

MONSANTO CANADA, INC.
Streetsville, P.O. Box 787
Mississauga, Ontario L5M 2G4
St. John • Montreal • Thunder Bay • Winnipeg • Vancouver

IN CASE OF EMERGENCY INVOLVING THIS PRODUCT, Call Monsanto Collect, day or night:

Accidents/Spills	(514) 366-5588
Medical Emergency	(314) 694-4000
or CANUTEC	(613) 996-6666

GENERAL INFORMATION

When applied as directed under conditions described, this product controls undesirable vegetation listed on this label. This product also suppresses or controls undesirable vegetation listed on this label, when applied at recommended rates for release of established coniferous or deciduous species listed in the "Conifer Release" and "Deciduous Release" sections of this label.

This product may be applied using aerial or ground spray equipment for silvicultural site preparation, rights-of-way, and conifer release, and ground spray equipment for forest road-side vegetation management, deciduous species release, and forest tree planting nurseries. Woody vegetation may be controlled by injection or frill application of this product. See the "Mixing" and "Application Instructions" sections of this label for information on how to properly apply this product.

For herbaceous weeds, woody brush, and trees controlled, see the "Vegetation Controlled" section of this label.

For specific site preparation instructions, see the "Site Preparation, Forest Roadside and Rights-of-Way Vegetation Management" sections of the label.

For specific conifer or deciduous release instructions see the "Conifer Release" or "Deciduous Release" sections of this label.

Treatments should not be made to trees or brush after fall leaf drop has begun.

For specific forest tree planting nursery instructions, see the "Forest Tree Planting Nurseries" section of this label.

For specific injection and frill application instructions, see the "Injection and Frill Applications" section of this label.

This product moves through the plant from the point of foliage contact to and into the root system. Visible effects on most annual weeds occur within 2 to 4 days, but on most susceptible perennial weeds, trees and woody brush, may not occur until 7 to 14 days. Extremely cool or cloudy weather at treatment time may slow down activity of this product and delay visual effects or control. Visible effects are a gradual wilting and yellowing of the plant which advance to complete browning of above-ground growth and deterioration of underground plant parts.

Delay application until vegetation has emerged to the stages described for control of such vegetation under the "Vegetation Controlled" section of this label to provide adequate leaf surface to receive the spray. Unemerged plants arising from underground rhizomes or root stocks of perennials will not be affected by the spray and will continue to grow. For this reason best control of most perennial herbaceous vegetation is obtained when treatment is made at late growth stages approaching maturity. Always use the higher rate of this product per hectare within the recommended range on hard to control species or when vegetation growth is heavy or dense.

Do not treat vegetation under poor growing conditions such as drought stress, disease or insect damage as reduced vegetation control may result. Reduced results may also occur when treating vegetation heavily covered with dust.

Rainfall occurring within 6 hours after application may reduce effectiveness. Heavy rainfall within 2 hours after application may wash the product off the foliage and a repeat treatment may be required.

Do not mix with any surfactant, pesticide, herbicide oils or any other material other than water unless specified in this label.

For best results spray coverage should be uniform and complete. Do not spray weed foliage to the point of runoff.

ATTENTION

AVOID DRIFT. EXTREME CARE MUST BE USED WHEN APPLYING THIS PRODUCT TO PREVENT INJURING DESIRABLE PLANTS AND CROPS. Do not allow spray mist to drift, since even minute quantities of spray can cause severe damage or destruction to nearby crops, plants or other areas on which treatment is not intended, or may cause other unintended consequences. Do not apply when winds are gusty or in excess of 8 km/h or when other conditions, including lesser wind velocities, will allow drift to occur. When spraying, avoid combinations of pressure and nozzle type that will result in fine particles (mist) which are more likely to drift.

NOTE: Use of this product in any manner not consistent with this label may result in injury to persons, animals or crops, or other unintended consequences. Keep container closed to prevent spills and contamination.

Clean sprayer parts immediately after using this product by thoroughly flushing with water. Do not contaminate water sources by disposal of wastes or cleaning of equipment.

MIXING INSTRUCTIONS

This product mixes readily with water.

For ground, aerial or industrial type sprayers, fill the spray tank with one half the required amount of water. Add the proper amount of herbicide (see "Application Instructions" section of the label) and mix well before adding the remaining portion of water. Placing the filling hose below the surface of the liquid solution will prevent excessive foaming. Removing hose from tank immediately will avoid back siphoning into water source. Use of mechanical agitators may cause excessive foaming. By-pass lines should terminate at the bottom of the tank.For use in knapsack sprayers, it is suggested that the proper amount of this herbicide be mixed with water in a larger container. Fill sprayer with the mixed solution.

NOTE: REDUCED RESULTS MAY OCCUR IF WATER CONTAINING SOIL IS USED, SUCH AS WATER FROM PONDS AND UNLINED DITCHES.

APPLICATION INSTRUCTIONS

APPLY THESE SPRAY SOLUTIONS IN PROPERLY MAINTAINED AND CALIBRATED EQUIPMENT CAPABLE OF DELIVERING DESIRED VOLUMES. HAND GUN APPLICATIONS SHOULD BE PROPERLY DIRECTED TO AVOID SPRAYING DESIRABLE PLANTS.

AVOID DRIFT—Drift may cause damage to any vegetation contacted for which treatment is not intended. Applications in wind conditions in excess of 8 km/h are not recommended.

To prevent injury to adjacent vegetation appropriate buffer zones must be maintained.

Do not apply directly to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

APPLICATION RATES

To control or suppress most herbaceous weeds, woody brush and trees, apply 3 to 6 litres of this product per hectare using aerial, ground boom or boomless, or mist blower equipment, or apply as a 1 to 2% solution using hand-held high volume equipment. Apply as directed in the recommended volume of clean water to foliage of actively growing vegetation. Use the 6 L/ha rate for Maple, Alder and Rubus species, as well as for hard to control perennial weed species.

AERIAL EQUIPMENT

Use the recommended rates of this herbicide in 30 to 100 L of water per hectare. As density of vegetation increases, spray volume should be increased within the recommended range to ensure complete coverage. Coarse sprays are less likely to drift, therefore do not use nozzles or nozzle configurations which dispense spray as fine spray droplets. Do not angle nozzles forward into the airstream and do not increase spray volume by increasing nozzle pressure.

Ensure uniform application—To avoid streaked, uneven or overlapped application, use appropriate marking devices. The use of a spotter plane is recommended.

Thoroughly wash aircraft, especially landing gear, after each day of spraying to remove residues of this product accumulated during spraying or from spills. PROLONGED EXPOSURE OF THIS PRODUCT TO UNCOATED STEEL SURFACES MAY RESULT IN CORROSION AND POSSIBLE FAILURE OF THE PART. LANDING GEAR ARE MOST SUSCEPTIBLE. The maintenance of an organic coating (paint) which meets aerospace specification MIL-C-38412 may prevent corrosion.

BOOM EQUIPMENT

For control of herbaceous weeds and woody brush and trees listed in the "Vegetation Controlled" section of this label using conventional boom equipment—Apply this product in 100 to 300 L of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

BOOMLESS EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label using boomless equipment such as cluster nozzles—Apply this product in at least 300 L of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

HAND HELD AND HIGH VOLUME EQUIPMENT

(use coarse sprays only)

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label using knapsack sprayers or high volume spraying equipment utilizing handguns or other suitable nozzle arrangements.—Applications should be made on a spray-to-wet basis. Spray coverage should be uniform and complete. Do not spray to point of runoff.

MIST BLOWER EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label—Use the recommended rate of this product in at least 200 L of water per hectare.

VEGETATION CONTROLLED

A PARTIAL LIST OF WOODY BRUSH AND TREE SPECIES CONTROLLED INCLUDES:

Birch Betula spp.	**Raspberry/Salmonberry** Rubus spp.
Cherry Prunus spp.	**Snowberry (Western)** Symphoricarpos occidentalis
Maple Acer spp.	**Willow** Salix spp.
Poplar Populus spp.	**Alder** Alnus spp.

See "Mixing", "Application Instructions" and "Forest-" or "Woodland-Management" sections of this label for additional information.

For perennial broadleaf weeds, apply when most weeds have reached early head or early bud stage of growth. For annual and perennial grasses, apply when most weeds are at least 20 cm in height (the 3-4 leaf stage of growth).

If herbaceous weeds have been mowed, tilled, or scarified, do not treat until regrowth has reached the recommended stages, as reduced effectiveness will result. Most herbaceous weeds can be treated after a mild frost, provided the leaves are still green and actively growing at the time of application. Do not apply after the first damaging frost. Allow 7 or more days after application before tillage or other soil disturbance. Repeat treatments may be necessary to control weeds regenerating from underground parts or seed.

DIRECTIONS FOR USE

Spray coverage should be uniform and complete. Do not spray to the point of runoff.

Do not allow spray drift to contact non-target desirable vegetation as severe damage may occur.

RESTRICTED USES

FOREST and WOODLANDS MANAGEMENT

Ground/Aerial Application for Sites greater than 500 ha (Forestry Use)

Aerial Application for Sites 500 ha or less (Woodlands Use)

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offense under the Pest Control Products Act to use a control product under unsafe conditions.

NATURE OF RESTRICTION: This product is to be used only in the manner authorized; consult local pesticide authorities about use permits which may be required.

Do not apply to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

In order to reduce the drift hazard to non-target plants and aquatic species when aerially treating silvicultural sites, ensure that appropriate buffer zones are maintained.

SITE PREPARATION

Use this product as broadcast treatment at recommended rates, as listed in the "Application Rates" section, to control herbaceous weeds, woody brush and tree species listed in the "Vegetation Controlled" section. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colors on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

CONIFER RELEASE

Use this product as a broadcast spray at recommended rates, as listed in the "Application Rates" section, to control herbaceous weeds, woody brush and tree species, as listed in "Vegetation Controlled" section of this label, to release from competition the coniferous species listed below:

Douglas Fir Pseudotsuga spp.	**Pine** Pinus spp.
Fir Abies, spp.	**Spruce** Picea spp.
Hemlock Tsuga, spp.	

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds, and 3 to 4 weeks prior to deciduous species leaf senescence. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colors are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE: This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries, or in year of anticipated harvest in Christmas tree plantations.

WOODLAND MANAGEMENT
Treatment of 500 ha or less

SITE PREPARATION (Ground Only), FOREST ROADSIDE (Ground Only) and RIGHTS-OF-WAY VEGETATION MANAGEMENT (Ground or Aerial)

Use this product as broadcast treatment at recommended rates to control herbaceous weeds, woody brush and tree species listed in the "Vegetation Controlled" section. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colors on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

CONIFER RELEASE (Ground Only)

Use this product as a broadcast spray at recommended rates, as listed in the "Application Rates" section, to control herbaceous weeds, woody brush and tree species, as listed in "Vegetation Controlled" section of this label, to release from competition the coniferous species listed below:

Douglas Fir Pseudotsuga spp.
Pine Pinus spp.
Fir Abies spp.
Spruce Picea spp.
Hemlock Tsuga spp.

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds, and 3 to 4 weeks prior to deciduous species leaf senescence. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colors are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE: This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries, or in year of anticipated harvest in Christmas tree plantations.

DECIDUOUS RELEASE (Ground Only)

Use this product to control herbaceous weeds and woody brush mentioned in the "Vegetation Controlled" section of the label.

Apply when the undesirable species are actively growing, and the foliage is well developed. This product has no pre-emergent activity. Repeat treatments may be required for species which regenerate from underground stems or from seeds. Applications may be made to undesirable deciduous species with some autumn colours, provided that major leaf fall has not yet occurred.

Use a directed spray to thoroughly cover the foliage of the undesirable vegetation. Take all necessary precautions to prevent contact of the spray, spray mist or spray drift with the foliage or green bark of desirable species.

A partial list of species for use with this product on regenerated sites includes: ASH (Fraxinus spp.); WALNUT (Juglans spp); LINDEN or BASSWOOD (Tilia spp); CHERRY (Prunus spp.); OAK (Quercus spp); ELM (Ulmus spp) and POPLAR (Populus spp). Product may be applied immediately after transplanting.

For use rates and application instructions, refer to the "Application Rates" and "Application Instructions" section of this label.

INJECTION AND FRILL APPLICATIONS

Woody vegetation may be controlled by injection or frill application of this product. Apply this product using suitable equipment which must penetrate into living tissue. Use this product without dilution and apply at least 1 mL for each 10 cm of trunk diameter breast height (DBH). Space applications evenly around the circumference of the trunk. Application should be made during periods of active growth and full leaf expansion. Control of tree species with tree diameters greater than 20 cm may not be acceptable. A partial list of tree species controlled includes DOUGLAS FIR (Pseudotsuga spp), HEMLOCK (Tsuga spp), CEDAR (Thuja spp), MAPLE (Acer spp), ALDER (Alnus spp), CHERRY (Prunus spp), WILLOW (Salix spp) and BIRCH (Betula spp). Total control may not be evident until one year after treatment.

FOREST TREE PLANTING NURSERIES (Ground Only)

This product may be used to control most annual and perennial weeds for site preparation prior to establishing plantations, or as a post directed spray in established plantations. Application may be made to established deciduous plantings of ASH, Fraxinus spp.; CARAGANA, Caragan spp.; CHERRY, Prunus spp.; ELM, Ulmus spp.; LILAC, Syringa spp.; MAPLE, Acers spp.; MOUNTAIN ASH, Sorbus spp.; POPLAR, Poplulus spp.; RUSSIAN OLIVE, Elaeagnus spp., and WILLOW, Salix spp. Applications may be made prior to or in established conifer plantings of FIR, Abies spp.; JUNIPER, Juniperus spp.; PINE, Pinus spp.; SPRUCE, Picea spp.; and YEW, Taxus spp.. SPRAY MAY CONTACT MATURE BARK ONLY. AVOID SPRAY CONTACT WITH FOLIAGE OR GREEN BARK OF ESTABLISHED PLANTINGS IN POST DIRECTED APPLICATIONS.

For specific rates and applications instructions, see "Application Instructions" section of this booklet. DO NOT APPLY UNDER WIND OR OTHER CONDITIONS WHICH ALLOW DRIFT TO OCCUR. If weeds have been mowed or tilled do not treat until regrowth has reached the recommended stages.

This product does not provide pre-emergence weed control. Repeat treatments may be necessary to control weeds generating from underground parts or seed.

NOTE: This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries, or in year of anticipated harvest, in Christmas tree plantations.

PHYSICAL OR CHEMICAL HAZARDS

Spray solutions of this product should be mixed, stored and applied only in stainless steel, aluminum, fiberglass, plastic and plastic-lined steel containers. DO NOT MIX, STORE OR APPLY THIS PRODUCT OR SPRAY SOLUTIONS OF THIS PRODUCT IN GALVANIZED STEEL OR UNLINED STEEL (EXCEPT STAINLESS STEEL) CONTAINERS OR SPRAY TANKS. This product or spray solutions of this product react with such containers and tanks to produce hydrogen gas which may form a highly combustible gas mixture. This gas mixture could flash or explode, causing serious personal injury, if ignited by open flame, spark, welder's torch, lighted cigarette or other ignition source.

STORAGE

Store product in original container only, away from other pesticides, fertilizer, food or feed. Avoid contamination of seed, feed and foodstuffs.

SPILLS

Soak up small amounts with absorbent clays.

Sweep or scoop up spilled materials and dispose of in an approved landfill.

Wash down surfaces (floors, truckbeds, streets, etc.) with detergent and water solution.

Avoid direct applications to any body of water.

Do not contaminate water by disposal of waste or cleaning of equipment.

DISPOSAL

RETURNABLE CONTAINERS:
DO NOT RE-USE. Return emptied container with seals intact to the supplier or Monsanto.

DISPOSABLE CONTAINERS:
Rinse the emptied container thoroughly and add the rinsings to the spray mixture in the tank. Follow provincial instructions for any required additional cleaning of the container prior to its disposal. Make empty container unsuitable for further use. Dispose of container in accordance with provincial requirements.

For more information on the disposal of unused, unwanted product and the cleanup of spills, contact the regional office of Conservation and Protection, Environment Canada.

NOTICE

Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer, assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offense under the Pest Control Products Act to use a control product under unsafe conditions.

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APPENDIX C

DETAILED REFERENCE INFORMATION WITH RESPECT TO EXPERIMENTAL TOUCHDOWN 480™ (GLYPHOSATE)

The following information was adapted from Zeneca Agro R&D (1989).

TOUCHDOWN is an experimental non-selective post-emergent, translocated herbicide that controls a broad range of annual and perennial grass and broadleaf weeds, and certain woody perennials.

TOUCHDOWN is the trimethylsulphonium salt of glyphosate. It is a discovery of ICI Agrochemicals and being developed in Canada by Chipman.

TOUCHDOWN is a trademark of Imperial Chemical Industries PLC, England.

Issued 02/89

1. CHEMICAL AND PHYSICAL PROPERTIES

Code Number: ICIA 0224 (formerly SC0224, TF1242)
Common Name: glyphosate TMS
Chemical Name: N-phosphonomethylglycine trimethyl-sulphonium salt

1.1 TECHNICAL MATERIAL

Concentrate: Aqueous concentrate of 52.2% by weight
Appearance: Clear, straw to brown coloured liquid, free from visible extraneous material.
Density: 1.23 - 1.25 g/ml at 20 °C
Flashpoint: > 105 °C (setaflash cc)
Cold Stability: < -28 °C
pH: 3.8 -5.0 (1 g/20 ml water)

1.2 FORMULATION

Solution Concentration: a. salt 480 g/l
b. acid equivalent 330 g/l

Transport Hazards: a. ground Not Restricted
b. air Not Restricted

2. TOXICOLOGY (TECHNICAL MATERIAL)

Glyphosate TMS has low oral and dermal toxicity to mammals. The data indicates that there should be very little hazard from the recommended use of the product.

2.1 ACUTE TOXICITY

2.1.1 Oral LD_{50}

The acute oral LD_{50} in male and female rats are 748 and 755 mg/kg respectively. In male and female mice, it is 1383 and 1250 mg/kg respectively.
When formulated as TF1242 the acute oral LD_{50} in male and female rats are 1760 and 1298 mg/kg, respectively.

2.1.2. Dermal LD_{50}

The acute dermal LD_{50} in rabbit is 2000 mg/kg and greater than 2000 mg/kg of the TF1242 formulation.

2.1.3. Skin and Eye Irritation

Glyphosate TMS is a mild skin and eye irritant. The TF1242 formulation is non-irritant.

2.1.4. Inhalation

The inhalation LC_{50} in rats is greater than 0.81 mg/l. Glyphosate TMS and its formulations pose no inhalation hazard.

3. ENVIRONMENTAL PROFILE

3.1 Birds

Glyphosate TMS does not represent a dietary hazard to birds. The agricultural uses of glyphosate TMS normally results in zero or negligible residues in food consumed by birds.

3.2 Bees

Glyphosate TMS represents no hazard to honeybees. In toxicity tests, 62 micrograms/bee was applied to groups of honeybees which were observed for 96 hours. No mortality occurred.

3.3 Fish and Aquatic Invertebrates

Although the extremely low toxicity to fish of glyphosate TMS is increased when formulated, it does not increase to a level where it becomes hazardous to fish as a result of normal use.

Studies are incomplete against aquatic invertebrates, but data so far indicates that formulated material is less toxic than active ingredient.

3.4 Fate in Soil

Glyphosate TMS is rapidly and ultimately degraded to carbon dioxide and mineral compounds within days or at most a few weeks of application to soil. There is no risk of leaching or ground water contamination.

3.5 Residues in Crops

No residues were found in crops following the majority of use patterns (pre-crop sowing, pre-emergence and directed spray). Slight accidental contamination of growing crops by drift from directed spray may occur but residues in harvested crops are negligible. When used in cereals as a pre-harvest application, measurable residues may be found but these are of no toxicological significance since the majority of the residues are destroyed or removed during the processing of the cereals.

4. BIOLOGICAL ACTIVITY

Glyphosate TMS is absorbed into plants via leaves and stems. Uptake is thought to occur by diffusion and can be enhanced by favourable environmental conditions such as high relative humidity. It is possible that light mist will re-wet glyphosate TMS deposits on leaf surfaces and give secondary uptake. Uptake via roots and woody stems is minimal, although spray additives have been shown to assist uptake through "difficult" woody and waxy stems.

Inside the plant, glyphosate TMS is readily transported with the phloem and xylem. Movement can be very rapid and is typically toward the most actively growing parts of the plant. Accumulation at actively dividing meristems result in symptoms being seen here first, followed by a gradual die-back of more mature parts of the plant. If applied when root systems are actively growing, glyphosate TMS will accumulate at these sites and give excellent control of regrowth.

The primary mode of action of glyphosate TMS is inhibition of production of aromatic amino acids, preventing protein synthesis. Although this is the primary explanation for herbicidal effects, other processes are involved which include inhibition of photosynthesis, and reduction in level of IAA produced.

5. APPLICATION

5.1 Weather Conditions

Optimum effect will be achieved when soil and air moisture are high. Plants suffering drought stress may not be controlled effectively. Glyphosate TMS is only slowly absorbed into the plant, thus rain falling shortly after spraying will reduce amount taken up. Ideally a rain free period of 6 hours is required to maximize herbicidal effect.

5.2 Timing

Best results are obtained when weeds are actively growing. Species differ in their susceptibility according to growth stage, but generally, good control will result when plants are established with sufficient target foliage to receive spray. Broadleaf weeds are often the least susceptible. Optimum timing for control is at or near flowering. Effective long term control of perennial species is most likely to occur when applications are made to undisturbed planted during the growth of new rhizomes/roots.

5.3 Trial Uses

When trials compare TOUCHDOWN and ROUNDUP, they should do so as salts, not as acid equivalents. Trials to date indicate that TOUCHDOWN performance is equal to or better than ROUNDUP in comparative tests.

Rates of 1 to 2 kg ai/ha provides control of annual grasses and broadleaf weeds and 1 year's control (suppression) of perennial weeds such as Quack grass. For perennial grass and broadleaf weed control, 2 to 3 kg ai/ha is required.

Spray volumes of 150 to 300 L/ha have proven effective. More work is needed on the interaction of spray volumes and selected adjuvant systems such as FRIGATE and ammonium sulphate.

6. HANDLING PRECAUTIONS

When handling the concentrate, wear protective gloves and eye protection. Wash splashes from skin or eyes immediately.

When spraying, avoid working in spray mist. After spraying, wash clothing.

When using, do not eat, drink or smoke. Wash hands and exposed skin before meals and after work.

Keep out reach of children. Keep away from food, drink and animal food. Do not contaminate ponds, waterways or ditches with the chemical.

Store in original container, tightly closed, in a safe place. Wash out container thoroughly, empty washings into spray tank and dispose of safely.

7. FIRST AID

If swallowed, DO NOT INDUCE VOMITING. If on skin, wash thoroughly. If in eyes, flush out thoroughly with clean water for at least 15 minutes. For all cases, seek medical attention immediately. Treat symptomatically.

APPENDIX D

THE LOCATION OF FIELD STUDY #1

LOCATION OF FIELD STUDY #1

Figure D-1 illustrates the general location of the field study #1 in relation to Thunder Bay, Ontario.

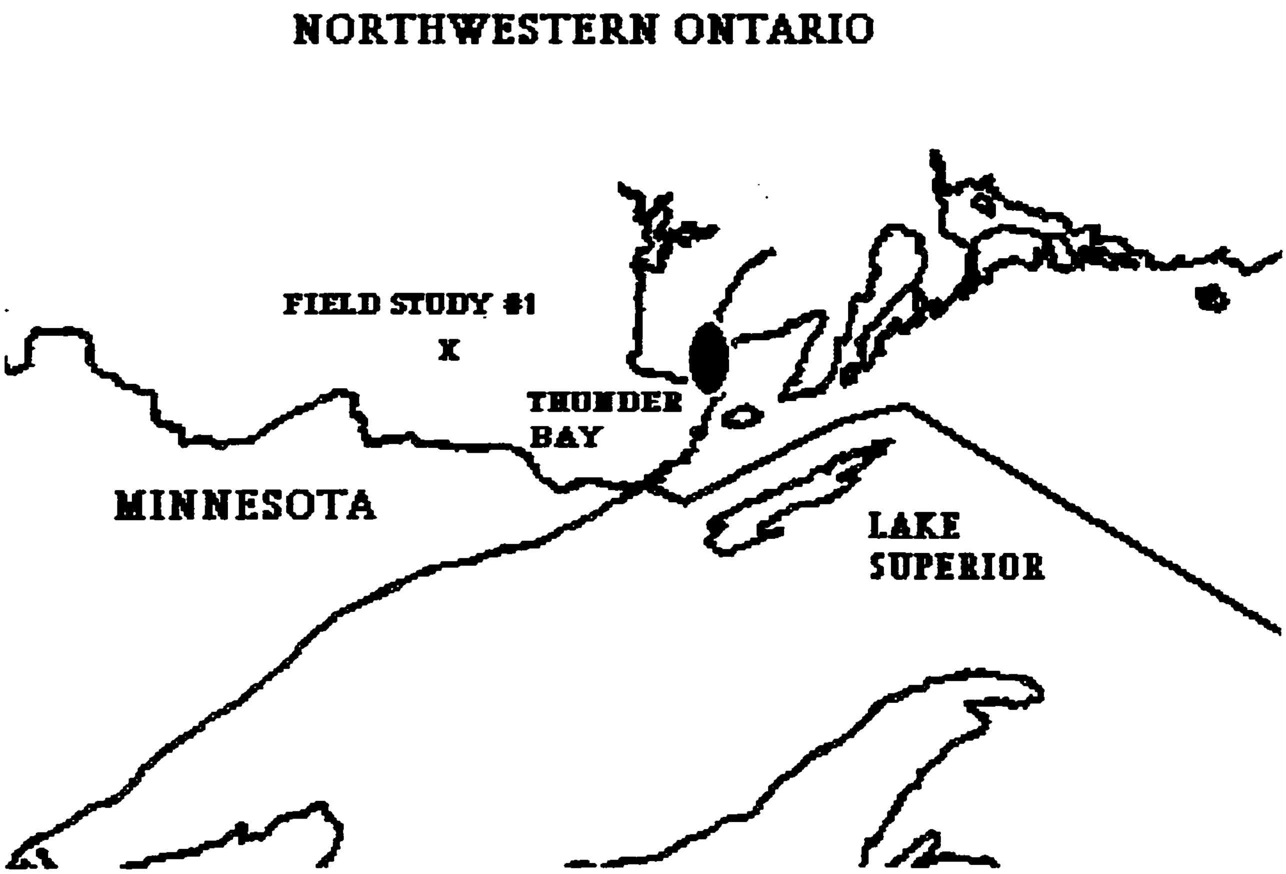

Figure D-1. The general location of field study #1 in relation to Thunder Bay, Ontario.

Figure D-2 presents a more detailed map of the location of field study #1. The site is located to the west of Kakabeka Falls, Ontario. Kakabeka Falls is located approximately 30 km west of Thunder Bay on Highway 11/17. To access the study area, one must travel west on Highway 590 for approximately 10 km to the Boreal Timber Road and west on this road for 20 km. The plots were established in a cutover adjacent to the Ontario Ministry of Natural Resources 'Mattawin Seed Orchard'; east of the Mattawin River.

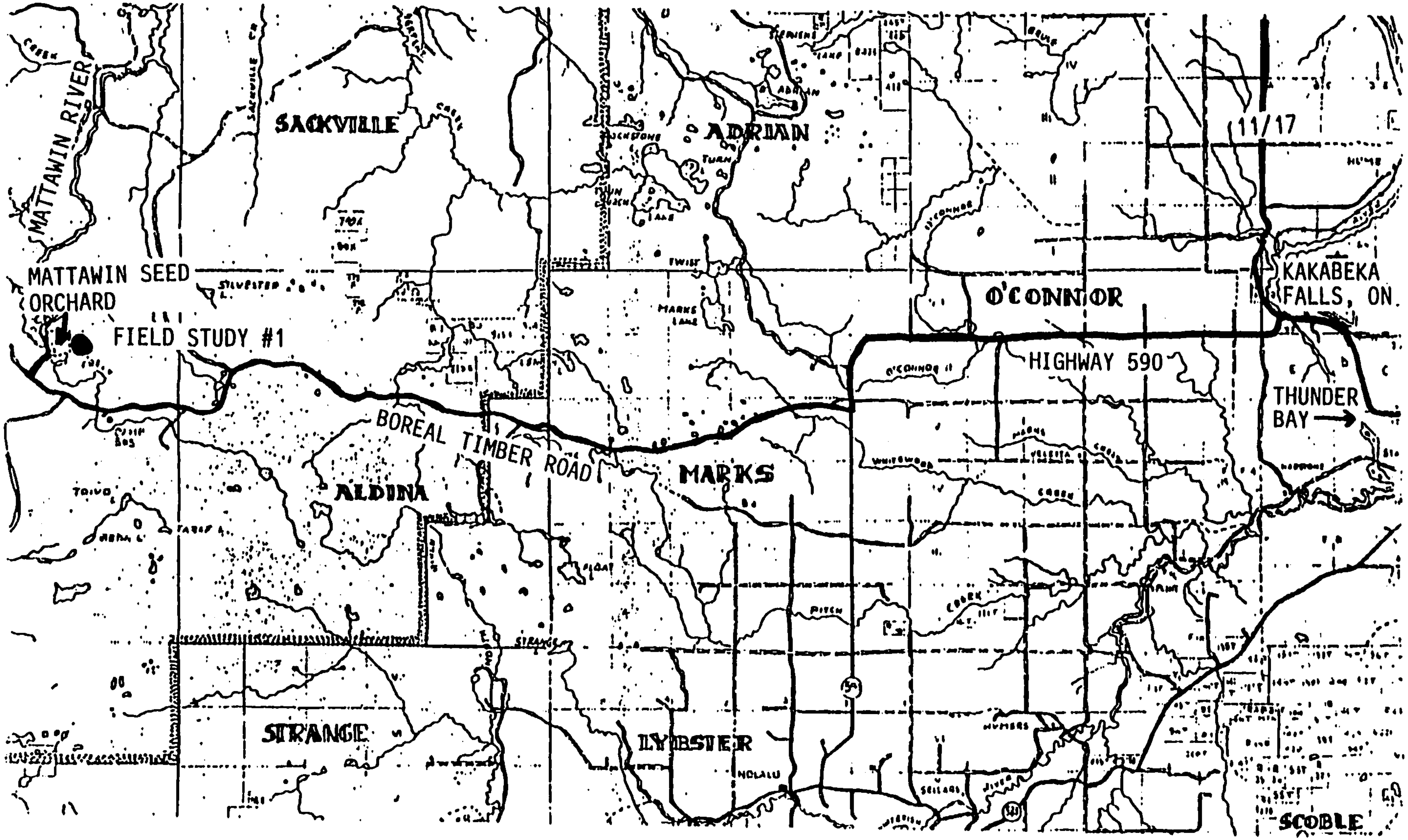

Figure D-2. A detailed map of the location of field study #1.

NOT TO SCALE

APPENDIX E

FIELD STUDY #1: RESULTS OF THE ANALYSIS OF VARIANCE

Table E-1 presents a summary of the probabilities of obtaining a larger F-ratio for herbicide treatment effects, planting time treatment effects and interaction effects, which resulted from the ANOVA, for each mean seedling response variable.

Table E-1. A summary of the probabilities of obtaining a larger F-ratio for herbicide effects, planting time effects and interaction effects for each mean seedling response variable. An asterisk (*) denotes significant and '**' denotes highly significant effects, at p = 0.05.

SOURCE OF VARIATION	DF	TRANSFORMED SURVIVAL	PHYSICAL CONDITION	NEEDLE LENGTH	VOLUME INCREMENT
Block (B)	2	--	--	--	--
Herbicide (H)	1	0.000 **	0.005 **	0.990	0.018 *
Time (T)	4	0.000 **	0.000 **	0.016 *	0.000 **
BxH	2	0.010 **	0.015 *	0.071	0.132
BxT	8	0.003 **	0.006 **	0.488	0.050 *
HxT	4	0.006 **	0.001 **	0.206	0.112
BxHxT (Error)	8	--	--	--	--

APPENDIX F

THE LOCATION OF FIELD STUDY #2

LOCATION OF FIELD STUDY #2

Figure F-1 illustrates the general location of the field study #2 in relation to Thunder Bay, Ontario.

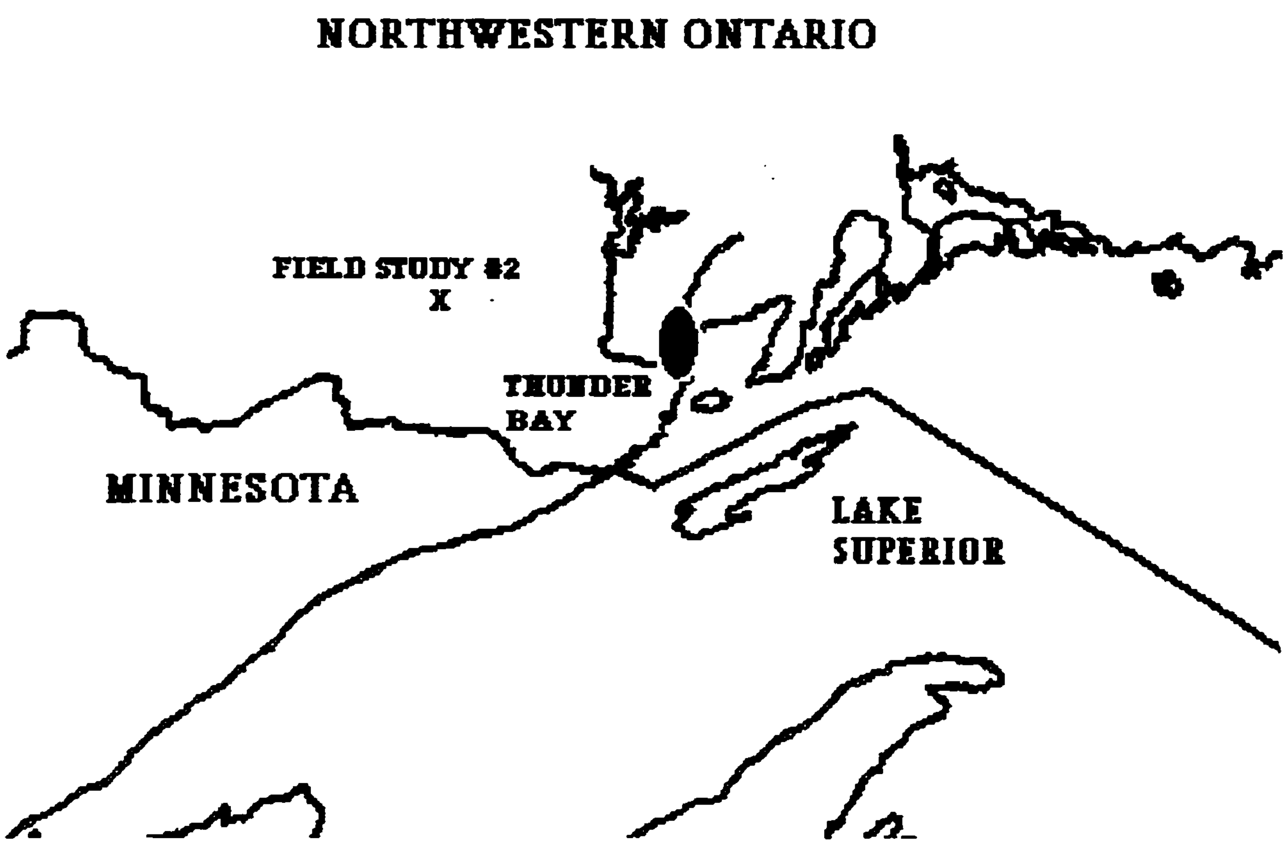

Figure F-1. The general location of field study #2 in relation to Thunder Bay, Ontario.

Figure F-2 presents a more detailed map of the location of field study #2. The site is located to the west of Kakabeka Falls, Ontario. Kakabeka Falls is located approximately 30 km west of Thunder Bay on Highway 11/17. To access the study area, one must travel west on Highway 590 for approximately 9.5 km to the Adrian Lake Road (just north of the Boreal Timber Road) and then northwest on this road for 9 km to the Adrian Extension Road (at Adrian Lake). The plots were established in a cutover approximately 1 km up the Adrian Extension Road, on the right hand side (see Figure F-3) for detailed road map.

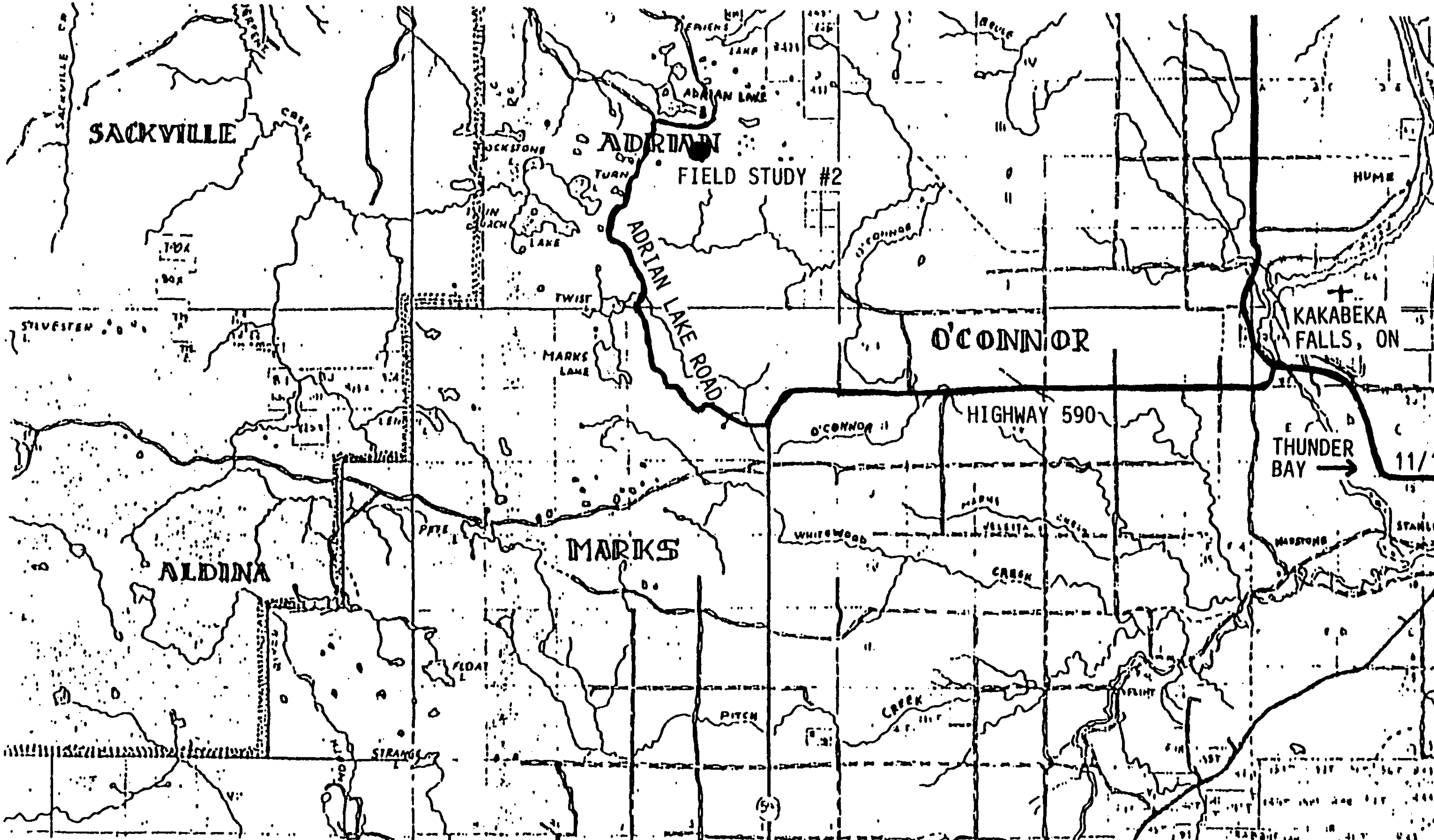

Figure F-2. A detailed map of the location of field study #2.

NOT TO SCALE

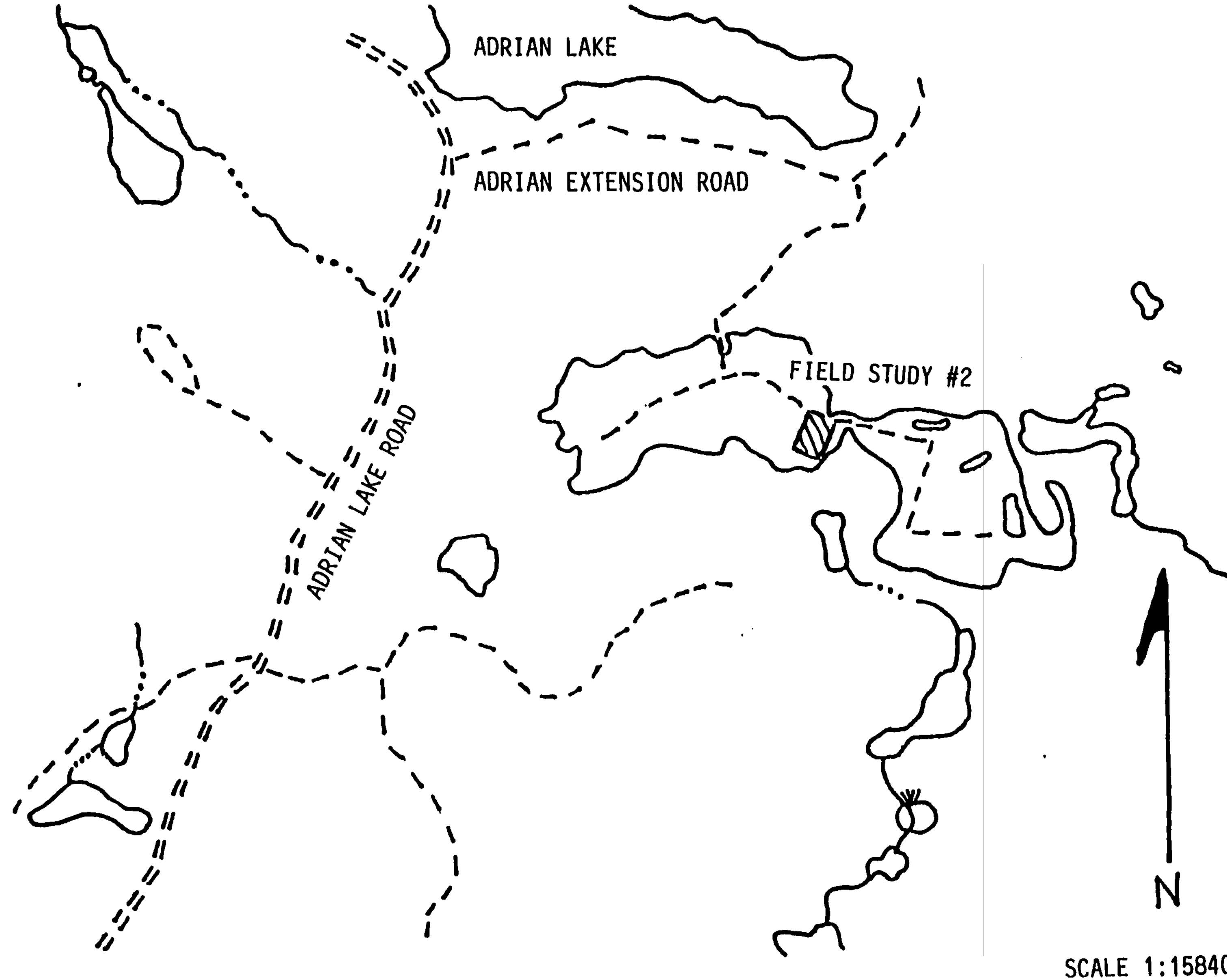

Figure F-3. A map of the location of cutover and the plots for field study #2.

APPENDIX G

FIELD STUDY #2: RESULTS OF THE ANALYSIS OF VARIANCE FOR THE VEGETATION INDICES

Table G-1 presents a summary of the probabilities of obtaining a larger F-ratio for herbicide treatment effects, tested against a residual error term with 44 degrees of freedom; and with block effects removed (p = 0.05); for each of the vegetation type response variable, which resulted from the analysis of variance (ANOVA).

Table G-1. Summary of the probabilities of obtaining a larger F-ratio for treatment effects tested against residual error for mean vegetation indices for each vegetation type (variable); one year after each treatment. An asterisk (*) denotes significant and '**' denotes highly significant effects at p = 0.05.

VEGETATION RESPONSE VARIABLE	F - RATIO PROBABILITY
Total Vegetation Index	0.011 *
Shrub Vegetation Index	0.000 **
Herb Vegetation Index	0.76
Graminoid Vegetation Index	0.331
Bracken Fern Vegetation Index	0.414

APPENDIX H

FIELD STUDY #2: MEAN VEGETATION INDICES FOR EACH OF THE VEGETATION TYPES, IMPORTANT INDIVIDUAL SPECIES AND CORRESPONDING RESULTS OF MULTIPLE RANGE TESTING

Figure H-1 illustrates the mean total vegetation indices of all vegetation observed on the site one year after each treatment. Letters denote any significant differences between the treatment means as determined by the Tukey's - HSD Multiple Range tests at p = 0.05.

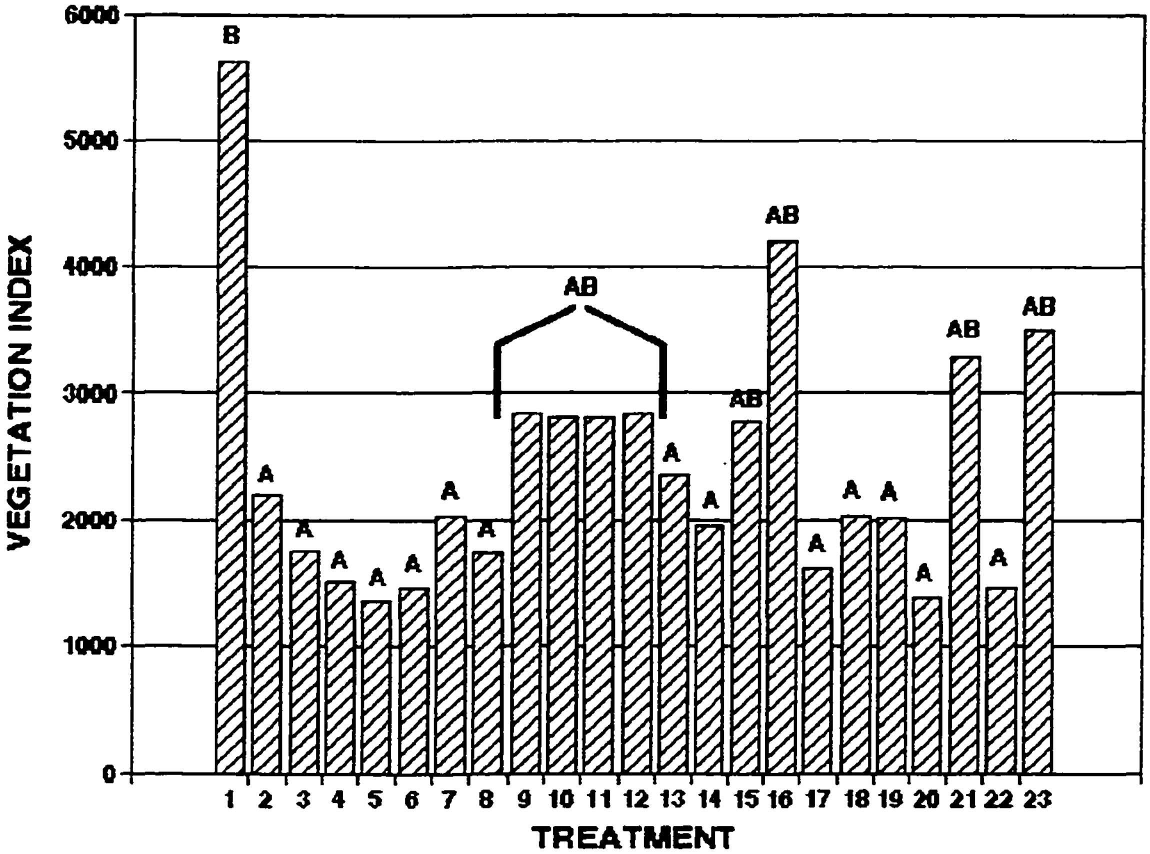

Figure H-1. The mean total vegetation indices observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

Figure H-2 illustrates the mean shrub vegetation indices observed on the site one year after each treatment. Major shrubs were those of most interest to DowElanco Canada Inc. while minor shrubs include all others (Table 9). Letters denote any significant differences between the treatment means as determined by the Tukey's - HSD Multiple Range tests at p = 0.05.

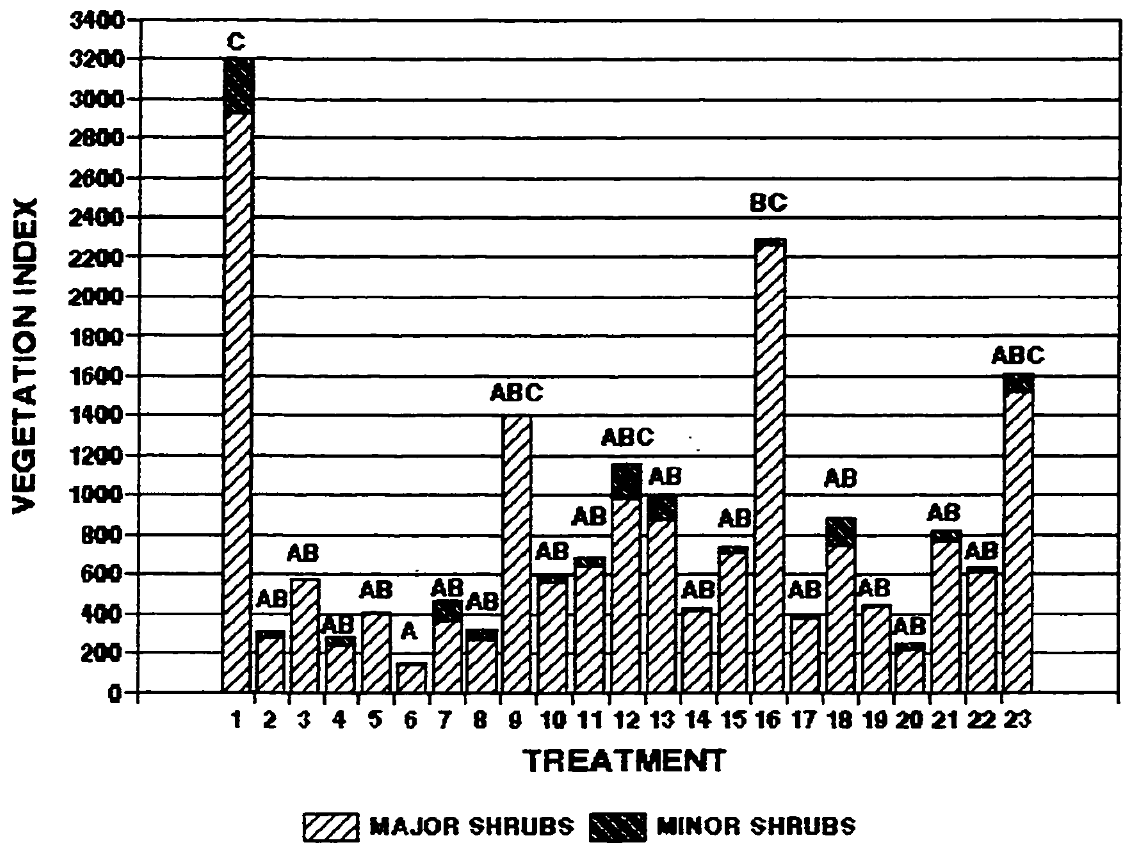

Figure H-2. The mean vegetation indices of the major and minor shrubs observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

Figures H-3 through H-8 illustrate the mean vegetation indices by treatment for each of the six major shrubs. Letters denote any significant differences between the treatment means as determined by the Tukey's - HSD Multiple Range tests at p = 0.05.

Trembling Aspen

Figure H-3 shows that, with the exception of treatments #11 (6-0-0), #12 (0.9-0.9-0), #22 (5.1-5.1-0) and #23 (6-3-0), all the treatments controlled trembling aspen relative to Control A. Mixtures of triclopyr and glyphosate reduced the vegetation index of trembling aspen to a greater degree than did either of the two herbicides applied alone. The best control was achieved with treatment #20 (3-6-0).

Mountain Maple

Figure H-4 shows that all the treatments, except #16 (2-2-0), reduced the vegetation index of mountain maple relative to Control A. The high index which resulted in treatment #16 seems to be an anomaly and could not be explained. Although the differences were not significant, herbicides applied alone tended to provide better control of mountain maple than did the mixtures.

Beaked Hazel

Figure H-5 shows that, with the exception of treatment #9 (4-0-0), all treatments significantly reduced the mean vegetation index of beaked hazel to less than half of that found on Control A. Treatments #4 and #7 (6 l/ha of Vision and of Touchdown, respectively) eliminated the beaked hazel completely. Treatment #9 was not as effective in reducing the mean index of beaked hazel as the rest of the treatments.

***Prunus* L. spp.**

Figure H-6 shows that all the treatments, with the exception of treatment #23 (6-3-0), were effective in reducing the mean vegetation index of *Prunus* L. spp. Treatments #5 (0-3-0) and #9 (4-0-0) were not as effective in reducing *Prunus* spp. as the remainder of the treatments were. It is not known why treatment #23 resulted in more than twice the index observed in Control A. The Tukey's - HSD Multiple Range Test identified that there were significant difference between the poor result in treatment #23 and several of the other herbicide treatments.

Bush Honeysuckle

Figure H-7 shows that the mean vegetation index of bush honeysuckle was significantly reduced by all herbicide treatments and by the manual vegetation control treatment; relative to the unweeded control. However, the manual weeding (Control B) was not as effective as the other herbicide treatments. Generally, lower rates of triclopyr and glyphosate applied singly and in mixture did not control bush honeysuckle as effectively as did higher herbicide rates.

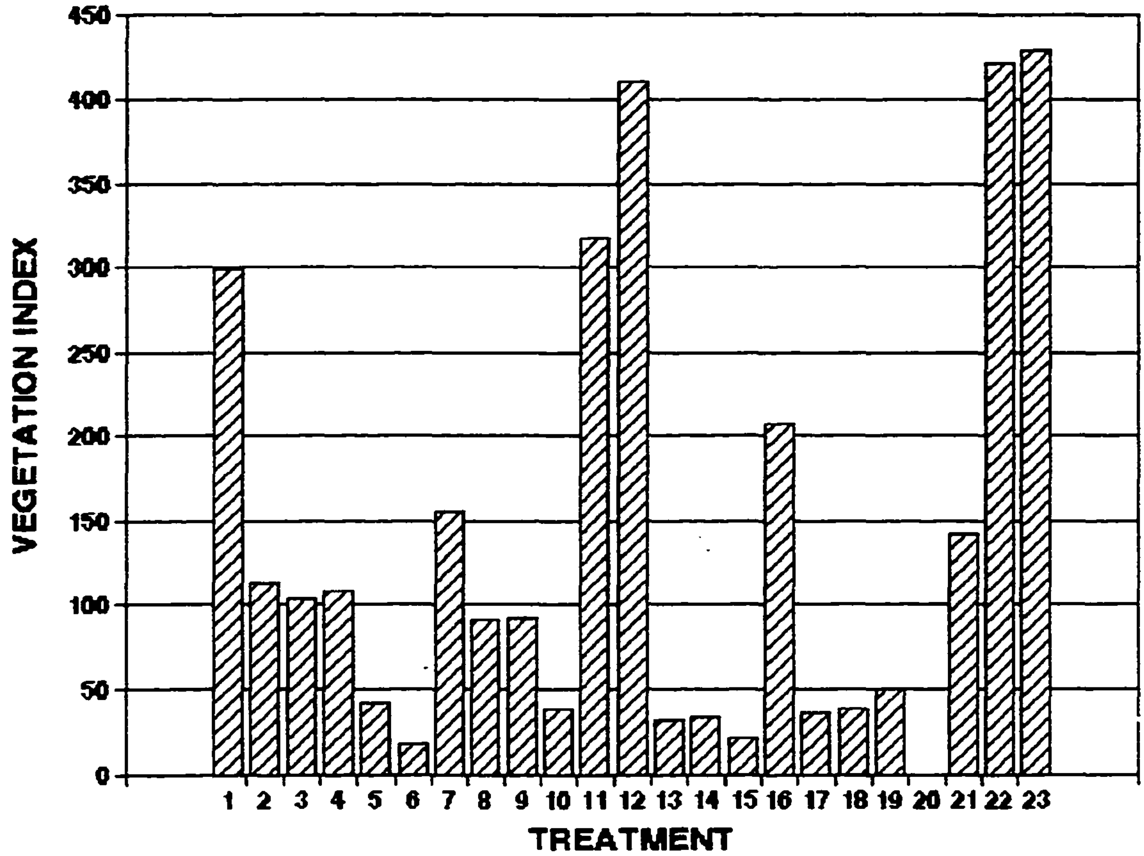

Figure H-3. The mean vegetation indices of trembling aspen observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

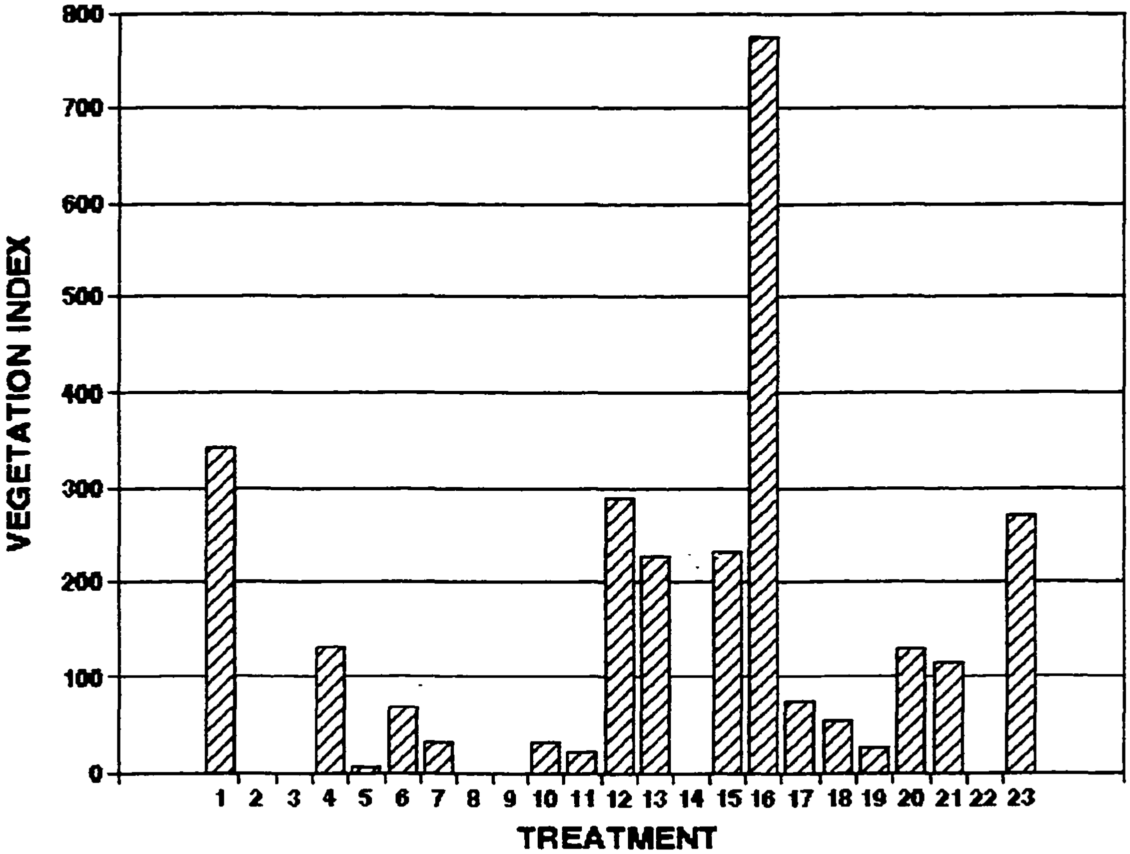

Figure H-4. The mean vegetation indices of mountain maple observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

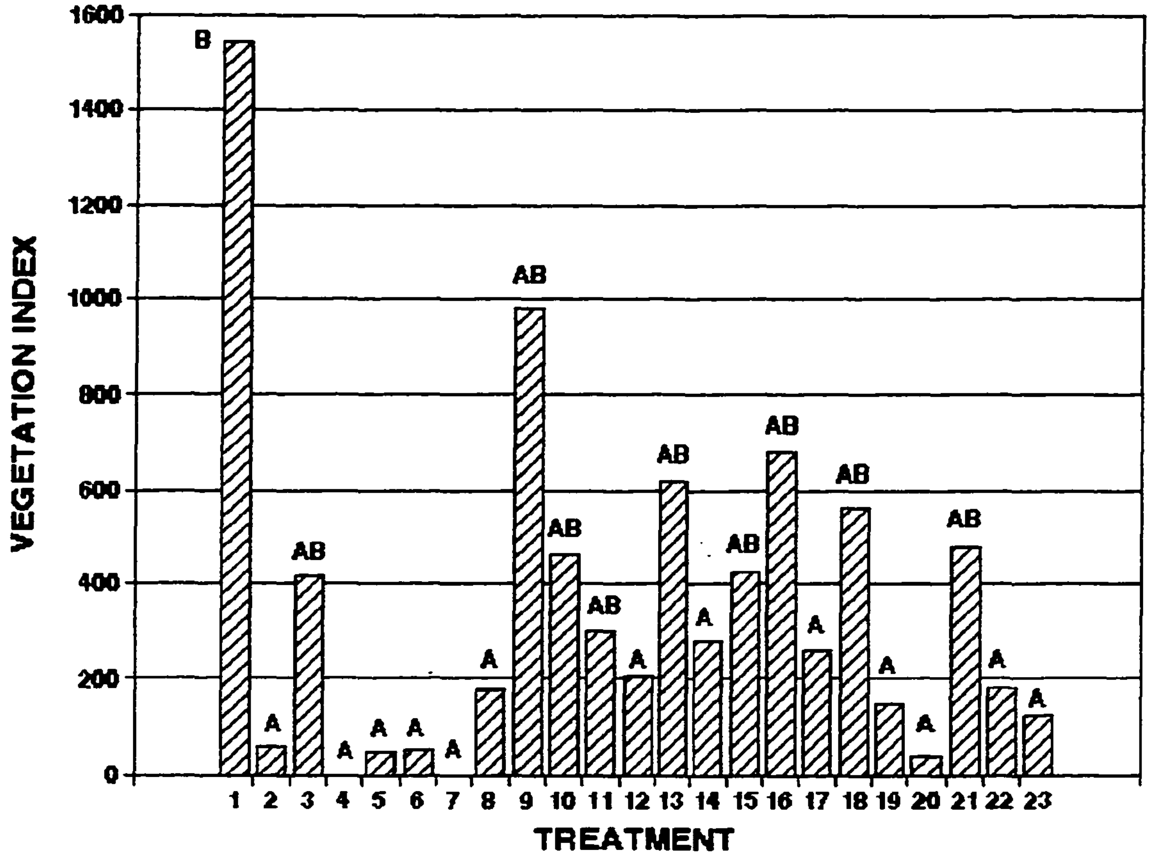

Figure H-5. The mean vegetation indices of beaked hazel observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

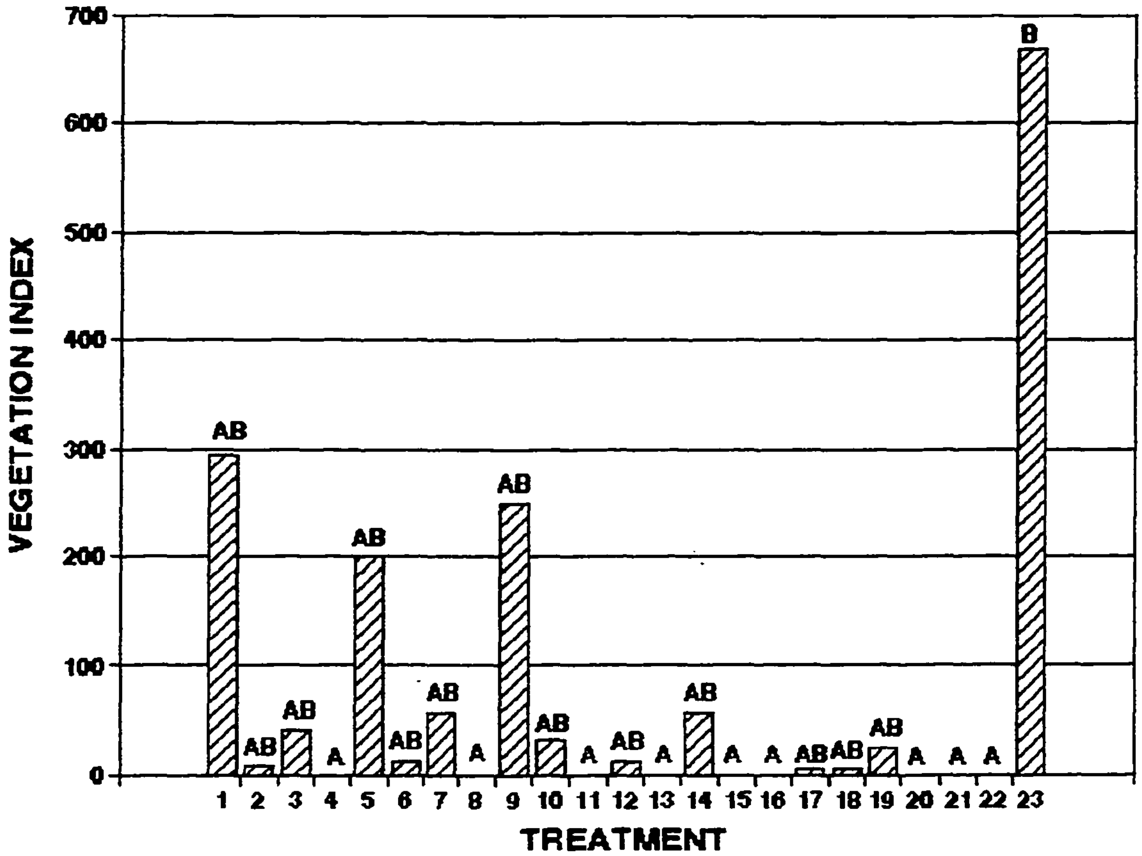

Figure H-6. The mean vegetation indices of *Prunus* spp. observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

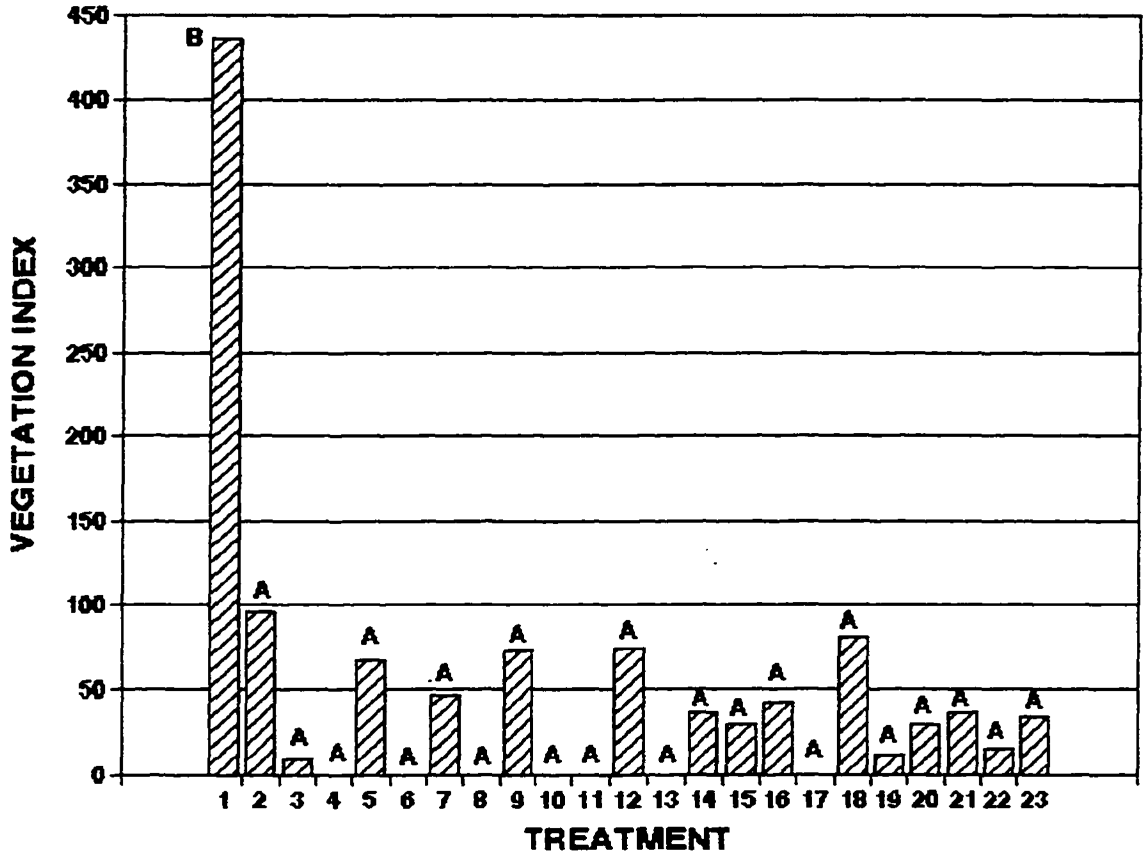

Figure H-7. The mean vegetation indices of bush honeysuckle observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

***Rubus* L. spp.**

Figure H-8 shows that there was very little or no *Rubus* L. spp. observed one year after most treatments. There were no significant differences between mean indices identified by Tukey's - HSD Multiple Range Test. As with the control of mountain maple, treatment #16 (2-2-0) had an extremely high index relative to the rest of the treatments.

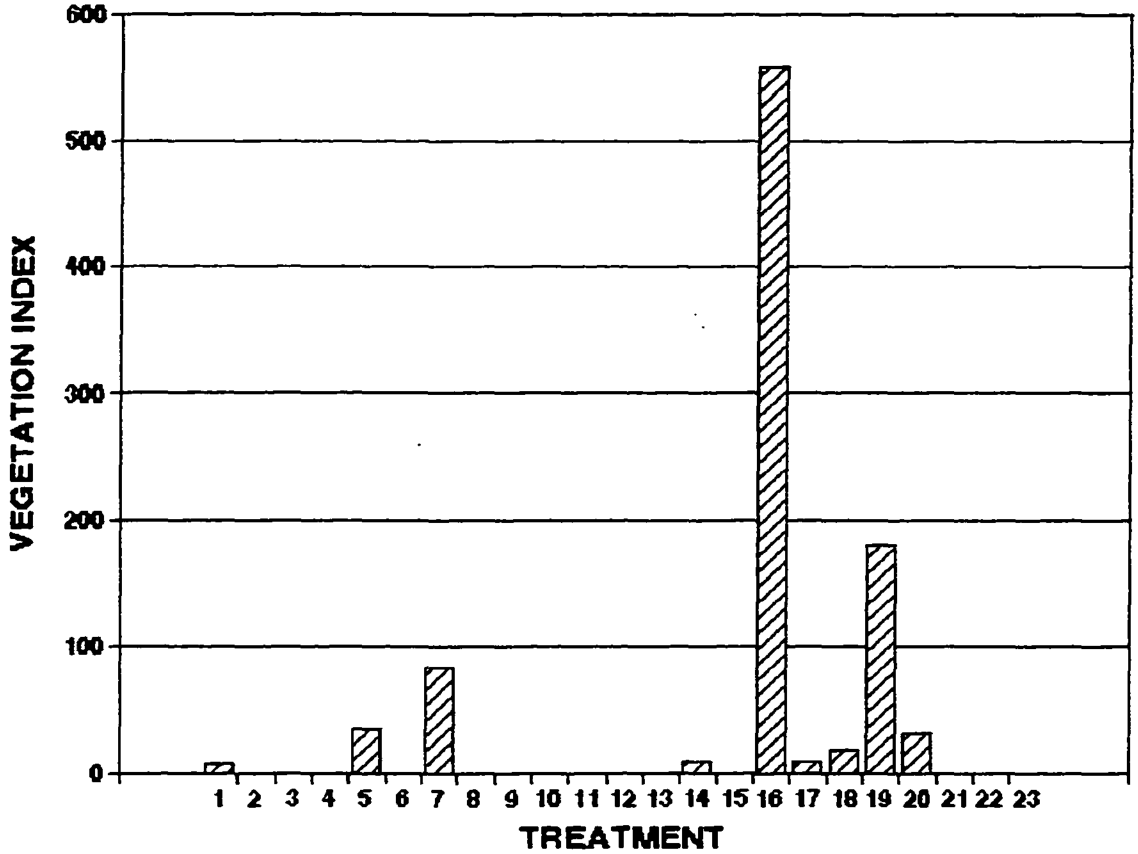

Figure H-8. The mean vegetation indices of *Rubus* spp. observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	**9)** 4-0-0	**17)** 3-1-0
2) CTL B	**10)** 5-0-0	**18)** 3-2-0
3) 0-0-4	**11)** 6-0-0	**19)** 3-3-0
4) 0-0-6	**12)** 0.9-0.9-0	**20)** 3-6-0
5) 0-3-0	**13)** 0.9-5.1-0	**21)** 5.1-0.9-0
6) 0-4-0	**14)** 2-0-2	**22)** 5.1-5.1-0
7) 0-6-0	**15)** 3-0-1	**23)** 6-3-0
8) 3-0-0	**16)** 2-2-0	

Figure H-9 illustrates the mean herb vegetation indices observed on the site one year after each treatment. With the exception of treatment #21 (5.1-0.9-0), all the treatments reduced *Aster* L. spp. to some degree, relative to Control A. There were no distinguishable trends in the degree of control, treatment #22 (5.1-5.1-0) was the most effective in reducing the mean vegetation index of *Aster* spp.. All the herbicide treatments did control fireweed to some degree. The least effective treatments were: #10 (5-0-0), #13 (0.9-5.1-0), #4 (0-0-6) and #7 (0-6-0). Generally, high rates of Release and Touchdown in mixture tended to be the most effective. Overall, there were no significant differences in mean vegetation indices for aster, fireweed or for all herbs combined.

Figure H-10 illustrates the mean graminoid vegetation index indices observed on the site one year after each treatment. The mean indices of Canada blue-joint grass was very low (vegetation indices <60). Treatment #6 (0-4-0) was the least effective in controlling grass. Herbicide treatments with triclopyr ester applied alone and in mixture with low rates of glyphosate did not effectively control grass, relative to no vegetation control. The mean indices of *Carex* (Dill.) L. spp. were relatively high with treatments of triclopyr applied singly and in mixture with lower rates of glyphosate. Treatments with the higher rates of glyphosate controlled *Carex* spp. most effectively. Overall, there were no significant differences in mean vegetation indices of Canada blue-joint grass, *Carex* spp. or of both graminoids combined.

Figure H-11 illustrates the mean vegetation indices for bracken fern observed on the site one year after each treatment. Several treatments resulted in an increase in index relative to Control A. Although differences between means were not significant, treatments #14 (2-0-2) and #11 (6-0-0) resulted in the highest mean indices.

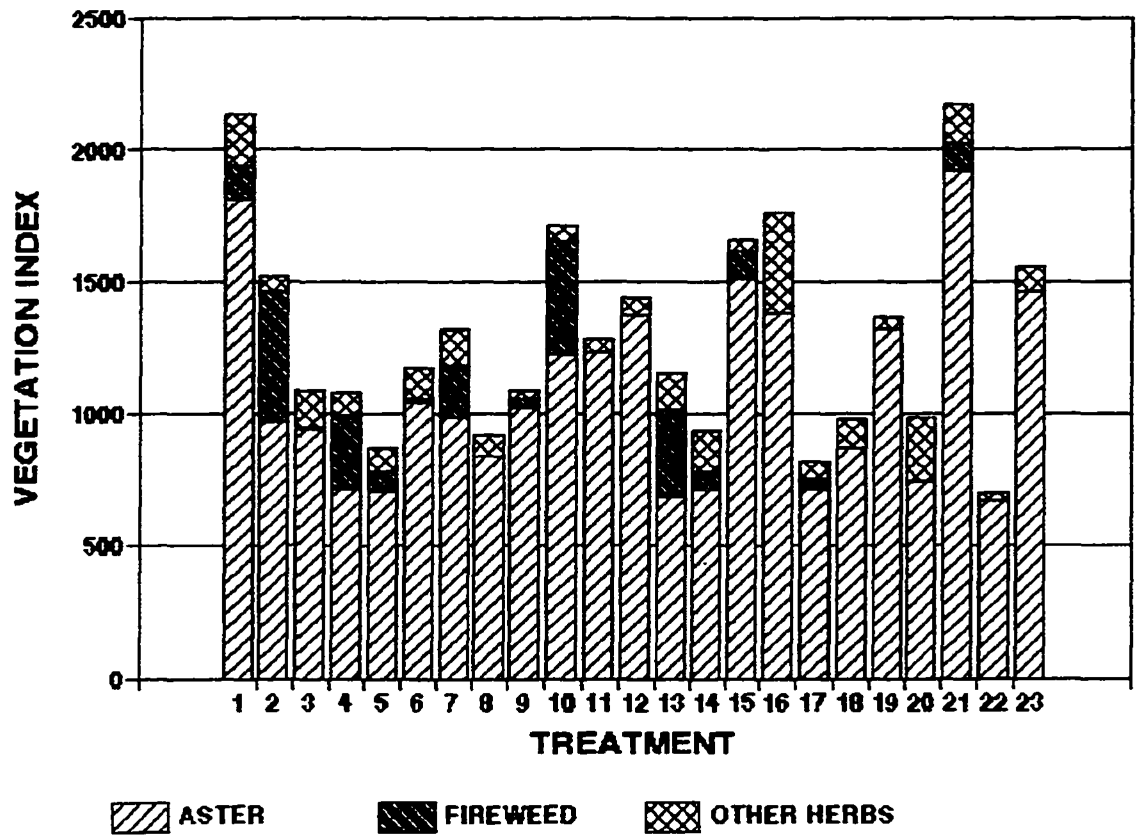

Figure H-9. The mean vegetation indices of *Aster* spp., fireweed and other herbs observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

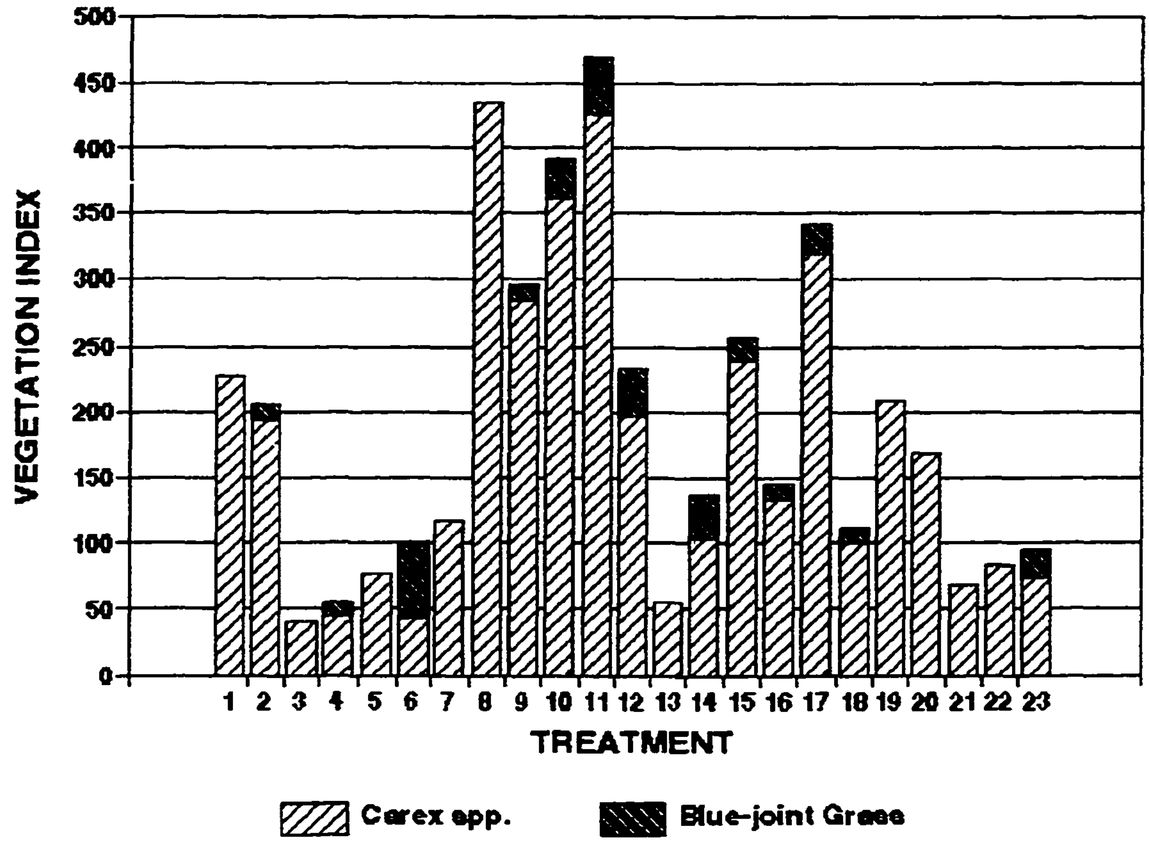

Figure H-10. The mean vegetation indices of *Carex* spp. and Canada blue-joint grass observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

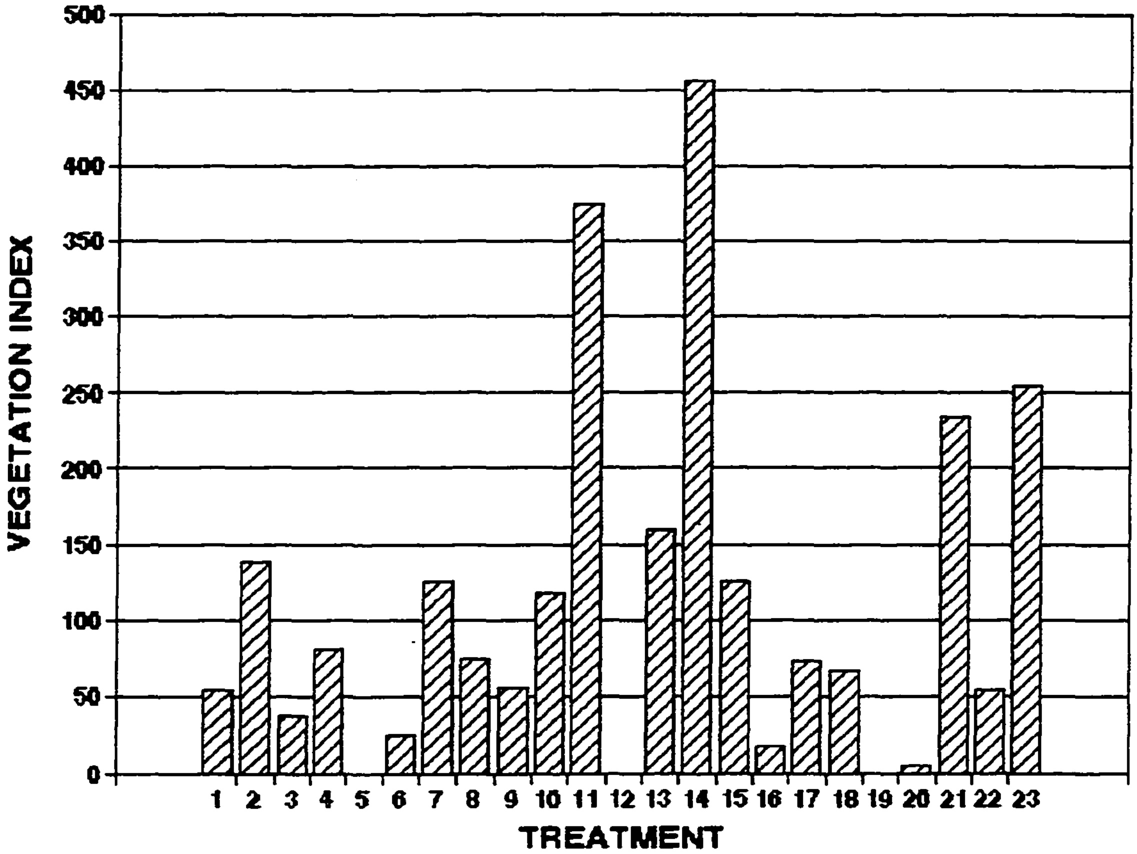

Figure H-11. The mean vegetation indices for bracken fern observed one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	**9)** 4-0-0	**17)** 3-1-0
2) CTL B	**10)** 5-0-0	**18)** 3-2-0
3) 0-0-4	**11)** 6-0-0	**19)** 3-3-0
4) 0-0-6	**12)** 0.9-0.9-0	**20)** 3-6-0
5) 0-3-0	**13)** 0.9-5.1-0	**21)** 5.1-0.9-0
6) 0-4-0	**14)** 2-0-2	**22)** 5.1-5.1-0
7) 0-6-0	**15)** 3-0-1	**23)** 6-3-0
8) 3-0-0	**16)** 2-2-0	

APPENDIX I

FIELD STUDY #2: MEAN VEGETATION INDICES GROUPED INTO HERBICIDE RATE CONCENTRATION GRADIENT

Mean indices for each vegetation type were calculated for herbicide treatments on the basis of a grouped herbicide rate concentration gradient: 0, 1-3 and 4-6 l/ha. This was done in an attempt to determine if any trends in vegetation control existed. Tables I-1 to I-5 present this information in tabular format. Refer to text for graphical presentation.

Table I-1. The mean total vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 5162 (1) Ctl B 2183 (1)	1349 (1)	1740 (2)	N/A	1624 (2)
RELEASE 1-3	1740 (1)	2539 (5)	1871 (2)	2361 (2)	N/A
RELEASE 4-6	2820 (3)	3387 (2)	1458 (1)	N/A	N/A

Table I-2. The mean shrub vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 3023 (1) Ctl B 317 (1)	409 (1)	312 (2)	N/A	432 (2)
RELEASE 1-3	323 (1)	1043 (5)	624 (2)	587 (2)	N/A
RELEASE 4-6	900 (3)	1217 (2)	641 (1)	N/A	N/A

Table I-3. The mean herb vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 2140 (1) Ctl B 1526 (1)	870 (1)	1255 (2)	N/A	1092 (2)
RELEASE 1-3	919 (1)	1167 (5)	1071 (2)	1302 (2)	N/A
RELEASE 4-6	1364 (3)	1873 (2)	704 (1)	N/A	N/A

Table I-4. The mean graminoid vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 11). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 227 (1) Ctl B 206 (1)	77 (1)	105 (2)	N/A	48 (2)
RELEASE 1-3	433 (1)	208 (5)	225 (2)	198 (2)	N/A
RELEASE 4-6	386 (3)	825 (2)	83 (1)	N/A	N/A

Table I-5. The mean bracken fern vegetation indices grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 13). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 54 (1) Ctl B 138 (1)	0 (1)	65 (2)	N/A	60 (2)
RELEASE 1-3	75 (1)	32 (5)	82 (2)	291 (2)	N/A
RELEASE 4-6	183 (3)	244 (2)	54 (1)	N/A	N/A

APPENDIX J

FIELD STUDY #2: RESULTS OF THE ANALYSIS OF VARIANCE FOR THE JACK PINE CROP TREE RESPONSES

Table J-1 presents a summary of the probabilities of obtaining a larger F-ratio for herbicide treatment effects, tested against a residual error term with 44 degrees of freedom; and with block effects removed (p = 0.05); for each of the seedling response variables, which resulted from the analysis of variance (ANOVA).

Table J-1. Summary of the probabilities of obtaining a larger F-ratio for treatment effects tested against residual error for the mean seedling response variables; one year after each treatment. An asterisk (*) denotes significant and '**' denotes highly significant effects at p = 0.05.

SEEDLING RESPONSE VARIABLE	F - RATIO PROBABILITY
Survival	0.019 *
Physical Condition	0.241
Needle Length	0.021 *
Volume Increment/ha	0.187

APPENDIX K

FIELD STUDY #2: JACK PINE SEEDLING RESPONSES ONE YEAR AFTER EACH OF THE TWENTY-THREE TREATMENTS

Figure K-1 illustrates the mean percent survival rates of the jack pine seedlings one year after each treatment.

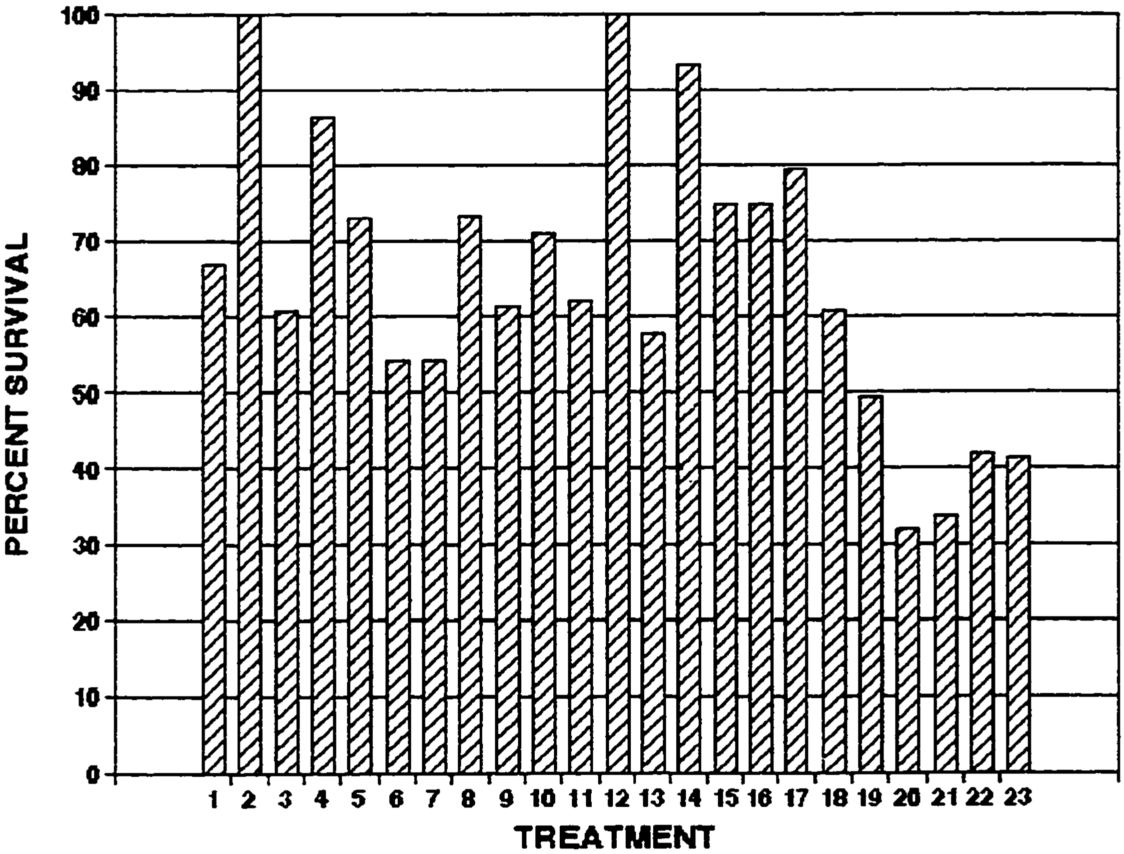

Figure K-1. The mean percent survival rates of the jack pine seedlings one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

Figure K-2 illustrates the mean physical condition codes of the jack pine seedlings one year after each treatment.

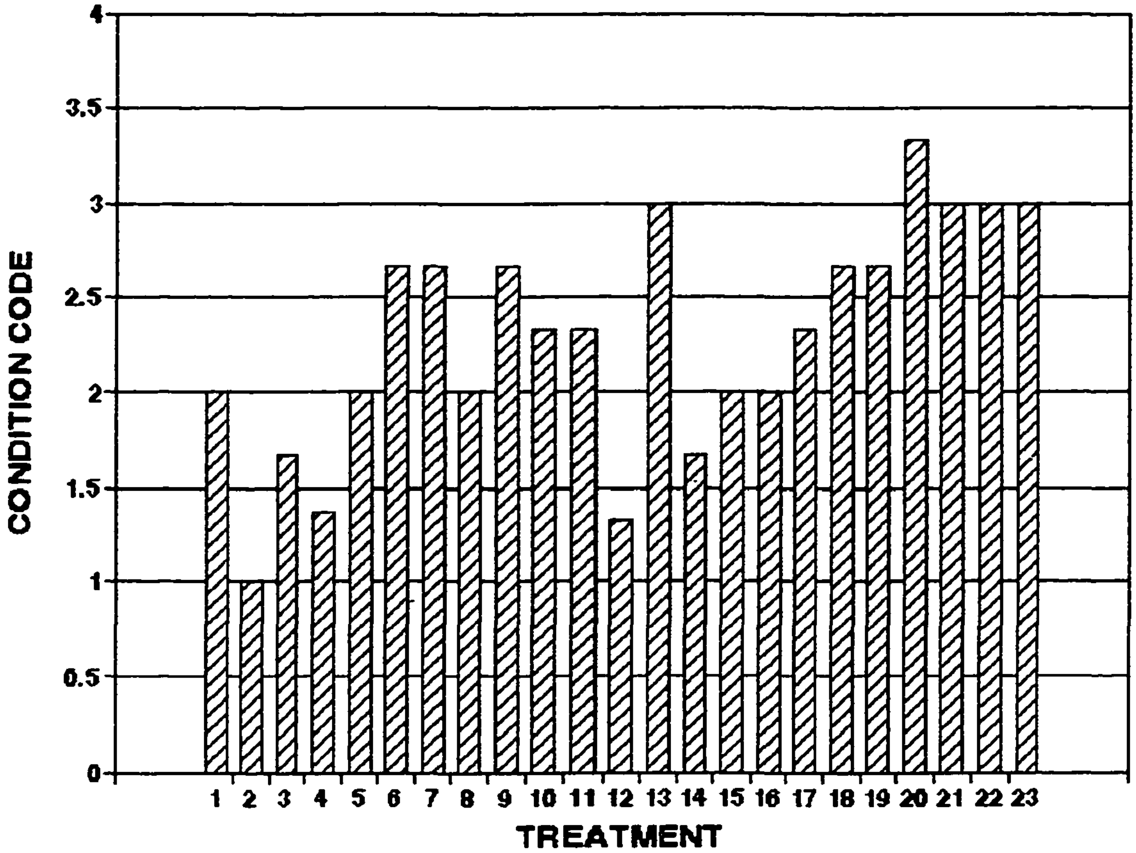

Figure K-2. The mean physical condition codes of the jack pine seedlings one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

Figure XI-3 illustrates the mean needle lengths of the jack pine seedlings one year after each treatment.

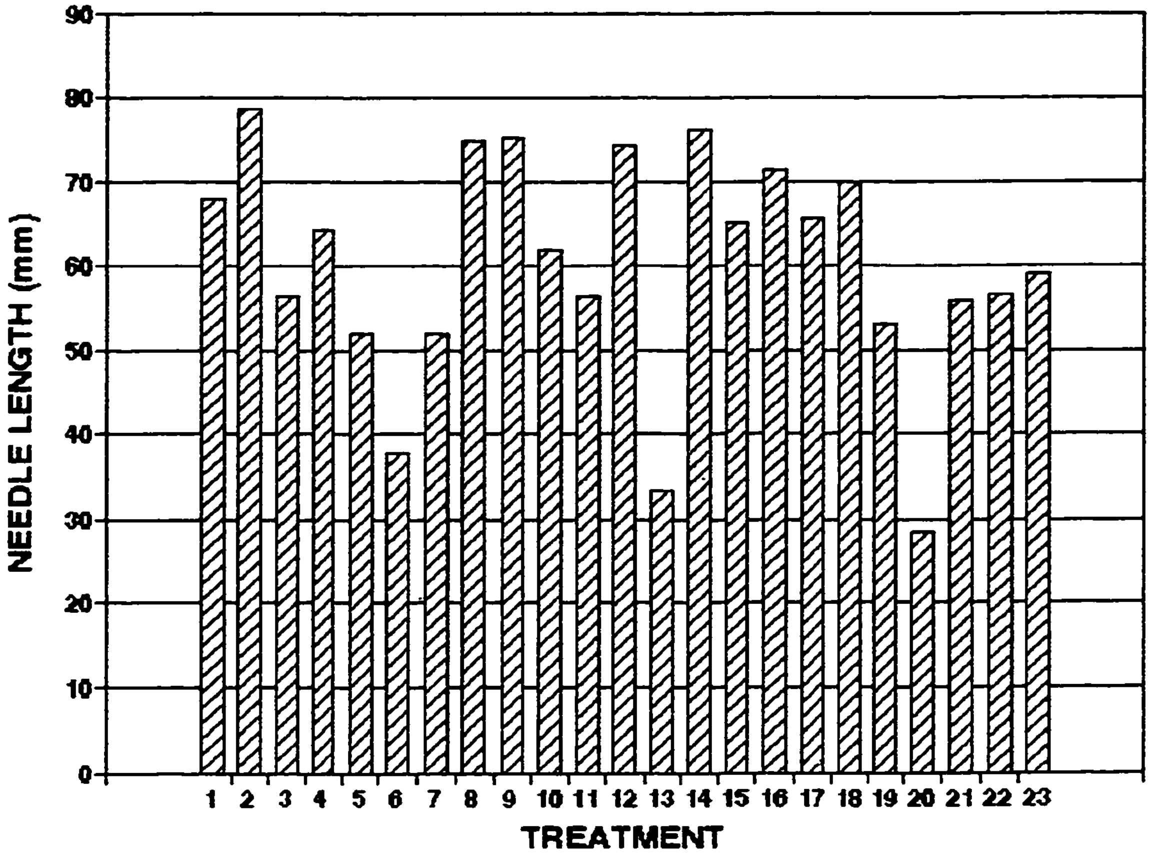

Figure K-3. The mean needle lengths (in mm) of the jack pine seedlings one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	**9)** 4-0-0	**17)** 3-1-0
2) CTL B	**10)** 5-0-0	**18)** 3-2-0
3) 0-0-4	**11)** 6-0-0	**19)** 3-3-0
4) 0-0-6	**12)** 0.9-0.9-0	**20)** 3-6-0
5) 0-3-0	**13)** 0.9-5.1-0	**21)** 5.1-0.9-0
6) 0-4-0	**14)** 2-0-2	**22)** 5.1-5.1-0
7) 0-6-0	**15)** 3-0-1	**23)** 6-3-0
8) 3-0-0	**16)** 2-2-0	

Figure K-4 illustrates the mean volume increments/ha of the jack pine seedlings one year after each treatment.

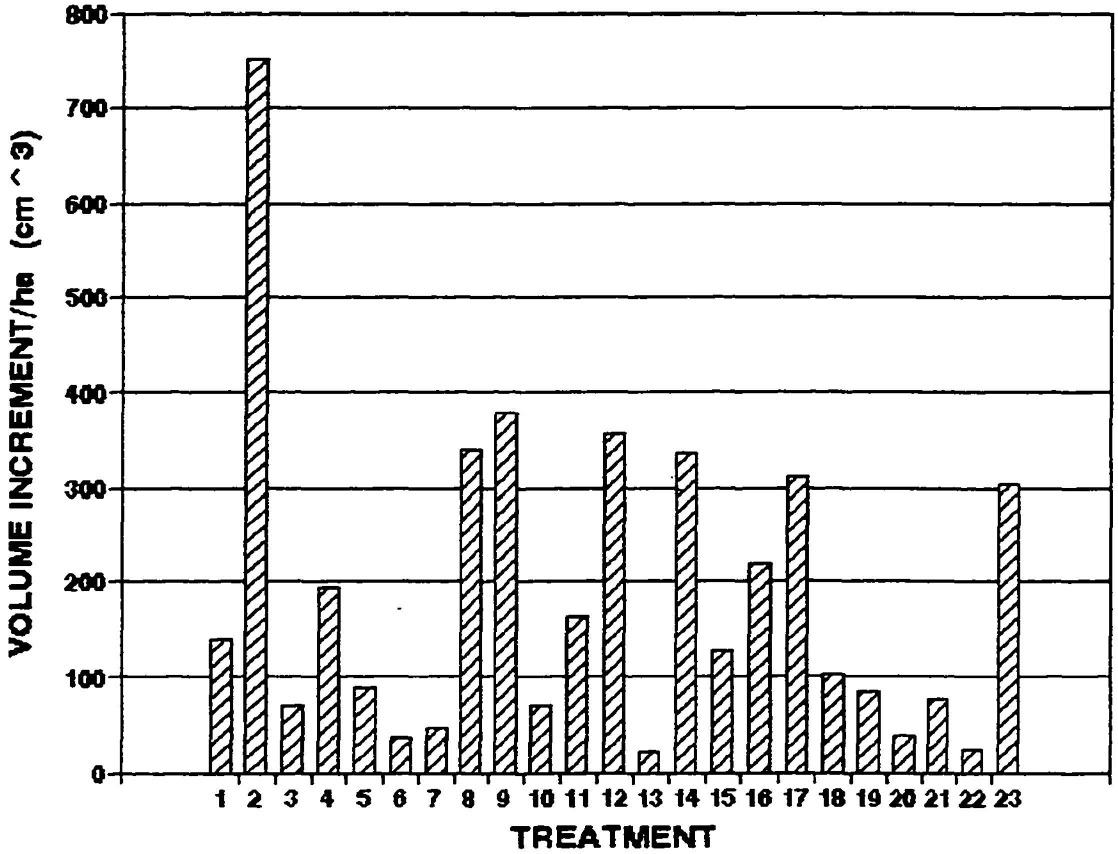

Figure K-4. The mean volume increments/ha in cm^3 of the jack pine seedlings one year after each treatment.

Treatment List [Release-Touchdown-Vision in l/ha]

1) CTL A	9) 4-0-0	17) 3-1-0
2) CTL B	10) 5-0-0	18) 3-2-0
3) 0-0-4	11) 6-0-0	19) 3-3-0
4) 0-0-6	12) 0.9-0.9-0	20) 3-6-0
5) 0-3-0	13) 0.9-5.1-0	21) 5.1-0.9-0
6) 0-4-0	14) 2-0-2	22) 5.1-5.1-0
7) 0-6-0	15) 3-0-1	23) 6-3-0
8) 3-0-0	16) 2-2-0	

APPENDIX L

FIELD STUDY #2: MEAN JACK PINE SEEDLING RESPONSES GROUPED INTO HERBICIDE RATE CONCENTRATION GRADIENT

Means for each response variables were calculated for herbicide treatments on the basis of a grouped herbicide rate concentration gradient: 0, 1-3 and 4-6 l/ha. This was done in an attempt to determine if any trends in seedling response existed. Tables L-1 to L-4 present this information in tabular format. Refer to text for graphical presentation.

Table L-1. The mean percent seedling survival grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	**0**	**TOUCHDOWN 1-3**	**TOUCHDOWN 4-6**	**VISION 1-3**	**VISION 4-6**
0	Ctl A 67 (1) Ctl B 100 (1)	73 (1)	54 (2)	N/A	74 (2)
RELEASE 1-3	73 (1)	68 (5)	45 (2)	84 (2)	N/A
RELEASE 4-6	65 (3)	38 (2)	42 (1)	N/A	N/A

Table L-2. The mean physical condition codes grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	**0**	**TOUCHDOWN 1-3**	**TOUCHDOWN 4-6**	**VISION 1-3**	**VISION 4-6**
0	Ctl A 2.0 (1) Ctl B 1.0 (1)	2.0 (1)	2.7 (2)	N/A	1.7 (2)
RELEASE 1-3	2.0 (1)	2.3 (5)	3.0 (2)	1.8 (2)	N/A
RELEASE 4-6	2.3 (3)	3.0 (2)	3.0 (1)	N/A	N/A

Table L-3. The mean seedling needle lengths (in mm) grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	**0**	**TOUCHDOWN 1-3**	**TOUCHDOWN 4-6**	**VISION 1-3**	**VISION 4-6**
0	Ctl A 68 (1) Ctl B 79 (1)	52 (1)	45 (2)	N/A	60 (2)
RELEASE 1-3	75 (1)	67 (5)	31 (2)	70 (2)	N/A
RELEASE 4-6	64 (3)	58 (2)	57 (1)	N/A	N/A

Table L-4. The mean seedling volume increments/ha (in cm^3) grouped by herbicide rate (0, 1-3 and 4-6 l/ha) (adapted from Table 12). The number enclosed in brackets is the number of treatments involved in calculating the mean.

l/ha	0	TOUCHDOWN 1-3	TOUCHDOWN 4-6	VISION 1-3	VISION 4-6
0	Ctl A 141 (1) Ctl B 751 (1)	88 (1)	41 (2)	N/A	132 (2)
RELEASE 1-3	339 (1)	189 (5)	30 (2)	231 (2)	N/A
RELEASE 4-6	204 (3)	190 (2)	24 (1)	N/A	N/A

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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Phone: 716/482-0300
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