UNIVERSITY OF ALBERTA

PERFORMANCE OF SELECTED NATIVE AND INTRODUCED PLANT SPECIES UNDER MOWING AND HERBICIDE MANAGEMENT DURING THE ESTABLISHMENT PERIOD

by

WILLIAM EDWARD PELECH

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

LAND RECLAMATION AND REMEDIATION

Department of Renewable Resources

Edmonton, Alberta

Fall 1997

0-612-22652-2

UNIVERSITY OF ALBERTA

LIBRARY RELEASE FORM

NAME OF AUTHOR: William Edward Pelech

TITLE OF THESIS: Performance of Selected Native And Introduced Plant Species Under Mowing And Herbicide Management During The Establishment Period

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1997

William Edward Pelech
26 Fairway Avenue
Red Deer, Alberta
T4N 4Y8

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled PERFORMANCE OF SELECTED NATIVE AND INTRODUCED PLANT SPECIES UNDER MOWING AND HERBICIDE MANAGEMENT DURING THE ESTABLISHMENT PERIOD submitted by WILLIAM EDWARD PELECH in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in LAND RECLAMATION AND REMEDIATION.

M. Anne Naeth

M.A. Naeth, Ph.D.
Supervisor

D.S. Chanasyk, Ph.D.

V.S. Baron

V.S. Baron, Ph.D.

Victor Lieffers

V.J. Lieffers, Ph.D.

T.S. Veeman

T.S. Veeman, Ph.D.

ABSTRACT

There is much controversy on the merits of introduced versus native plant species for resource conservation and agricultural productivity. The objectives of this research were to evaluate selected native and introduced plant species emergence, survivability and productivity in their response to mowing and herbicides during the establishment period.

Four completely randomized split blocks of six species mixes (4 native, 4 introduced and 1 mixed) (thirty five plant species; 21 introduced and 14 native) were evaluated for emergence, survivability, canopy cover, ground cover and productivity under mowing and herbicide treatments.

In general native species were slower to emerge and become established. Significant differences in survivability and canopy cover occurred among species with plants of the same genus having similar survivability. Mowing and herbicides did not consistently affect species density, survivability, productivity or cover; ground and canopy cover were similar after two years.

ACKNOWLEDGMENTS

I wish to express my appreciation to my supervisor Dr. Anne Naeth for the opportunity to pursue this thesis project, for our numerous stimulating discussions and persevering with me through this learning adventure.

I would like to thank the Alberta Agricultural Research Institute Matching Grants Program and NOVA Corporation for their funding for this research and the Lacombe Agriculture and Agri-Food Canada Research Institute for technical support and provision of a research site. A special thank you to Dr. Vern Baron and Dave Young in this regard. I appreciate the support and funding of sponsors and individuals who provided insight and financial support for this project: particularly Ducks Unlimited Canada, Prairie Seeds Inc. and Hannas Seeds.

To the following people, I have cherished memories and humble appreciation for your help and guidance in making this research a rewarding experience: to Ted Harms for his patience in teaching me and trouble shooting my computer endeavors; to Robin Lagroix-McLean, Kelly Ostermann, Pola Genoway and others for their help in the field and lab; to Dr. Prasad and Thaun Thach for their statistical support; to Dr. Chanasyk for a practical approach to and support of my later-in-life return to higher learning and critical thinking.

Foremost, I would like to thank my children Murray and Stephen for accepting my time away from home, and my wife Cynthia and my extended family, including Mr. William Arthur Bower and Mr. James A. Bower for their encouragement and financial support thus enabling me to return to university. Lastly I would like to acknowledge my grandparents John and Helen Pelech who gave me many fond childhood memories and instilled in me an appreciation of the need to use the land resource wisely.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Chapter 2

Appendix A

I. INTRODUCTION

1. BACKGROUND

There is currently an increased interest in using native plant species within the agricultural industry for livestock grazing, within the oil and gas industry for reclamation of disturbed lands and within forestry and parks for revegetation/reclamation and wildlife habitat. There are undocumented general assumptions and anecdotal information on desirable characteristics of native plant species for use in these industries. The wide adaptation of native species to a variety of soils and climate extremes, along with their longevity and erosion reducing potential, make native species desirable for these purposes. Due to their diverse dates of maturity, their ability to adapt to grazing and their ability to remain palatable and nutritious late into the growing season, native plants are well suited for late season grazing (Trottier 1992). Native plant communities are generally more diverse, providing more habitat and food sources, than agronomic communities. Because of increased biodiversity, native plant communities are potentially more resistant to disease and stress. Native plants have a variety of rooting depths, facilitating use of both short sporadic and low intensity, high-volume rainfall events; this makes them more adaptable to drought or wet periods. Native and introduced species have soil binding roots and an association with a host of microorganisms that help aggregate soil particles, thus providing good erosion reduction.

Traditional agriculture has relied on a small number of highly productive introduced species (non-native of European or Asian origin) in reclamation for ecosystem construction and development. A larger number of plant species are needed to achieve natural biodiversity. Plant species selection requires a knowledge of factors affecting species establishment to achieve a desired end land use.

In the energy industries there is interest in a rapid establishment and erosion-reducing ground cover under poor soil conditions. Long-term sustainability and the ability to meet legislative ground cover requirements are the main considerations in reclamation.

Presently there is no legal requirement to re-establish native species; the goal is equivalent land capability. This means returning land to a capability to a use which may or may not be the same as the original (Alberta Environmental Protection 1995). Eighty percent cover (live and litter) of undisturbed off right-of-way is a reclamation criteria based on the prevention of erosion by revegetation. Both the Alberta and Canadian Government insist on native species in reclamation and restoration in park systems to promote natural vegetation features.

In agriculture there is a focus on long-term sustainability with better utilization of existing resources. Lower input costs and therefore lower costs of production is one area in which agriculture can benefit from native and non-native plant species. The Canada-Alberta Environmentally Sustainable Agriculture Agreement (CAESA) initiative has continued a late 1980s focus on the awareness and prevention of wind and water erosion in Alberta. The use of native plants on degraded soil (particularly the seeding of perennial forages on annual cropland of low productivity) is a potential area for development and expansion.

1.1. Traditional Thinking - Why Use Native Plants?

The traditional view that native is natural and therefore desirable is a fundamental belief of naturalist groups and governments in the protection of natural areas. There are numerous anecdotal sources in the literature to native plants being desirable because they are well adapted to a given situation, require fewer inputs (fertilizer, moisture) and have greater longevity. Each native plant displays phenotypic plasticity which exhibits the ecological adaptability of that species to a general environment. Cultivars of non-native plants are bred and selected for specific desirable traits.

A growing movement on behalf of the general public for natural solutions has spurred the protection of native and natural areas and their restoration. Native plant species are favoured for their intrinsic value, which includes their genetic makeup and biodiversity. Recent public demands for the preservation of biodiversity are often use this concept as a surrogate for the value of rare species, nature preserves and wilderness (Burton 1991).

Efforts to restore biodiversity provide a useful means of experimenting with the factors controlling ecosystem structure and function (Burton 1991). Although each sector of society may have a different reason for pursuing native plant use, the extent to which they are used lies in understanding the attributes of the plants themselves. Knowledge of their role in the ecosystem and their adaptability to microsite conditions is required. This will aid in establishing the competitive advantage of employing a native plant over a non-native plant in a given situation, should such an advantage exist.

Information on restoration and reclamation projects is anecdotal or observational; they are generally not carried out in an experimental fashion (Kerr et al. 1993). While a few studies have attempted to compare native to agronomic plant species subjectively, statistically tested quantitative evaluations are virtually non-existent (Sims et al. 1984).

It is also generally agreed that native plants mature later than non-native plants. This would improve their versatility for late season grazing. Native grasslands have a high proportion of live plants to litter on the soil surface while reclaimed grasslands have a high proportion of litter to live growth (Hofmann and Reis 1983, cited by Kerr et al. 1993). Soil protection in a native mixed grass community is largely obtained as a result of the live component of the total ground cover while protection in a reclaimed grass community results to a greater degree from the litter component. Monitoring and management of the litter component in a reclaimed grassland is required to ensure adequate protection from soil loss by water erosion. Without grazing or litter removal, reclaimed grasslands are less likely to annually rejuvenate themselves. However, initial ground cover (live, litter) may be superior for erosion control (i.e. raindrop impact).

Most of the comparative research between native and introduced plant species has been conducted in the montane, or green areas of Alberta (Goff 1971, Mihajlovich 1979, Takyi and Islam 1984, Takyi 1984, Russell Ecological Consultants 1986). Takyi and Islam (1984) concluded that cultivated grasses performed well in plant cover and biomass production and generally developed adequate plant cover for erosion control faster than native grasses in the eastern slopes area. In subalpine tests, Russell Ecological Consultants

(1986) concluded the most consistently successful species in terms of plant cover were (1) native: *Agropyron dasystachyum* (northern wheatgrass), *Agropyron trachycaulum* (slender wheatgrass), *Festuca rubra* (red fescue) and *Koeleria macrantha* (june grass) and (2) nonnative: *Agropyron pectiniforme* (crested wheatgrass-'Fairway'), *Agropyron trachycaulum* (slender wheatgrass-'Revenue'), *Alopecurus pratensis* (meadow foxtail) and *Festuca rubra* (creeping red fescue-'Boreal'). Information obtained from these studies can be used to supplement current documentation (e.g. Varieties of perennial hay and pasture crops for Alberta, Manual of plant species suitability for reclamation in Alberta). This in turn will aid in plant species selection and establishment.

2. SPECIES SELECTION FOR AGRICULTURE AND RECLAMATION

Appropriate plant species selection is of equal concern in agriculture and reclamation. Species selection should be dictated by regional and microsite conditions (Takyi 1984). Alberta Agriculture, Food and Rural Development (AAFRD) publishes an annual forage seeding guide which lists commercially available native and introduced species, based on vegetative zones related to climate and soil zones (AAFRD 1995). The Alberta Forage Manual lists various hay and pasture crops and their management considerations (Alberta Agriculture 1981), while the Ecoregions of Alberta categorizes general plant communities and soils (Strong and Leggat 1992). A Manual of Plant Species Suitability for Reclamation includes a species suitability map and reclamation suitability criteria for a number of grasses, forbs, shrubs and trees (Hardy BBT Limited 1989). However, most of this information is general in nature and more site specific data are required for plant species selection and determining successful establishment methods.

2.1. Use Of Legumes

The use of legumes in a seed mix has been encouraged to provide a natural source of nitrogen to grasses. Takyi (1984) stated that alfalfa should be considered in seed mixes in the sub-alpine region. However, *Medicago* species (alfalfa) dominated grass-legume mixes, while *Astragalus cicer* (milkvetch) was less competitive, resulting in a greater percentage of grass growth in a grass-legume mix (Lloyd and Smoliak 1983). The researchers concluded grass should be seeded separately from alfalfa (separate row) or cross seeded ninety degrees to alfalfa for grass establishment. However, *Astragalus cicer* can be seeded directly with grasses. For reclamation, alfalfa's domination in a mixed stand was due to its ability to obtain water and nutrients at lower depths in the soil profile (Lloyd and Smoliak 1983). Smreciu (1993) concluded data were needed on invasiveness, persistence, competitive ability with weedy species, animal palatability and relationships with other plants in seeding mixes.

2.2. Companion Crops

Using companion crops, where annual cereal crops are seeded at a reduced rate with grass or grass-legume mixes to reduce erosion and/or provide a crop in the establishment year, is contentious. Takyi (1984) found no significant advantage for ground cover with companion crops at two disturbed sites (Cadomin, Adanac). In field trials with native grasses, Russell Ecological Consultants (1986) found no trends with companion crops. Competitive effects were weak or non-existent for six species tested. *Alopecurus pratensis* (meadow foxtail) and *Festuca rubra* (creeping red fescue) were the best grasses for companion cropping for cover. Kerr et al. (1993) noted companion crops were beneficial to protect slower establishing species from drying winds, solar radiation and weeds, if seeded at low rates, cross seeded with native seeds and fertilized sparingly. At Swan Hills, Goff (1971) found without mulch or companion crops, grasses dominated, but legumes grew better with mulches or companion crops. A successful mulch treatment was simulated by spraying existing vegetation with glyphosate (Lloyd and Smoliak 1983). *Avena* species (oats) was used by Syncrude Canada as a companion crop to promote rapid soil stabilization and reduce erosion (Rowell 1977).

2.3. Species Mixes

Species mixes are used to maximize microsite variability. Mixes of native, introduced and mixed species have yet to be adequately addressed through research (Kerr 1993).

Although certain species give adequate to superior performance in a given mix, no criteria for plant species selection are apparent. Each seed company has its own mix for a given area and end land use. The key is to place these species in a mix which will achieve an adequate level of performance for a given end land use. Individual species performance in a mix may be more a function of intra and inter-specific competition, than of its ability to perform in a given ecosystem. For example, range managers have long used plants classified as increasers and decreasers as principal indicators of deteriorating or improving conditions, respectively.

Russell Ecological Consultants (1986) concluded three non-native grass legume mixes performed as well as four native grass mixes in cover, biomass and species richness. These mixes included *Agropyron dasystachyum* (northern wheatgrass), *Agropyron subsecundum* (awned wheatgrass), *Agropyron trachycaulum* (slender wheatgrass), *Deschampsia caespitosa* (tufted wheatgrass), *Festuca saximontana* (Rocky mountain fescue), *Koeleria macrantha* (june grass), Poa alpina (alpine bluegrass), *Poa interior* (bluegrass) and *Trisetum spicatum* (spike trisetum). Cultivated grass-legume mixes contained *Agropyron pectiniforme* (crested wheatgrass-Fairway), *Festuca rubra* (creeping red fescue-Boreal), *Phleum pratense* (timothy- Climax), *Poa compressa* (Canada bluegrass), *Trifolium hybridum* (alsike clover-Aurora) and *Trifolium repens* (white clover). The mixes producing the most cover had *Agropyron dasystachyum* and *Agropyron trachycaulum* (Russell Ecological Consultants 1986).

3. CONCERNS WITH USE OF NATIVE SPECIES

3.1. Seed Availability

One of the main reasons for low use of native plants is lack of a regular commercially available volume of species at an affordable price (Sutton 1975). Generally, the seed industry considers native plants slow to germinate and establish. Suitable seeding methods are required to produce large quantities of good legume seed (Smreciu 1993). Goff (1971) recommended local Alberta grown seed should be selected from varieties grown in sufficient quantities for large scale application. Research at Lethbridge and Vegreville, among others, is being conducted to develop suitable varieties of native seed for comercial propogation for use in reclamation. With no suitable seed source, the use of native hay as a seedbank may require an after-ripening period to break seed dormancy (Smreciu 1992, cited by Kerr et al. 1993).

3.2. Seeding Methods

No comprehensive guidelines for seeding native grasslands were found in a literature review (Kerr et al. 1993). However, recently, a few general publications have become available (Hardy BBT Limited 1989, Ducks Unlimited Canada 1995, Morgan et al. 1995, Gerling et al. 1996). Germination should coincide with the period of most abundant soil moisture. Spring seeding should be early, but not so early that seedlings may be subjected to heavy frosts (Vallentine 1989, cited by Kerr et al. 1993). Seeding in late fall may allow time for seedbed preparation; seeds are scarified by frost and soil movement while seed dormancy is broken by cool moist conditions over winter (Romo and Lawrence 1990, cited by Kerr et al. 1993).

Russell Ecological Consultants (1986) concluded the most successful methods of establishment were those which provided the most protection for the seed. These were drill seeding or broadcast seeding with a mulch treatment. Many native seeds are too small to be effectively drill-seeded and should therefore be broadcast (Kerr et al. 1993). Due to lighter smaller seeds, inadequate seeding rates and improper seed depths are achieved through drill seeding (Sadasivaiah et al. 1980). Additional studies are required for optimum seeding rates and depths for obtaining an adequate seedling establishment (Sadasivaiah et al. 1980).

In tallgrass prairie, seeding rates are typically 20 to 24 kg ha^{-1} for broadcasting and 10 to 12 kg ha^{-1} for drilling. More research is needed to understand why such rates are successful or if they are optimum (Collicut and Morgan 1990, cited by Kerr et al. 1993). No information is cited for mixed prairie or fescue grasslands, although similar rates have been used.

Drought at early stages of establishment may result in death of the seedlings (Mihajlovich 1979). Other causes of seedling mortality include frost heaving, lack of water, wind erosion, excessive grazing and damage caused by recreational vehicles (Takyi 1984).

3.3. Invasibility

A concern in reclamation is that non-native plant species are too aggressive and result in a monoculture or mix which does not allow other species to invade (Smreciu 1994). This may not be a concern in a hay field where species selection is based on maximum productivity by a minimum of plant species over a specific period of time. However, it should be a consideration in pastures and native range where sustained season-long productivity and ground cover may require plants which mature at different times.

Smreciu (1994) documented the invasion of native species on wellsites. Invasion depended primarily on the amount of competition by aggressive agronomic species (Smreciu 1994). Invasibility depended on the number of native species in the surrounding native stands and the density of the agronomic species they compete against (generally as ground cover decreased, diversity increased) (Smreciu 1994). Generally, agronomic grasses and legumes invaded more into grassland communities than the aspen or poplar woodlands. *Poa pratensis* (Kentucky bluegrass), *Poa compressa* (Canada bluegrass), *Phleum pratense* (timothy), *Festuca rubra* (red fescue), *Festuca longifolia* (hard fescue), *Festuca ovina* (sheep fescue), *Trifolium repens* (white clover) and *Bromus inermis* (smooth brome) invaded surrounding native communities. A greater diversity of native species re-established on a grazed site where agronomic species were kept under control by grazing.

4. GENERAL MANAGEMENT CONSIDERATIONS

Before native plant use in Alberta will be accepted readily by industry and can expand, some basic questions need to be answered. We still know relatively little about the management of native plant species. We try to seed them the same way we seed agricultural forages (with a seed drill and all at the same time). We do not know whether weed management and fertilization of native species will enhance their establishment and/or development or if we can view them as low input crops. We need to determine the length of time for stand establishment and both the initial and long-term use.

Another major question to be addressed before native species will be more widely used is how do native and agronomic species compare. Although productivity data are available to show agronomic species are often more productive (biomass) than native species, few other aspects have been addressed in direct comparison studies. For example, it is often assumed native species are less demanding requiring little if any fertilization or weed maintenance. Yet industry is often concerned about eliminating weed management since they have few data to show whether native species will compete well with weedy pioneer species in the agricultural zone that must be managed when seeding agronomic species.

Duebbert et al. (1981, cited by Kerr et al. 1993), stated that inadequate weed suppression is the leading cause of grass seeding failures. Since weeds frequently cause more damage than a companion crop, a companion crop is preferred in weedy areas (Walton 1983).

Weed control by herbicides is currently limited as few herbicides are registered for use in hay or pasture plantings. Few data are available on native species as most registrations are on licensed native and non-native species which are used for agronomic purposes.

At early stages of plant growth mowing is preferred to herbicide spraying, provided compaction is not a problem. Mowing can reduce annual and perennial weeds which generally outperform the seeded mix. Mowing also increases litter-to-ground contact (improves biocycling) and tillering in many grass species. Generally, post-emergent weed spraying tends to slow the development of, or cause a reduction in, seedling grass and legume stands (particularly emerging plants).

5.THEORETICAL CONSIDERATIONS

Niche is a term for specialization of a species population within a community (Whittaker 1971). Niches are species specific, responding to environmental gradients. Each species has an ideal range or set of environmental conditions. It is proven that plants do better in their own ecological niche. A community is a system of interacting, niche differentiated species populations that tend to compliment one another. Species co-exist along overlapping environmental gradients. Species tend to share parts of other species fundamental niches. These in turn form communities. Most organisms do not inhabit their potential, fundamental niche. Rather, due to interactions with other organisms, they occupy a reduced, realized niche (Giller 1984).

Ecological succession implies that niches are dynamic, succession being the changes observed in an ecological community over time, at a single location due to a disturbance. Initial competition by ruderals (weeds) may determine the final composition of a plant stand. All native plant species do not react the same. Connell et al. (1977) proposed three models for or mechanisms of succession. The facilitation model suggests that early succession plants prepare the way for later species. The tolerance model suggests that later species have evolved to tolerate lower levels of resources than earlier species. The inhibition model suggests that all species resist invasions by competitors.

There is species uniqueness regardless of the plant being native or introduced. All native plants are not equal. Grouping is based on country of origin. Are they unique enough or distinct enough to compare as groupings? Each has a specific niche and plays a role in ecological succession. Tilman et al. (1996) state that biodiversity influences ecosystem productivity, sustainability and stability. This is consistent with Grime's (1973) reiteration that the greatest diversity occurs in the moderate or middle range of a physiological gradient. Four consistent features of competitive species were recognized by Grime (1973) (tall stature, genotypic growth form allowing extensive use of below and above ground environments-rhizome or tufted, maximum potential relative growth rate and a tendency to deposit a dense layer of litter on the ground surface).

Grime (1977) proposed three primary strategies for succession in plants based on stress and disturbance, stress being defined as the external constraints that limit the rate of dry-matter production of all or part of the vegetation. These strategies, although based on extremes, are considered viable as plant habitats. They are low stress with low disturbance (competitive plants), high stress with low disturbance (stress-tolerant plants) and low stress with high disturbance (ruderal plants). There is phenotypic and genotypic variation in the competitive ability of a plant species (competitive). Dry matter production is subject to a wide variety of environmental constraints (stress-tolerant). Severe disturbance selects species with phenologies adapted to exploit temporarily favorable conditions (ruderal). The high rates of carbon and nutrient acquisition necessary to support a rapid growth of competitive and ruderal species are best attained in a fertile unshaded environment where light and water are not unduly limiting (Chapin 1980).

Plants were chosen for this study based on their adaptation to the parkland area. They are adapted to this particular ecological system and zone. Some species will do better than others because they are provided with closer to their ideal conditions (soil temperature, nutrients and soil moisture). Individual species have specific ideal parameters. Planting of species adapted to a particular ecological zone is an attempt at promoting ecological succession to achieve a community for a desired end land use. Specific desirable attributes of individual species are selected to maximize the potential of reaching this goal.

Management of populations, through mowing and the use of herbicides, has been used to direct succession. Mowing and the response of individual plants to the removal of topgrowth are critical to further succession. Plant species ability to utilize stored carbohydrates are important to community development after mowing. Mowing may also involve a radical change in population structure of plants by affecting apical dominance (Luken 1990). The removal of annual plant species which may have the added benefit of nutrient recycling for future populations while reducing future competition through the prevention of seed set. Herbicides are used as a management technique to eliminate undesirable plants or a species from a population, This may direct the future development of a plant community. Of concern are the selectivity of the herbicide(s) and the affect on non-target species.

6. RESEARCH JUSTIFICATION

Since the oil drilling industry started in Alberta, over 110,000 ha have been disturbed (Sims et al. 1984), most on agricultural lands. Pipelines constitute approximately 40% of this total. In 1981, Hardy Associates (1978) Ltd. (1983) estimated that approximately 303,300 ha of Alberta's forested land had been disturbed by petroleum construction and related activities. Of this total area, seismic lines composed 70% with an additional 10% in oil and gas roads and well sites. Other natural resource extraction constitutes a significant area of disturbance. Areas presently dominated by native species will need to be reclaimed with native species. A great potential remains as well for improving tame pasture and haylands and for dealing with concerns associated with problem soils such as the salt affected Solonetzic soils (estimated to be over 4,000,000 acres in Alberta) (Pawluk 1994). Wind and water erosion and degradation must be addressed on all the above. Non-row planted native species can help address erosion concerns. Specific native plant species may have evolved which are better adapted to a given soil, climate and topography and end land use. The use of native species needs to be encouraged to protect existing healthy native communities, to restore disturbed areas and to establish wildlife corridors between existing protected areas as well as to enhance livestock utilization.

The literature contains many references on desirable traits of native species. However, there are few or no scientific data to support these claims. Present research contains many contradictions on plant species selection and establishment. More research is required to determine the competitive advantage of native plant species over introduced plant species, should it exist. Site variability in climate, topography, nutrient availability, soil and plant species composition make it difficult to make any direct comparisons or correlations. Present research into ecovars is a further attempt to select plant species best adapted to a specific site.

There is still a need for research into plant species selection, focusing on intra and interspecific competition, establishment considerations (fertilization, companion cropping, weed control, topdressing) and invasibility as it relates to specific end-land use. The goals of industry, agriculture and restorationists can best be attained through applied research and in the comparison of established plant stands. Thus the overall objective of this research is to compare native and introduced species establishment and survival under mowing and herbicide treatments in the establishment period.

7. REFERENCES

Alberta Agriculture. 1992. Agricultural statistics yearbook. Print Media Branch, Alberta Agriculture. Edmonton, AB. Agdex 853-10.

Alberta Agriculture. 1981. Alberta forage manual. Print Media Branch, Alberta Agriculture. Edmonton, AB. Agdex 120/20-4. 86 pp.

Alberta Agriculture, Food and Rural Development. 1995. Varieties of perennial hay and pasture crops for Alberta. Publishing Branch, Alberta Agriculture, Food and Rural Development. Edmonton, AB. Agdex 120/32. 7 pp.

Alberta Environmental Protection. 1995. Reclamation criteria for wellsites and associated facilities. 1995 Update. 62 pp.

Burton, P. 1991. Ecosystem restoration versus reclamation: the value of managing for biodiversity. Reclamation and Sustainable Development Seminar. Sixteenth Annual CLRA Meeting. Kamloops, BC.

Chapin, S.F.III. 1980. The mineral nutrition of wild plants. Ann. Rev. Ecol. Syst. 11:233-260.

Collicutt, D.R. and J.R. Morgan. 1990. Tall grass restoration project 1990 report. Prepared by Prairie Habitats for Hoechst Canada Inc., Agriculture Division and Wildlife Habitat Canada.

Connell, J.H. and R.O. Slater. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. Amer. Natur. Vol .3, No. 982. Pp. 1122-1144.

Ducks Unlimited Canada. 1995. Revegetating with native grasses. Native Plant Materials Committee. 133 pp.

Duebbert, H.F., E.T. Jacobson, K.F. Higgins and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat for the prairie porthole region. U.S. Department of Interior. Fish and Wildlife Service. Special Scientific Report - Wildlife No. 234. Washington, DC. 20 pp.

Gerling, H.S., M.G. Willoughby, A. Schoepf, K.E. Tannas and C.A. Tannas. 1996. A guide to using native plants on disturbed lands. Alberta Agriculture, Food and Rural Development and Alberta Environmental Protection. Edmonton, AB. 247 pp.

Giller, P.S. !984. Community Structure and the Niche. Chapman and Hall, New York. 176 pp.

Goff, C.D. 1971. Erosion control research in Swan Hills. Alberta Forest Service, Department of Lands and Forests. Edmonton, AB. 92 pp.

Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its its relevance to ecological and evolutionary theory. Amer. Natur. Vol.3, No.982. Pp. 1169-1194.

Grime, J.P. 1973. Competitive exclusion in herbaceous vegetation. Nature 242: 344-347.

Hardy Associates (1978) Ltd. 1983. Evaluation of pipeline reclamation practices on agricultural lands in Alberta. Land Conservation and Reclamation Council. Edmonton, AB. Report # RRTAC 83-3. 186 pp.

Hardy BBT Limited. 1989. Manual of plant species suitability for reclamation in Alberta - 2nd Edition. RRTAC Report #89-4. Edmonton, AB. 436 pp.

Hofmann, L. and R.E. Reis. 1983. Relationship of runoff and soil loss to ground cover of native and reclaimed grassland. Agron. J. 75: 599-602.

Kerr, D.S., L.J. Morrison and K.E. Wilkinson Environmental Management Associates. 1993. Reclamation of native grasslands in Alberta: A review of the literature. RRTAC Report #93-1. Edmonton, AB. 246 pp.

Lloyd, D.A. and K.S. Smoliak. 1983. Revegetation and reclamation of sandy regosols: Proceedings of the Eighth Annual Meeting. Canadian Land Reclamation Association. Calgary, AB. 23 pp.

Luken, J.O. 1990. Directing Ecological Succession. Chapman and Hall. New York. 251 pp.

Mihajlovich, M. 1979. Influence of agronomic grass-legume mixtures on the establishment and growth of commercial softwood tree species. Alberta Forest Service. Edmonton, AB.

Morgan, J.P., D.R. Collicut and J.D. Thompson. 1995. Restoring Canada's native prairies. Argyle, MB. 84 pp.

Pawluk, S. 1994. Soils 420 Class Notes. University of Alberta. Edmonton, AB.

Romo, J. and D. Lawrence. 1990. A review of vegetation management techniques applicable to Grasslands National Park. Canadian Parks Service Technical Report 90-1/GDS, Environment Canada. Pp. 1-63.

Rowell, M. 1977. Continued studies of soil improvement and revegetation of tailings sand slopes. Norwest Research Ltd. Environmental Research Monograph 1977-4. Prepared for Syncrude Canada Ltd. by Norwest Soil Research Ltd. Edmonton, AB. 156 pp.

Russell Ecological Consultants. 1986. Reclamation with native grasses in Alberta: Field trial results. Alberta Forestry, Lands and Wildlife, Forest Services. Edmonton, AB. 57 pp.

Sadasivaiah, R.S. and J. Weijer. 1980. The utilization and genetic improvement of native grasses from the Alberta Rocky Mountains. Department of Genetics. University of Alberta. Edmonton, AB. 125 pp.

Sims, H.P., C.B. Powter and J.A. Campbell. 1984. Land surface reclamation review of the international literature. Alberta Environment Reclamation Research Technical Advisory Committee Report Number 84-1. Edmonton, AB. 1549 pp.

Smreciu, A. 1992. Personal communication. Consultant, Wild Rose Consulting Inc. Edmonton, AB.

Smreciu, A. 1993. Native legumes for reclamation in Alberta. RRTAC Report #93-9. Edmonton, AB. 94 pp.

Smreciu, A. 1994. A survey of native and agronomic plants on gas well sites in southwestern Alberta. RRTAC. Edmonton, AB. 45 pp.
Strong, W.L. and K.R. Leggat. 1992. Ecoregions of Alberta. Alberta Forestry, Lands and Wildlife. Edmonton, AB. 55 pp.
Sutton, R.K. 1975. Why native plants aren't used anymore. J. Soil Water Conserv. Sept-Oct. Pp. 240-242.
Takyi, S.K. 1984. Role of topsoil, fertilizers and companion crops in revegetation of two severe sites in the Alberta foothills and mountains. Alberta Energy and Natural Resources. Edmonton, AB. 29 pp.
Takyi, S.K. and R.M. Islam. 1984. Performance of native grasses and cultivated legumes and grasses and disturbances in the eastern slopes of the Rockies. Alberta Energy and Natural Resources, Forest Service. Edmonton, AB. 30 pp.
Tilman, D., Wedlin, D. and J. Knops. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature Vol.379. Pp. 718-720.
Trottier, G.C., 1992. Conservation of Canadian prairie grasslands: a landowner's guide. Environment Canada; World Wildlife Fund; North American Waterfowl Management Plan. Pp. 1-92.
Vallentine, J.F. 1989. Grazing management. Academic Press. San Diego, CA.
Walton, P.D. 1983. Production and management of cultivated forages. Reston Publishing Company Inc. Reston, VI. 336 pp.
Whittaker, R. H. 1971. Communities and Ecosystems. The Macmillan Company, New York. 58 pp.

II. EMERGENCE AND SURVIVABILITY OF SELECTED NATIVE AND INTRODUCED PLANT SPECIES IN RESPONSE TO MOWING IN THE ESTABLISHMENT PERIOD

1. INTRODUCTION

There are numerous anecdotal references to native plant species being more desirable for reclamation and resource conservation than introduced plant species because they are better adapted to less than ideal growing conditions (compacted soils, hostile unprotected sites), require fewer inputs (fertilizer, moisture) and have greater longevity. However, little research has been conducted to test that hypothesis or on direct comparisons of native and introduced species for agricultural or reclamation purposes.

The ability to emerge, survive and develop a rapidly establishing cover is essential in reducing erosion potential and developing sustainable cover, particularly on newly reclaimed industrial or erosion prone agricultural sites. Although research has been conducted on surface mined areas in the foothills and mountains in Alberta (Tayki 1967, Takyi and Islam 1967), little information is available on plant species of the central Alberta parkland. Research in the parkland on ground cover development in the establishment period is currently being conducted at the University of Alberta (Naeth 1997), but it is in the early stages and only preliminary data are available.

One of the natural seed characteristics of species which have not been subjected to intensive breeding or domestication is deep dormancy (Larsen 1980). This is an important survival mechanism for these species enabling them to survive long term stress (e.g. drought, flood) and is also one of the reasons they are desirable for the revegetation of many hostile sites (Larsen 1980). A conflicting goal within reclamation is that this may make native plants less desirable in situations where a rapidly establishing ground cover is required. Seed dormancy or the inhibition of germination is not well understood. It is therefore possible that a degree of dormancy exists within the native species gene pool which has been selectively bred out of the introduced plant species gene pool, resulting in the introduced plant species having a higher initial germination and survival rate than the native plant species.

Mowing may be a management tool to reduce the amount of bare ground in a newly established site. Mowing can be used for tiller enhancement that will subsequently lead to increased ground cover, reduced weed competition and higher productivity. Mowing can also increase fallen litter, thereby also reducing bare ground. As cutting height was reduced within the tolerance range of a given species (generally being from 0.5 to 10 cm), the size of individual plants decreased but tillering and increased shoot density occurred if the stem apex was removed (Beard 1971). Paulsen and Smith (1969) found the relationship between number of tillers and regrowth after mowing was poor for *Bromus inermis*. However, after heading number of tillers developed by basal axillary buds increased through mowing.

Mowing has been used for maintenance of specific species by providing a selective advantage to those species that can tolerate defoliation. Mowing can eliminate some species by causing a break in their life cycle. It can reduce or eliminate populations of other species if conducted when carbohydrate reserves are low or depleted thereby starving the plant. Mowing can be used as a management strategy to control species populations or as a surrogate for grazing. Timing of mowing is critical. Annuals must be mowed prior to seed production and seed set and perennials must be mowed prior to carbohydrate store replenishment. Frequent mowing can kill a plant, but it is expensive and impractical in many agricultural and reclamation scenarios. Thus knowledge of the optimum timing of one or two defoliations is necessary.

There is also a belief that weed species perform a valuable ecological function in providing short term ground cover (Naeth 1997). If seeded species can compete with weed species during the establishment phase, the weed species provide the necessary rapidly establishing ground cover for erosion reduction later on in the establishment of the stand. The perennial seeded species assume dominance. Mowing once or twice in the establishment period may allow the necessary ground cover provided by the weed species, but control them to the extent that they do not dominate the stand and compete too heavily for often scarce resources (netrients, water, light, space). Competition for such resources is of critical concern in the establishment period of perennials, particularly since many nonseeded species are adapted to compete for resources when they are limited.

2. OBJECTIVES AND HYPOTHESES

2.1. Objectives

The objectives of this research were to:

1. Evaluate emergence and survivability of selected native and introduced plant species (grasses and legumes) and plant species mixes during the establishment period.
2. Evaluate the response of selected native and introduced plant species mixes to early and late season mowing in the establishment period.

2.2. Hypotheses

The hypotheses to be tested were:

1. Native and introduced plant species emerge and develop at the same rate.
2. Native and introduced plant species have the same overwinter survivability.
3. Native and introduced plant species respond the same to mowing through tiller enhancement and a decrease in weed competition.

3. MATERIALS AND METHODS

3.1. Site Description

The study site is located at the Agriculture and Agri-Food Canada Lacombe Research Centre (52° north latitude and 113° west longitude). The climate is continental prairie and is mildly affected by chinook winds most winters (Environment Canada 1991). The moisture regime is sub-humid with 446.9 mm of annual precipitation (de St. Remy 1990). Mean annual air temperature is 2.3 °C with average high temperatures ranging from -13.8 °C in January to 16.1 °C in July.

The soil on this site is classified as an Eluviated Black Chernozem (Malmo series), developed from fine glaciolacustrine parent material of loam to sandy loam texture. Soils are black silt loam at 0 to 30 cm, dark brown silty clay loam at 30 to 71 cm and dark brown loamy clay at 71 to 107 cm (Agriculture Canada unpublished data). The site is located on a low slope ranging from 1 to 6 degrees with a slight northerly aspect. Average elevation is 870 m above sea level.

3.2. Experimental Design

Nine plant species mixes (four native, four introduced, one mixed) were each replicated four times in a randomized split block (Figure 1, Appendix A). Treatment plots were 10 by 30 m in size. Species and mowing treatments are discussed in Sections 3.4 and 3.5.

3.3. Site Preparation And Seeding

The plot area was summerfallowed in 1994 and cultivated, harrowed and packed in the week prior to seeding in 1995. Each species mix was seeded with a four row plot seeder with hoe-type openers and packing wheels. Soil moisture conditions were optimum at the time of planting. Replicates were seeded in a north-south direction with the blocks aligned west-east. Seeding depth was approximately 1.3 cm. After seeding on May 23 to 25, 1995, a Brillion grass seeder, run at right angles to the seeded rows, was used to pack the seed and minimize row ridging. *Agropyron pectiniforme* L. Gaertn. (crested wheatgrass) was seeded in the roadways.

3.4. Plant Species Treatments

Mixes were of introduced species commonly used in the study area and native species present in the study area. Each mix consisted of four grasses, one legume and an annual or short-lived species. It was anticipated that annual or short-lived species would deter weeds and provide rapid cover for erosion control. The other species would provide a layered canopy to enhance cover. The nine mixes consisting of six species each (thirty-five species) were selected and developed, based on percentages and criteria outlined in Table

1 (Appendix A). Mix compositions are listed in Tables 2 and 3 (Appendix A); mixes 1 through 4 were native, mixes 6 through 9 were introduced and mix 5 was of introduced and native species.

Seed analysis certificates were obtained and germination, tetrazolian and purity tests were conducted as required. Certified varieties and ecovars were used, if available. Alfalfa, clover and sainfoin inoculants were added to the seed at packaging for alfalfa, alsike clover and American vetch seed, respectively. American vetch seed was scarified with sand paper. Seeds were weighed based on 1000 seeds and prepackaged prior to seeding. Seed distribution was based on 22.9 cm row spacing at 350 live seeds m^{-2}. This number was a compromise between agricultural productivity and reclamation ground cover requirements. Reclamationists use 175 to 250 plants m^{-2} while agriculturalists use 250 to 800 plants m^{-2} based on the species selected. Seed numbers were based on the following formula: [350 seeds m^{-2} x plot area (10 x 40 m) x % in mixture divided by number of seeds kg^{-1} x germination rate x % pure live seed (PLS)]. Calculations for native and introduced species seed mixes are presented in Tables 4 and 5 (Appendix A), respectively. Seeded species are listed in Table 6 (Appendix A).

3.5. Mowing Treatments

Four mowing treatments, no mow (NM), mow early (ME), mow late (ML), mow early and late (MEL)] were implemented. The first mowing was conducted with a 1.83 m three point hitch flail mower on July 15, 1995 when the majority of the weeds were in full bloom and some were starting to set seed. Mowing was conducted at a height of 11 cm to cut above seeded species, potentially reducing weed competition. The north halves of Blocks 1 and 4 and the south halves of Blocks 2 and 3 were mowed. A second random mowing was conducted with a 4.27 m swather at an 8 cm height, on the east or west half of each replicate on September 2, 1995. The mowed vegetation was removed to prevent covering of standing vegetation and subsequent loss of seedlings due to smothering.

3.6. Preliminary Soil Sampling And Analysis

In year one (1995), prior to seeding, soil was sampled at eight locations per block in sample depth increments of 0 to 5 and 5 to 15 cm then composited. Samples were analyzed by Norwest Labs for sodium adsorption ratio (SAR), pH, electrical conductivity (EC), nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) according to M^{c}Keague (1978). Fertilizer was not added as initial soil fertility was at the optimum recommended level for introduced species (Table 7, Appendix A).

3.7. Vegetation Field Measurements

A 1 m buffer was left unsampled on the border of each treatment to eliminate edge effects. Vegetation measurements were made in five randomly placed 0.1 m^2 (20 x 50 cm) permanent quadrats per treatment. The quadrat frame was placed lengthwise at right angles across two seeded rows. All quadrats were marked with a washer and 15 cm spike in the top left and right hand corners and a colored marker flag in the top left hand corner. Each pin and washer combination was sprayed with fluorescent paint to enable long-term location. A magnetic pin finder was used to locate pins.

3.7.1. Plant density and survivability

Density of grasses, legumes, forbs and weeds was determined in each fixed quadrat (5 per mowing treatment per mix) weekly in June and July, every second week in August and once in September 1995 and once a month in 1996 (May to August, inclusive). Individual plant species density was assessed from 21 to 30 of August 1995, 22 to 29 of May 1996 and 6 to 16 of August 1996. Average emergence and survivability were based on [number of plants per 0.1 m^2 quadrat x 10 / number PLS planted of that species per m^2 x 100]. Survivability of individual species was limited to 100% to minimize the effect of seed recruitment from seeded sources of a given species (this affected <2% of quadrats). To standardize plant counts, only two seeded rows were included in the quadrat.

3.7.2. Ground cover

Ground cover was visually assessed in each fixed quadrat as percent live vegetation, litter, bare ground, rock and moss cover. All vegetation at ground lewel , growing in the frame and lying on the ground, even if it originated outside the frame, was included. Any vegetation with direct ground contact was classified as ground cover. Leaves from forbs, which had fallen on the ground, were categorized as ground cover. The live vegetation (any vegetation which showed signs of green) was assessed by drawing the stalks and leaves loosely together at approximately 5 cm from the ground surface and comparing this circumference to a known measured cross section. Litter (dead material, vegetation not showing signs of green), bare ground, rock and moss cover were assessed as that present within 2 cm of the ground surface and compared to a known cross section.

3.7.3. Canopy cover

Canopy cover was assessed by looking directly down onto each fixed quadrat and assessing the percent of live vegetation, litter, bare ground and rock and moss cover present and comparing this area to a known measured cross section. All vegetation in the frame was included in the assessment whether or not it was rooted in the frame.

3.7.4. Leaf area index (LAI)

An LAI meter (Model 2000) was used to take eight random measurements (later averaged) below each mowing treatment canopy by placing the meter sensor at ground level against a row. The sensor was shaded to provide uniform light exposure and a 90 degree insert was used to gather indirect and reflected light. An initial reading taken above each canopy was used as a reference point and to compensate for changing sunlight angles. LAI measurements were used to give an indication of canopy density and hence ground cover.

3.7.5. Plant height

Plant height was determined by measuring the longest portion of a plant and averaging the height of the plant species present. Average canopy height, based on three levels, was measured with a meter stick and recorded, if present, in each of the fixed quadrats at the end of each growing season.

3.7.6. Tillering

The number of tillered plants per species was determined by counting at the beginning of the second growing season and at the end of each growing season (fall 1995, spring 1996, fall 1996).

3.7.7. Productivity

A disc meter was used to determine volume of forage in each treatment. This device consisted of a round weighed disc (200 g $\pm$ 1 g, 30.5 cm diameter) which slid up and down a calibrated pole. The disc was placed primarily on seeded species in 5 random sites per treatment and disc resting ight was recorded. An increase in this height corresponds to an increase in forage volume under the disc. This stratified, random sampling was conducted on seeded species as excessive growth, height and stem strength of the weed species would negate specific results pertaining to seeded species present. Main and two-way effects and appropriate error terms were partitioned according to Block, Mix, Replicate and Season.

3.8. Statistical Analyses

SPSS Release 6.1.3 (August 24, 1995) was used for K-means cluster classification on the survivability data to determine if there were group associations. Survivability of each species in each mix for each mowing treatment was computed with Excel 5.0. Four clusters were analyzed per treatment per sampling date. Cluster centers of native and introduced species were analyzed to determine if significant differences existed. All zero values were replaced with 0.9 to allow the program to run without discarding any values or interactions. All species percentages used for percent survivability of mix data were adjusted based on 100% to minimize the effect of reseeding from the first year's seed production.

Ground cover and canopy cover data were converted to a value of 1 and analyzed with a custom model within the general linear model (ANOVA, SPSS 7.0) after square root of square root transformations as determined after normality (Montgomery and Peck 1982, Kuehl 1994) (Table 10). Residuals were plotted against a normal distribution curve. Bar charts were also used to plot the uniformity of the means among groups. Normal Q-Q plots were used to pair observed values against expected values from a normal distribution (Taerem 1997). Density and survivability data were transformed using natural log transformation (Prasad 1997). LAI, disc meter and height measurements did not require transformation as they are discrete data (Prasad 1997). Tukey's HSD was used to statistically rank treatment means at 95% confidence.

3.9. Air Temperature And Precipitation

A meteorological station adjacent the site included a Sierra-Misco Inc. Model RG2501 tipping rain gauge to measure precipitation and a Campbell Scientific Co. Model 101 temperature probe to monitor air temperature. This equipment was mounted on a Campbell Scientific Model CM10 tripod and connected to a Campbell Scientific Inc. Model CR21 micrologger. Data collected from 1908 to 1992 were used for long term normal values. Measurements were recorded hourly then converted into daily minimum and maximum temperatures and daily precipitation. Data are presented as mean minimum and maximum monthly air temperature (°C) and monthly precipitation.

4. RESULTS

4.1. Air Temperature And Precipitation

Precipitation for the research period (1995 and 1996) was generally higher than the long term normal (Table 8, Appendix A). Precipitation for September 1995 was very low (21% of long term normal). Mean monthly temperatures were near their long term normals.

4.2. Plant Density And Survivability

Seeded and nonseeded plant species found in the treatments are listed in Tables 6 and 9 (Appendix A), respectively.

4.2.1 Plant density

In fall 1995, spring 1996 and fall 1996 there were no consistent significant differences between native and introduced seeded or nonseeded (weedy and volunteer) species densities (Table 2.1). The range of seeded densities was high, with 12 to 95 plants m^{-2} for native species and 15 to 104 plants m^{-2} for introduced species. Variability among sampling quadrats was also high. Mowing did not significantly affect either native or introduced seeded species densities. Seeded species densities were similar throughout the three measurement times for introduced species but increased for native species from fall 1995 to spring 1996. Although not generally statistically significant, mix 1 consistently had the lowest seeded plant density of all mixes. Mixes 2 and 3 had high seeded plant densities across all dates; mix 8 had high seeded plant densities in fall 1996. Nonseeded species densities were very dynamic over time; being very high in spring 1996 then declined by fall 1996. Nonseeded species densities were very high in mixes 3, 4, 8 and 9 in spring and fall 1996.

4.2.2. Plant survivability

Cluster analysis of individual plant species survivability indicated that block, mix and native or introduced categories explained less than 10% of the variation shown. Therefore the ANOVA model was utilized for more accurate analysis of the data.

Plant survivability was species dependent (Table 2.2), with seeded species with large seeds having a higher survivability than those with small seeds. Survivability of individual species ranged from 0 to 83% of PLS with high values in both native and introduced categories. *Agropyron* and *Bromus* species had highest survivability. Other species with high survivability were *Dactylis glomerata*, *Elymus dahuricus*, *Festuca elatior*, *Lolium perenne*, *Secale cereale*, *Stipa viridula* and *Vicia americana*. Species with the largest survivability decline from spring to fall 1996 were *Agropyron smithii* and *Vicia americana*. *Bromus biebersteinii* and *Bromus inermis* had the largest survivability increase. Grass companion crops (*Bromus anomalous*, *Secale cereale*, *Elymus dahuricus*, *Lolium perenne* and *Bromus inermis*) to compete with weedy species and provide initial erosion control were still present, but in reduced numbers, in fall 1996 (Table 2.2).

There was no significant trend in individual species survivability with the specified mowing treatments. However, several species responded to mowing (Table 2.2). *Agropyron elongatum*, *Agropyron intermedium* and *Agropyron trachycaulum* all survived better under NM. *Lolium perenne* survived better with ML and *Secale cereale* survived best under MEL.

Survivability, from a mix perspective, was generally similar for all mixes and mowing treatments across all dates, ranging from 4 to 26% (Table 2.3). Although not statistically significant, mixes 1 and 4 had the lowest overall survivability.

4.3. Ground Cover

In fall 1995 and 1996 there was no significant difference in bare ground between native or introduced mixes (Table 2.4). However, the introduced species mixes averaged 75% bare ground in fall 1995 whereas the native species averaged 89%, an important difference from a practical perspective. Bare ground was significantly reduced from 80 to 85% in fall 1995 to 20 to 25% in fall 1996. This decline was particularly evident in mixes 3 and 8. In fall 1996, numerous significant differences in bare ground occurred, with mixes 1, 4, 5 and 9 having the highest bare ground.

In fall 1995, bare ground was significantly higher under ME than under NM treatments for four (1, 4, 5, 6) of the nine mixes. Mowing in fall 1995 significantly affected bare ground for six (1, 2, 4, 6, 7, 8) of the nine mixes. In these significant cases, bare ground was higher under ML and MEL than under NM or ME treatments. From a practical perspective focusing on absolute values, mixes 1, 4, 5, 6, 7 and 8 were affected by mowing, with NM or ME reducing bare ground for introduced species but with variable results for native species (mix 4 had less bare ground under NM than any early mowing but mix 1 had less bare ground under ME).

In fall 1995 and 1996 litter cover was significantly lower in the ME treatment for mixes 5 to 9, inclusive (Table 2.5). In fall 1995 there were significant differences in litter among mixes with mixes 5 and 9 having significantly higher litter for both mowing treatments. In fall 1996 significant differences among mixes continued, but with mixes 5 and 9 having lowest litter; mix 1 also had low litter at that time. Litter ranged from 43 to 87% in fall 1996, a dramatic increase from 3 to 24% in fall 1995. From a practical perspective, absolute values for litter cover were only affected by mowing in mixes 6 and 7, where NM or ME was best.

4.4. Canopy Cover

In fall 1995 there were significant differences in bare ground between mowing treatments for all four native species mixes and one introduced species mix (mix 8) with ME treatments having more bare ground than NM treatments (Table 2.6). There was a large decline in bare ground from fall 1995 to fall 1996; values were very low in 1996, ranging from 0 to 11%. Significant differences among mowing treatments in fall 1996 were few; only in mixes 5, 8 and 9. In these cases the absolute differences in bare ground among mowing treatments were small (< 9%). In fall 1995 there were significant differences in bare ground among mixes, with the highest amounts in the native mixes. In fall 1996 absolute differences among mixes for a given mowing treatment were very small.

The response to mowing on canopy cover was species specific but was also affected by mix (Table 2.7). *Agropyron smithii*, *Stipa viridula*, *Vicia americana*, *Bromus inermis* and *Secale cereale* all had high canopy covers. *Agropyron smithii* responded differently to mowing in mix 2 than in mix 4, being higher in the latter. Similarly *Stipa viridula* was reduced more with mowing in mix 5 than in mix 2; *Bromus inermis* was higher in mix 7 than in mixes 5 and 9; *Dactylis glomerata* was higher in mix 8 than in mixes 5 and 9.

Canopy litter was generally low, especially in fall 1995, with a maximum value of 17% in mix 4 in 1996 (Table 2.8). Litter increased from fall 1995 to fall 1996, especially in mixes 3 and 5. Significant differences among mowing treatments and mixes were few.

In fall 1995 canopy composition by seeded species was statistically higher for ME than NM treatments for all mixes except 2 and 3 (Table 2.9). Although not statistically significant, seeded species had a lower canopy cover percent in native mixes than in introduced mixes. By fall 1996 there was a large increase in canopy cover of seeded species, with native mixes again generally having lower canopy cover than introduced mixes. In fall 1996 there were generally no significant differences in canopy cover among mowing treatments, with the exception of mix 4 which was lowest under ML.

The response of canopy cover to mowing was species specific (Table 2.10). *Bromus* and *Agropyron* species, along with *Dactylis glomerata*, *Elymus dahuricus*, *Lolium perenne*, *Secale cereale*, *Stipa viridula*, *Festuca elatior* and *Vicia americana* had the highest canopy cover under all treatments. *Bromus inermis* and *Agropyron elongatum* increased with NM or ME. The development of canopy levels was not affected by mowing treatments (Table 2.11).

4.5. Productivity

4.5.1. LAI

There were significant differences in LAI among mowing treatments in fall 1995 in five of nine mixes, mixes 1, 4, 5, 6 and 9 (Table 2.12). However, there was no consistent trend among mowing treatments. Significant effects of mowing occurred again in fall 1996, in all but mixes 3 and 9. At this time LAI under ML was generally lowest, with LAI higher under either NM and ME treatments. There was a large increase in LAI from 1995 to 1996 for all mixes except 5 and 9 which already had high LAI in fall 1995. Fall 1995 LAI of introduced mixes and the native/introduced mix were generally significantly higher than those of native mixes. This was only true for mixes 6, 7 and 8 in fall 1996.

4.5.2. Disc meter height

In fall 1995 there were significant differences in disc meter values among mowing treatments in only three of the nine mixes; mixes 1, 2 and 9 (Table 2.13). By fall 1996 there were no significant differences among mowing treatments. Disc meter heights increased dramatically from fall 1995 to fall 1996; 4 to 6 fold for native mixes and 2 to 3 fold for introduced mixes.

There were significant differences in disc meter values among mixes in both fall 1995 and fall 1996. In fall 1995 mixes 3 and 4 had the lowest values. In fall 1996 mix 1 had this distinction. The introduced mixes generally had higher values in both years than did the native mixes, but especially so in 1995.

4.5.3. Plant height

There were significant differences in plant height in fall 1995 among mowing treatments for mixes 1, 2, 4, 5, 6 and 7, with plant height under the ME treatment consistently and significantly lower than the plant height under NM (Table 2.14). However, by fall 1996, plant height was significantly different among mowing treatments only for mix 5.

In fall 1995 mix 1 was higher than other native mixes; as was mix 8 in the introduced mixes. In fall 1996 mixes 5 to 9, inclusive, had similar heights, which were significantly greater than that for mix 3, which was lowest across all mowing treatments on both dates.

Height increased 2 to 3 fold from 1995 to 1996 for native mixes, 2 fold for the native introduced mix and 50% to 2 fold for introduced mixes. There were no consistent species trends between mowed and unmowed treatments in 1995 or 1996 (Table 2.15).

4.6. Tillering

There was generally no effect of mowing on number of tillered plants (Table 2.16). For the native mixes and mix 5, this number increased from fall 1995 to spring 1996, then declined slightly or stayed constant to fall 1996. In contrast, the introduced mixes declined in number of tillered plants from fall 1995 to spring 1996 then increased again by fall 1996 to fall 1995 levels. Approximately 90% of all plants tillered.

5. DISCUSSION

5.1. Survivability

The low densities of seeded mixes (4 to 17% of pure live seed (PLS)) after two growing seasons supports the literature. Ducks Unlimited Canada (1996) found that native seedling establishment was normally 20 to 25% of the PLS seeding rate. Munshower (1994) found that field emergence for small seeded grasses and forbs was 52% if germination was greater than 80%, 33% if germination was between 60 to 80%, or a combined average field emergence of 50%.

Although overall survivability did not not differ between measurement times in 1995, many seeded species emerged and died as seedlings. These dead seedlings were only counted in the plant group categories (grasses, legumes, forbs) so it is not known if the species with low end of year survivability actually had higher emergence but died as seedlings or if emergence and survivability were both low. The number of species in the seed mix (6) was higher than number of species that survived in each mix. Only mix 2 had four or more species survive at an average level over 2% under all mowing treatments. Some species with low survivability had small seed size and may have been seeded too deeply, or may have died as seedlings due to the weakening from emerging from greater depths. The packing with the Brillion seed drill may also have placed a greater depth of soil over small size seeds. An increase in native plant species density in spring 1996 indicates native species may have been slower to germinate in 1995.

Mowing was conducted to minimize seed set and dispersal of weedy (nonseeded) species but it may not have been timely enough since nonseeded species density was not affected by mowing. In spring 1996 there was a large flush of nonseeded plant seedlings (mostly annual weeds) which may be attributed to the seed bank or the seeding of these plants in 1995. It was expected that competition from large nonseeded plants would have reduced seeded plant densities. This was not supported by this research and may be attributed to not exceeding the available fertility, moisture and growing space (bare ground). The higher density of nonseeded plants in the native species mixes in spring 1996 was due to bare ground providing an opportune site for weed establishment.

Bromus anomalus, Secale cereale, Elymus dahuricus, Lolium perenne and *Bromus carinatus* (D.F.) were seeded as cover crops for short term cover, however, they persisted into 1996 with no reductions in cover or density. In spring 1996 *Bromus carinatus* (D.F.) appeared to have 100% winter kill. However, seeds produced the previous year germinated and persisted into fall 1996. *Secale cereale* was seeded at 10% and formed a dense canopy of 200 to 500 leaves per plant. As these plants matured they became more prostrate and rotted on the ground due to the high moisture retention under the plant canopy.

From summer 1995 onwards *Agropyron smithii* and *Vicia americana* grew profusely between the rows. Ducks Unlimited Canada (1996) cautioned against seeding more than one pound of PLS per acre of *Agropyron smithii* due to its strongly rhizomatous nature. In fall 1996 smut occurred in a large percentage of the *Agropyron trachycaulum* and less so in other wheatgrass species. This may affect the ability of these species to reseed over time. Some ergot was also present in the fall rye. Ground under the *Secale cereale* remained wet long after the ground under the other mixes dried.

5.2. Cover

It was anticipated that mowing would increase tillering and thus reduce bare ground. However, early mowing increased canopy bare ground in 1995 by removal of larger nonseeded species. In 1996 mowing early/late and late increased bare ground and decreased litter through removal of vegetation. Mix 3 had a large amount of weed leaves and seeds present which added to litter.

In fall 1996 canopy live vegetation may be high (approaching 100%) due to *Agropyron* species lodging and causing difficulty determining litter. Clumps of nonseeded *Bromus* species led to high live ground cover. Fall 1995 litter was high due to forb leaves and seed pods, notably *Galeopis tetrahit*, *Chenopodium album* and *Amaranthus retroflexus*, deposited on the ground. In fall 1995, leaves lying on the ground gave a high live vegetation ground cover for mixes 8 and 9. *Secale cereale* treatments had low litter but a high canopy cover. In other mixes (5, 7 and 9) it was difficult to assess canopy cover due to the tall standing vegetation. Litter was mostly standing in mix 4. For all mixes canopy litter was high due to dead *Thlaspi arvense* and *Descurainia sophia*. A lot of moss was present on bare ground in mix 4 as a result of sustained wet conditions under the canopy.

5.3. Productivity

LAI, disc meter and height measurements have been used to obtain quick reliable herbage yield estimates from fewer sampling sites than destructive sampling methods (Vartha and Matches 1977, Michalk and Herbert 1977, Griggs et al. 1988). Disc meters have also been used successfully to determine hay yields on grass-legume swards (14 mixes) (Baker et al. 1981). The measurements obtained appear to be a function of volume of herbage and resistance to compaction by the disc (Griggs and Stringer 1988).

Native species were initially slower to develop and had less leaf area as evidenced by the LAI and height values for no mow plots in 1995. There were more introduced species in head with more leaf development than native species. The tall growing species in each mix had reached maturity and were similar in height. Mixes with *Vicia americana* resulted in low average plant heights for corresponding mixes. The high heterogeneity of a mixed grass stand made it difficult to consistently measure average height.

In fall 1996 mixes 1, 2, 6 and 7 had the highest average LAI readings over all treatments indicating similar canopy development. Under no mow or mow early treatments LAI was highest due to the longer time for plant development. Many of the mixes were moderately or severely lodged and vegetation had to be lifted to determine canopy height. This also resulted in highly variable disc meter measurements. Disc height can be affected by changes in plant dry matter content, canopy structure and phenological stage (Griggs and Stringer 1988). If disc meter readings can be equated to forage volume or yield and not stem strength, the introduced species were more productive than the native species in fall 1995.

The greater height of the introduced species did not necessarily result in higher LAI values suggesting that larger canopies may not have been leafier. Average canopy heights were largely influenced by the tallest species in the mix. Species within the introduced mixes generally grew higher and matured earlier. Of note is that *Medicago* species grew taller than *Vicia americana* resulting in greater average canopy heights in those mixes.

The results of this research did not indicate a significant difference between native and introduced plant species disc meter measurements, and therefore productivity, within their respective treatments, after two years. These results support earlier studies conducted at Colorado State University. Redente et al. (1984) found grass biomass was initially higher for introduced species than native species. After four years, seeded grass biomass was equivalent in all seeded mixes. In the same study, *Medicago* species had the highest forb plant biomass over time due to the high productivity potential of individual plants and not an increase in plant density. Doerr et al. (1983) showed that grass production was initially higher in introduced than native species mixes. In the third year, there was no significant difference in biomass production.

5.4. Soil And Fauna Considerations

Soil test results were considered optimum for plant growth. EC values of less than 4 dS m^{-1} are generally not considered limiting to plant growth. As EC averaged 0.9 dS m^{-1}, it would not be considered significant in reducing plant survivability evidenced in this research. At pH 5.3, nutrient availability of nitrogen, phosphorus, potassium sulfur, calcium, magnesium and molybdenum are expected to be severely limited (Miller and Reetz 1995, Beard 1973). The solubility of toxic elements may increase while rooting and microorganism activity may decrease. According to these researchers, *Medicago sativa* and *Bromus inermis* are very sensitive to acidity. *Trifolium hybridum, Festuca elatior, Secale cereale, Poa compressa* and *Vicia* species may tolerate moderate acidity (pH 5.5 to 6.0). while *Poa pratensis, Dactylis glomerata, Lolium* species and *Phleum pratense* have only a slight acidity tolerance (pH 6.0 to 7.0). In this study, *Trifolium hybridum, Medicago* species and *Poa compressa* had lower survivability. It is difficult to determine if this was a result of acidity or the seeds being seeded too deep.

Native fauna affected measurements of cover and productivity. Seeded species were found in plots other than those into which they were seeded, some of these may have been wind dispersed but others were likely moved within animal feces. *Elymus dahuricus,* for example, was found throughout all plots although it was only seeded in one mix. In fall

1995 canopy cover was difficult to assess due to trampling from previous plant counts and from deer activity within the plots which resulted in lower canopy cover assessments. Deer browsed heavily on *Vicia americana* in winter 1995, as evidenced by the large amount of droppings present in these plots. This may have reduced spring 1996 litter. In summer 1995 pocket gopher activity occurred in Block 1. By fall 1995 Richardson's ground squirrel activity resulted in disturbance to some permanent quadrats in blocks 1 and 4. A large mouse population may have led to high litter counts in mix 3. Extensive use by wildlife in the establishment years may be detrimental to long-term survivability.

5.5. Species And Mix Assessment

Several native and introduced mixes performed better than others with respect to density, productivity and cover. Of the native species mixes, mix 3 had a similar seeded density to mix 2 but mix 2 had a lower nonseeded density. Of the introduced species mixes, mixes 6 and 7 had the highest density of seeded species and the lowest density of nonseeded species. Lower nonseeded plant densities may imply that these mixes are more competitive. Of the introduced species mixes, mix 7 had the highest percent survivability averaged over all mowing treatments and had more species which increased in survivability over 1995 levels. Mixes 3 and 7 had the lowest and highest canopy cover of seeded species, respectively. For these reasons mixes 2 and 7 are considered to have the best overall performance of the native and introduced plant species mixes, respectively.

Plant species with high densities generally contributed most to canopy cover in 1996 and thus to productivity as affected by LAI and disc meter height. *Agropyron* and *Bromus* species performed best, in density and canopy cover. Other species of note are *Secale cereale*, *Elymus dahuricus*, *Vicia americana*, *Stipa viridula*, *Festuca elatior* and *Lolium perenne*. Mixes with *Vicia americana* had a higher live ground cover in fall 1995, due to its' low growing nature but ground cover was reduced substantially in 1996 when they grew more erect and twisted in the canopy.

6. CONCLUSIONS

1. Survivability and density were similar between native and introduced plant species.
2. Although productivity was initially lower in native species mixes, over two growing seasons native species were as productive as introduced species as indicated by LAI and disc meter measurements.
3. Nonseeded species density increased from fall of year one to spring of year two then declined again by fall of year two.
4. Although not statistically significant, both ground and canopy cover under mowing were lower in native species mixes than introduced species mixes in the first year but were similar by the end of year two; the mow early treatment significantly increased canopy cover of seeded species over the no mow treatment.
5. Significant differences in survivability and canopy cover occurred among species; species of the same genus (whether native or introduced) had similar survivability; large seeded species had higher survivability than small seeded species.
6. Seeded species comprised a lower proportion of canopy cover in the native mixes than seeded species in the introduced mixes.
7. Mowing did not consistently affect species density, survivability, productivity or cover; early mowing reduced canopy litter in 1995 but remained similar in 1996.

7. REFERENCES

Baker, B.S., T. Vanden Eynden and N. Boggess. 1981. Hay yield determinations of mixed swards using a disk meter. Agron. J. 73:67-69.

Beard, J.B. 1973. Turfgrass: Science and culture. Prentice Hall Inc. Englewood Cliffs, NJ. 658 pp.

Chanasyk, D.S. 1995. ENCS 203 course notes. Department of Renewable Resources, University of Alberta, Edmonton, AB.

de St. Remy, E.A. 1990. Research highlights. Agriculture Canada Research Station. Lacombe, AB. 6 pp.

Doerr, T.B., E.F. Redente and T.E. Sievers. 1983. Effects of cultural practices on seeded plant communities on intensely disturbed soils. J. Range Manage.

Ducks Unlimited Canada. 1996. Revegetating with native grasses. 133 pp.

Environment Canada. 1991. The climates of Canada. Catalogue No. EN56-1/1990E. 125 pp.

Esau, K. 1977. Anatomy of seed plants. Second Edition. John Wiley and Sons. Toronto, ON. 550 pp.

Filella, I. and J. Penuelas. 1994. The red edge position and shape as indicators of plant chlorophyll content, biomass and hydric status. Int. J. Remote Sensing 15:1459-1470.

Griggs, T.C. and W.C. Stringer. 1988. Prediction of alfalfa herbage mass using sward height, ground cover and disc technique. Agron. J. 80:204-208.

Hyder, D.N., Everson, A.C. and R.E. Bement. 1971. Seedling morphology and seedling failures with blue grama. J. Range Manage. 24: 287-292.

Kuehl, R.O. 1994. Statistical principles of research design and analysis. Duxbury Press. California, CA. Pp. 118-121.

Larsen, A. 1980. Problems in testing seeds of revegetation species. Proceedings: High Altitude Revegetation Workshop No. 4. Colorado State University. Fort Collins CO.

McKeague, J.A. 1978. Manual on soil sampling and methods of analysis. Second edition. Canada Soil Survey Committee, Subcommittee on Methods of Analysis. Canadian Society of Soil Science. Ottawa, ON. 212 pp.

Michalk D.L. and P.K. Herbert. 1977. Assessment of four techniques for estimating yield on dryland pastures. Agron. J. 69:865-868.

Miller, D.A. and H.F. Reetz, Jr. 1995. Forage fertilization. In: Forages Volume 1 An introduction to grassland agriculture. Iowa State University Press. Iowa. Pp. 71-87.

Montgomery, D.C. and E.A. Peck. 1982. Introduction to linear regression analysis. John Wiley and Sons, Inc. New York, NY. Pp. 89-95.

Moore, K.J. and L.E. Moser. 1995. Quantifying developmental morphology of perennial grasses. Crop Sci. 35:37-43.

Munshower, Frank F. 1994. Practical handbook of disturbed land revegetation. CRC Press. Boca Raton, FL. 265 pp.

Naeth, M.A. 1997. Personal communication. Professor of reclamation and applied ecology. University of Alberta. Edmonton, AB.

Nelson, C.J. 1995. Photosynthesis and carbon metabolism. In: Forages Volume 1 An Introduction to grassland agriculture. Iowa State University Press. Iowa. Pp. 31-43.

Newman, P.R. and L.E. Moser. 1988. Seedling root development and morphology of cool-season and warm-season forage grasses. Crop Sci. 28:148-151.

Palazzo, A.J. and C.R. Lee. 1986. Biomass determination at reclamation sites using a weighted disk meter. Reclam. Reveg. Res. 4:307-312.

Paulsen, G.M. and D. Smith. 1969. Organic reserves, axillary buds activity and herbage yields of smooth bromegrass as influenced by time of cutting, nitrogen fertilization and shading. Crop Sci. 9:529-534.

Prasad, N.G.N. May 1, 1997. Personal communication. Associate Professor, Department of Mathematical Sciences, University of Alberta. Edmonton, AB.

Redente, E.F., B. Doerr, C.E. Grygiel and M.E. Biondini. 1984. Vegetation establishment and succession on disturbed soils in northwest Colorado. Reclam. Reveg. Res. 3:153-165.

Satterlund, D.R. and P.W. Adams, 1992. Wildland watershed management. John Wiley and Sons, Inc. Toronto, ON. 436 pp.

Takyi, S.K., 1966. Plant cover establishment methods on a severe Rocky Mountain foothills site. In: Ziemkiewicz, P.F. 1985 (Ed.). Revegetation Methods for Alberta's Mountains and Foothills. Proceedings of a Workshop held 30 April - May 1984, Edmonton, AB. Alberta Land Conservation and Reclamation Council Report #RRTAC 85-1. Pp. 112-145.

Takyi, S.K. and R.M. Islam. 1968. Performance of native grasses and cultivated legumes and grasses on disturbances in the eastern slopes of the rockies. In: Proceedings of a Workshop held April 30 - May 1, 1984. Edmonton, AB. Alberta Land Conservation and Reclamation Council Report #RRTAC 85-1. Pp. 4-33

Taerum, Terry. February 11, 1997. Personal communication. Team Leader Consulting, Computing and Network Services, University of Alberta. Edmonton, AB.

Vartha, E.W. and A.G. Matches. 1977. Use of a weighted-disk measure as an aid in sampling in the herbage yield on tall fescue pastures grazed by cattle. Agron. J. 68:888-891.

Table 2.1. 1995 and 1996 plant density (per m²) of seeded and nonseeded species by mix as affected by mowing.

	Fall 1995			Spring 1996					Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat	NM	ME	ML	MEL	SE of Treat
Seeded													
Mix 1	21 abA	14 aB	4 *2	26 bcA	20 aA	18 aA	17 aA	3 *1	22 aAB	16 aAB	18 aAB	12 aA	4 *1
Mix 2	74 dA	72 dA	7 *2	93 eA	87 bA	75 bcA	77 efA	6 *1	43 bcA	40 bcA	39 bcA	39 bA	7 *1
Mix 3	48 bcdA	64 cdB	8 *2	81 deA	95 bcA	88 cA	91 fA	7 *1	37 abA	35 abA	48 cA	48 bA	9 *1
Mix 4	18 aA	24 abA	6 *3	28 bA	43 abAB	27 abA	47 cdeB	5 *2	26 aA	27 abA	20 abA	34 bA	5 *1
Mix 5	31 bcA	31 abA	4 *2	25 bA	26 abA	23 aA	39 bcdB	3 *1	43 bcA	36 bcA	36 bcA	46 bA	5 *1
Mix 6	47 bcdA	44 bcA	4 *2	48 cA	54 cA	51 bA	57 deA	5 *1	42 bcA	37 bcA	46 cA	48 bA	5 *1
Mix 7	52 cdA	64 cdA	7 *2	54 cdA	51 cA	49 bA	63 deA	5 *1	44 bcA	37 bcA	49 cA	46 bA	5 *1
Mix 8	22 abA	27 abA	*1	15 aA	21 aAB	21 aAB	27 abB	4 *1	104 cA	63 bc	46 cA	43 bA	4 *2
Mix 9	25 abA	30 abA	4 *2	22 abA	22 aA	22 abcA	30 bcA	3 *1	34 abA	30 abA	34 bcA	36 bA	5 *1
SE of Mix	4 *2	4 *1		4 *1	4 *1	5 *1	5 *1		17 *1	5 *1	5 *1	14 *1	
Nonseeded													
Mix 1	14 abcA	16 abA	3 *2	362 bcAB	486 dAB	559 bB	403 bcA	39 *2	29 abA	29 abcA	50 aA	35 abA	16 *1
Mix 2	11 abcA	17 abB	3 *2	189 abA	548 bcdA	151 aA	277 abcA	36 *3	31 abA	29 bcA	33 aA	49 bcA	7 *1
Mix 3	18 cA	21 abA	5 *2	510 cB	333 cdA	614 bB	471 cAB	72 *2	82 cA	69 dA	150 bB	49 cA	13 *2
Mix 4	20 bcA	16 abA	*1	621 cA	467 dA	578 bA	324 bcA	05 *3	101 cB	43 cdA	140 bB	41 abcA	12 *2
Mix 5	7 aA	6 aA	*1	304 abB	70 aA	487 abBC	91 abB	74 *2	87 bcA	97 cdA	161 bAB	32 abcA	12 *2
Mix 6	15 abcA	11 abA	3 *2	218 abA	98 abcA	331 aA	123 abA	54 *3	55 abC	5 abA	60 aAB	13 aAB	15 *2
Mix 7	18 abcA	17 bA	4 *2	106 aA	96 abA	185 aA	143 aA	42 *3	20 aAB	2 aA	54 aB	15 aAB	14 *2
Mix 8	11 abcA	16 abA	*1	371 bcA	303 bcdA	413 abA	318 bcA	79 *2	89 cB	71 cdAB	108 bB	44 abcA	16 *2
Mix 9	10 abA	6 aA	*1	405 bcB	94 abA	328 abB	127 abA	66 *3	64 bcA	66 cdA	123 bA	77 cA	17 *2
SE of Mix	2 *1	2 *1		66 *3	107 *3	35 *2	66 *3		14 *2	11 *2	20 *2	10 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.2. 1995 and 1996 percent survivability by seeded species as affected by mowing.

	Fall 1995		Spring 1996				Fall 1996			
	NM	ME	NM	ME	ML	MEL	NM	ME	ML	MEL
Introduced Species										
Agropyron elongatum	10	11	5	7	5	9	12	4	2	4
Agropyron intermedium	16	27	23	27	20	34	40	22	25	28
Agropyron trichophorum	4	8	13	10	20	25	18	13	21	25
Alopecurus arundinaceus	0	0	0	0	0	0	0	0	0	0
Alopecurus pratensis	2	4	0	0	0	0	0	0	1	0
Bromus biebersteinii	35	39	3	6	4	7	24	21	27	27
Bromus carinatus (Don Frederico)	47	21	31	33	33	33	25	21	27	27
Bromus inermis	17	16	19	22	23	24	28	32	39	31
Dactylis glomerata	2	12	3	5	2	4	5	5	5	6
Elymus dahuricus	34	32	36	39	29	34	30	24	33	37
Festuca elatior	8	15	5	8	10	15	12	11	13	11
Festuca rubra	3	5	2	2	2	3	3	3	3	4
Lolium perenne	40	45	26	19	19	6	7	7	16	9
Medicago falcata (Anik)	1	3	10	3	2	4	1	1	1	4
Medicago sativa (Algonquin)	8	8	10	4	7	10	6	1	4	3
Medicago sativa (Rangelander)	9	7	6	7	9	5	4	4	4	1
Phleum pratense	4	2	2	4	2	6	2	2	1	9
Poa compressa	0	1	0	0	0	2	0	0	0	0
Poa pratensis	1	0	0	0	0	0	2	1	1	3
Secale cereale	49	46	43	39	42	61	38	35	37	58
Trifolium hybridum	1	1	0	1	0	0	0	1	1	0
Native Species										
Agropyron dasystachyum	18	16	18	18	33	32	24	32	39	30
Agropyron smithii	24	30	45	57	39	64	35	38	34	44
Agropyron trachycaulum	39	25	45	34	34	30	38	30	29	21
Bromus anomalus	5	10	9	12	6	7	7	7	5	4
Danthonia parryi	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	0	0	0	0	0	0
Festuca campestris	0	0	0	0	0	0	1	0	0	0
Festuca hallii	0	1	1	0	0	0	0	0	0	1
Festuca idahoensis	5	3	3	3	2	1	1	2	1	0
Koeleria macrantha	1	0	0	0	0	0	0	0	0	0
Petalostemon purpureum	1	2	0	0	0	0	0	0	0	0
Stipa curtiseta	0	2	0	3	1	0	1	2	1	2
Stipa viridula	16	16	27	26	12	20	20	14	14	20
Vicia americana	59	62	77	83	77	76	21	16	22	25

NM: no mow
ME: mow early
ML: mow late
MEL: mow early and late

Table 2.3. 1995 and 1996 percent survivability of seeded species by mix as affected by mowing.

	Fall 1995			Spring 1996					Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	6 abA	4 aA	1 *23	9 bA	6 abA	6 abA	5 aA	1 *2	7 abB	5 aAB	6 aAB	4 aA	1 *19
Mix 2	19 eA	19 deA	2 *13	26 dA	25 eA	21 eA	21 cA	2 *1	14 cA	12 bcA	12 cA	12 bcA	2 *17
Mix 3	12 cdeA	15 deA	1 *17	17 cdA	19 deA	19 bcA	19 cdA	2 *1	10 abcA	11 bcA	13 cA	13 bcA	2 *18
Mix 4	5 aA	8 abB	1 *29	9 abA	14 cdA	9 abcA	14 bcA	2 *2	8 aA	9 abA	6 abA	10 aA	1 *20
Mix 5	12 cdeA	12 cdA	1 *17	10 abAB	10 bcdAB	9 bcdA	15 bcB	1 *1	16 cAB	13 bcA	13 cAB	17 cB	1 *9
Mix 6	13 cdeA	13 cdeA	1 *14	13 abA	15 cdA	14 cdeA	16 bcA	2 *1	12 bcA	10 bcA	13 cA	14 bcA	1 *14
Mix 7	17 deA	21 eA	2 *20	17 cdeA	16 cdeA	16 deA	18 cA	1 *1	13 cAB	12 bcA	16 cB	14 bcAB	1 *9
Mix 8	10 bcA	10 bcA	1 *21	4 aA	5 aA	5 aA	8 aA	1 *1	17 cA	17 cA	13 bcA	13 bcA	2 *18
Mix 9	10 cdA	12 cdA	1 *21	10 bA	9 bcA	9 abcdA	11 abA	1 *1	13 bcA	11 bcA	12 cA	14 bcA	1 *13
SE of Mix	1 *14	1 *13		1 *15	1 *16	2 *16	2 *17		2 *15	1 *15	2 *17	1 *16	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.

Standard error of means shown preceded by * are based on transformed data.

NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.4. 1995 and 1996 bare ground percentage of ground cover by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	88 bA	91 bB	1 *0	39 eB	23 bcA	48 bB	43 bAB	5 *4
Mix 2	89 bA	89 bA	1 *0	12 bcA	13 abA	23 bcB	16 aAB	4 *3
Mix 3	87 bA	89 bA	2 *0	8 abcA	10 abA	14 aA	15 aA	2 *3
Mix 4	88 bA	90 bB	1 *0	19 cdA	42 dB	25 aB	37 abB	4 *2
Mix 5	51 aA	72 aB	5 *3	24 deA	19 bcA	22 aA	37 abA	4 *3
Mix 6	84 bA	89 bB	2 *0	9 abcA	8 aA	18 aB	25 abB	4 *3
Mix 7	86 bA	87 bA	2 *0	7 abA	11 abA	26 aB	38 bB	4 *3
Mix 8	87 bA	86 bA	2 *1	4 aA	8 abA	13 aB	22 abB	3 *3
Mix 9	62 aA	66 aA	5 *2	36 eA	34 cdA	28 abA	35 bA	4 *2
SE of Mix	2 *1	2 *1		3 *3	4 *3	4 *3	4 *3	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis were done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.5. 1995 and 1996 litter percentage of ground cover by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	7 abA	5 abB	1 *2	50 aAB	67 bcB	43 aA	50 abAB	5 *3
Mix 2	4 aA	3 aA	1 *2	79 bcA	81 cA	69 bcA	76 cA	4 *2
Mix 3	5 abA	5 abA	1 *2	81 bcA	83 cA	78 cA	78 cA	3 *1
Mix 4	8 bA	5 bA	1 *2	64 abB	40 aA	65 bcB	55 abAB	4 *2
Mix 5	24 cA	14 cB	4 *3	68 abcB	66 bcB	72 bcB	47 aA	4 *2
Mix 6	8 bA	4 abB	1 *2	81 bcAB	82 cB	69 bcAB	63 abcA	3 *2
Mix 7	8 bA	5 bB	1 *2	81 bcB	79 cAB	62 bcAB	54 abA	4 *2
Mix 8	8 bA	4 b	1 *2	87 cB	84 cB	78 bcAB	67 bcA	3 *1
Mix 9	24 cA	12 cB	3 *3	53 aA	55 abA	58 abA	49 abA	5 *3
SE of Mix	2 *2	1 *1		4 *2	4 *2	4 *2	4 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.6. 1995 and 1996 bare ground percentage of canopy cover by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	28 dA	36 cdB	4 *3	1 aA	1 aA	5 abA	3 aA	2 *2
Mix 2	19 cdA	24 cB	4 *3	1 aA	1 abA	1 aA	2 aA	1 *2
Mix 3	23 cdA	33 cdB	5 *3	1 aA	2 abA	2 abA	1 aA	1 *1
Mix 4	29 dA	45 dB	5 *3	1 aA	3 abA	1 aA	1 aA	1 *2
Mix 5	8 abA	13 abA	4 *4	2 aA	2 abA	4 abAB	8 bB	1 *2
Mix 6	15 bcA	17 abA	4 *4	2 aA	0 aA	1 aA	1 aA	1 *1
Mix 7	8 aA	9 abA	3 *3	1 aA	1 abA	1 aA	6 abA	2 *2
Mix 8	9 abA	15 abB	4 *3	0 aA	1 aA	1 aA	4 abB	1 *2
Mix 9	7 aA	6 aA	3 *4	2 aA	3 bA	7 bAB	11 bB	2 *3
SE of Mix	2 *2	3 *2		1 *1	1 *2	1 *2	2 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different (p<0.05) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different (p<0.05) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.7. 1995 and 1996 percent canopy cover by species within mix as affected by mowing.

		Fall 1995		Fall 1996			
	Mix	NM	ME	NM	ME	ML	MEL
Native Species							
Agropyron smithii	2	12	9	22	26	23	14
	4	28	42	39	53	23	48
Bromus anomalus	1	1	0	3	1	0	0
	2	3	1	9	7	2	2
	3	4	4	4	6	4	6
	4	5	1	1	7	6	2
Danthonia parryi	1	0	0	0	0	0	0
	3	0	0	0	0	0	0
Festuca hallii	1	0	0	0	0	0	0
	4	0	1	0	0	0	0
	5	0	0	0	0	0	2
Koeleria macrantha	1	0	0	0	0	0	0
	4	0	0	0	0	0	0
Petalostemon purpureum	1	0	0	0	0	0	0
	4	1	0	0	0	0	0
Stipa curtiseta	3	0	0	0	0	1	2
	4	0	1	1	3	0	1
Stipa viridula	2	19	19	42	40	31	42
	5	2	1	3	4	2	3
Vicia americana	2	23	31	5	7	4	5
	3	26	36	19	7	12	14
Introduced Species							
Bromus inermis	5	7	5	39	36	32	27
	7	17	16	61	44	49	44
	9	2	3	19	20	42	12
Dactylis glomerata	5	1	1	4	8	2	1
	8	1	11	30	39	24	32
	9	1	1	8	2	0	1
Festuca rubra	7	1	1	0	2	3	7
	9	0	0	0	0	0	0
Medicago falcata (Anik)	5	0	1	1	0	0	0
	8	0	2	0	1	1	5
Secale cereale	5	69	80	45	38	47	62
	9	61	83	61	69	39	77

NM: no mow
ME: mow early
ML: mow late
MEL: mow early and late

Table 2.8. 1995 and 1996 litter percentage of canopy cover by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	2 abA	2 abA	0 *2	2 ab A	3 abcA	4 abcA	3 abA	1 *2
Mix 2	1 aA	1 aA	0 *1	4 abB	1 aA	3 abAB	3 abAB	1 *2
Mix 3	2 abA	2 abA	0 *2	13 cA	8 cdA	9 abcA	6 bcA	3 *3
Mix 4	2 abA	3 bA	0 *2	3 abAB	4 abcA	17 cB	2 abA	3 *3
Mix 5	3 bA	1 aB	0 *2	5 bA	13 dA	8 bcA	13 cA	3 *3
Mix 6	2 abA	1 aA	0 *1	1 aA	2 abA	1 aA	1 aA	1 *1
Mix 7	1 abA	1 aA	0 *1	2 abA	3 abcA	3 abcA	1 aA	1 *2
Mix 8	1 aA	1 aA	0 *1	3 abA	3 abcA	5 abcA	6 abcA	2 *3
Mix 9	3 bA	1 aB	1 *2	2 abA	5 bcdAB	5 abcAB	7 bcB	1 *3
SE of Mix	0 *1	0 *1		1 *2	2 *2	3 *3	2 *3	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.9. 1995 and 1996 percent canopy cover of seeded and nonseeded species by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Seeded								
Mix 1	46 abA	42 a A	4 *6	82 bA	77 abA	70 bcdA	48 aA	9 *6
Mix 2	70 cA	60 bcdA	5 *4	78 dA	80 bA	61 bcdeA	64 abcA	7 *3
Mix 3	35 abA	50 abcB	5 *5	41 aA	33 aA	32 abA	38 aA	6 *4
Mix 4	33 aA	45 abA	5 *6	41 aAB	64 abB	29 aA	51 aAB	8 *5
Mix 5	79 cA	87 dA	3 *3	92 bA	85 bA	83 cdeA	95 bA	4 *2
Mix 6	63 cA	76 cdB	4 *3	92 bA	94 bA	98 eA	94 bA	4 *3
Mix 7	53 bcA	61 cdA	4 *4	99 bA	98 bA	94 deA	98 bA	2 *1
Mix 8	60 bcA	63 bcA	4 *6	80 bB	72 abAB	51 abcA	72 abAB	7 *4
Mix 9	72 cA	89 dB	3 *4	88 bA	91 bA	82 cdeA	91 bA	5 *3
SE of Mix	6 *3	5 *3		6 *3	6 *4	7 *4	6 *4	
Nonseeded								
Mix 1	54 abcA	38 cA	5 *6	18 abA	23 abcdA	30 abcA	37 bcA	9 *6
Mix 2	30 abA	40 cA	5 *7	22 bA	20 bcdA	39 cdA	36 cdA	7 *5
Mix 3	65 cA	50 cA	5 *6	59 cA	67 eA	68 dA	62 dA	6 *4
Mix 4	66 cA	55 aB	5 *5	59 cAB	36 deA	71 dB	49 cdAB	8 *5
Mix 5	22 aA	13 abA	3 *5	8 abA	15 abcA	17 bcA	5 abA	4 *4
Mix 6	37 abcA	24 abcA	4 *5	8 aA	6 abA	2 aA	6 abA	4 *3
Mix 7	47 bcA	39 cB	4 *5	1 aA	2 aA	6 abA	2 aA	2 *3
Mix 8	40 abA	37 bcA	4 *5	20 bA	28 cdA	49 dA	28 bcA	7 *5
Mix 9	28 abcA	11 aB	3 *5	12 abA	9 abcA	18 abA	9 abA	5 *4
SE of Mix	4 *4	4 *4		6 *4	6 *5	6 *4	7 *5	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.10. 1995 and 1996 percent canopy cover by species as affected by mowing.

	Fall 1995		Fall 1996			
	NM	ME	NM	ME	ML	MEL
Introduced Species						
Agropyron elongatum	9	7	15	11	2	5
Agropyron intermedium	5	13	18	36	28	37
Agropyron trichophorum	0	0	30	24	22	33
Alopecurus arundinaceus	0	0	0	0	0	0
Alopecurus pratensis	1	0	0	0	0	0
Bromus biebersteinii	43	22	53	50	61	49
Bromus carinatus (Don Frederico)	66	41	18	7	4	2
Bromus inermis	10	8	40	33	41	28
Dactylis glomerata	1	6	14	16	9	12
Elymus dahuricus	11	21	26	23	22	31
Festuca elatior	5	16	9	18	11	5
Festuca rubra	1	0	0	1	1	4
Lolium perenne	17	13	3	4	7	2
Medicago falcata (Anik)	0	1	1	1	0	3
Medicago sativa (Algonquin)	6	4	2	0	5	2
Medicago sativa (Rangelander)	4	11	4	2	4	0
Phleum pratense	0	0	0	1	0	3
Poa compressa	0	1	0	0	0	0
Poa pratensis	0	0	1	1	0	1
Secale cereale	68	81	53	53	43	70
Trifolium hybridum	0	1	0	0	0	0
Native Species						
Agropyron dasystachyum	5	4	17	19	13	16
Agropyron smithii	22	22	30	40	23	31
Agropyron trachycaulum	51	52	79	76	69	48
Bromus anomalus	2	2	4	5	3	3
Danthonia parryi	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	0	0
Festuca campestris	0	0	0	0	0	0
Festuca hallii	0	0	0	0	0	1
Festuca idahoensis	0	0	0	0	0	0
Koeleria macrantha	0	0	0	0	0	0
Petalostemon purpureum	1	0	0	0	0	0
Stipa curtiseta	0	1	0	2	1	1
Stipa viridula	13	12	22	22	17	23
Vicia americana	23	38	12	7	8	10

NM: no mow
ME: mow early
ML: mow late
MEL: mow early and late

Table 2.11. 1995 and 1996 percent of quadrats by mix with canopy levels as affected by mowing.

	NM			ME			ML			MEL		
	Canopy Level			Canopy Level			Canopy Level			Canopy Level		
	1	2	3	1	2	3	1	2	3	1	2	3
1995												
Mix 1	100	85	25	100	80	20	100	85	35	100	100	70
Mix 2	100	95	55	100	40	0	100	95	60	100	40	15
Mix 3	100	100	70	100	70	10	100	100	60	100	95	85
Mix 4	100	100	50	100	95	35	100	100	25	100	95	45
Mix 5	100	80	20	100	55	25	100	95	55	100	100	80
Mix 6	100	95	50	100	65	30	100	50	25	100	95	50
Mix 7	100	100	60	100	100	55	100	100	25	100	75	20
Mix 8	100	100	60	100	95	65	100	95	40	100	85	25
Mix 9	100	40	0	100	95	60	100	95	35	95	95	45
1996												
Mix 1	100	80	25	100	65	5	100	80	5	100	85	10
Mix 2	100	85	10	100	65	15	100	90	30	100	95	30
Mix 3	100	95	40	100	85	30	100	95	30	100	75	50
Mix 4	100	95	20	100	100	20	100	90	35	100	95	15
Mix 5	100	100	45	100	100	25	100	100	45	100	100	25
Mix 6	100	90	40	100	95	25	100	90	45	100	85	45
Mix 7	100	100	35	100	95	35	100	100	45	100	95	35
Mix 8	100	100	45	100	100	45	100	100	75	100	95	45
Mix 9	100	95	30	100	85	20	100	95	50	100	80	10

NM: no mow
ME: mow early
ML: mow late
MEL: mow early and late

Table 2.12. 1995 and 1996 LAI by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	2.35 aA	2.60 abB	0.13	6.01 bcAB	6.48 bcdC	5.67 bcA	6.31 cBC	0.11
Mix 2	2.91 bA	2.58 aA	0.17	6.34 cdC	6.09 bBC	5.73 bcAB	5.44 bcA	0.12
Mix 3	2.65 abA	2.10 aA	0.14	5.26 aA	5.05 aA	4.81 aA	4.84 abA	0.15
Mix 4	2.23 aA	2.04 aB	0.13	5.62 abB	5.94 bB	4.96 aA	5.08 abcA	0.10
Mix 5	4.71 deA	4.99 eB	0.13	5.72 abC	4.99 aAB	5.25 abBC	4.72 aA	0.13
Mix 6	3.82 cA	3.50 bcB	0.07	6.42 cdA	6.89 dB	6.10 cA	6.43 dA	0.11
Mix 7	4.05 cA	4.60 deA	0.29	6.59 dBC	6.72 cdC	5.91 cAB	5.72 cdA	0.21
Mix 8	4.25 cdA	4.04 cdA	0.15	6.47 cdB	6.21 bcB	5.08 aA	5.33 abcA	0.10
Mix 9	4.95 eA	4.98 eB	0.08	5.28 aA	4.84 aA	5.10 aA	4.79 abA	0.16
SE of Mix	0.19	0.13		0.12	0.13	0.13	0.17	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.13. 1995 and 1996 disc meter values by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	14.7 bcA	19.9 bB	2.7	29.8 aA	38.5 aA	36.9 aA	33.1 aA	2.7
Mix 2	9.8 abA	10.8 aB	1.9	40.8 abA	40.2 abA	42.2 abcA	48.6 abcA	2.7
Mix 3	6.8 aA	7.0 aA	1.0	47.7 bcA	40.2 abA	53.1 bcdA	48.2 abcA	3.5
Mix 4	7.7 abA	7.1 aA	1.2	46.2 bcA	44.5 abcA	56.0 cdA	48.2 abcA	3.9
Mix 5	19.5 cdA	21.5 bA	1.2	54.0 bcA	49.7 abcA	57.9 dA	56.6 cA	3.9
Mix 6	23.9 dA	24.6 bA	1.8	46.2 bcA	39.9 abA	39.6 abA	40.6 abA	2.2
Mix 7	23.5 dA	20.2 bA	2.8	51.7 bcA	45.7 abcA	53.2 bcdA	47.8 abcA	3.9
Mix 8	23.8 dA	23.9 bA	1.7	56.8 cA	57.8 cA	59.2 dA	55.4 bcA	3.5
Mix 9	20.0 cdA	21.9 bB	0.9	58.1 cA	54.5 bcA	58.8 dA	52.6 bcA	4.2
SE of Mix	1.6	1.3		3.4	3.5	3.4	3.6	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.14. 1995 and 1996 plant height (cm) by mix as affected by mowing.

	Fall 1995			Fall 1996				
	NM	ME	SE of Treat	NM	ME	ML	MEL	SE of Treat
Mix 1	61.2 bcA	54.2 bB	2.9	103.5 bA	106.9 bA	105.6 bcdA	101.5 abcA	4.0
Mix 2	37.3 aA	33.5 aB	2.1	98.6 bA	104.2 bA	101.5 bcA	100.1 bcA	5.6
Mix 3	33.1 aA	28.2 aA	3.0	74.5 aA	78.0 aA	79.9 aA	86.6 aA	4.4
Mix 4	38.9 aA	33.1 aB	3.0	95.4 abA	96.0 abA	90.4 abA	97.4 abA	4.4
Mix 5	57.5 bA	54.1 bB	1.9	117.5 bAB	105.1 bA	121.7 cdB	108.0 bcA	3.4
Mix 6	66.3 bcA	58.1 bcB	2.6	99.1 bA	104.3 bA	106.9 bcdA	107.9 bcA	5.4
Mix 7	61.5 bcA	50.2 bB	4.2	115.4 bA	108.8 bA	122.4 cdA	116.8 cA	5.1
Mix 8	71.6 cA	65.5 cA	3.7	109.7 bA	109.4 bA	122.8 dA	108.1 bcA	6.3
Mix 9	58.5 bA	55.9 bA	1.6	113.8 bA	111.7 bA	117.7 cdA	112.9 bcA	2.4
SE of Mix	2.9	2.0		5.1	4.6	4.8	4.1	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).

NM: no mow ME: mow early ML: mow late MEL: mow early and late

Table 2.15. 1995 and 1996 average plant height (cm) by species as affected by mowing.

	August 30, 1995		July 22, 1996	
Species	Mowed	No Mow	Mowed	No Mow
Agropyron dasystachyum			128	115
Agropyron elongatum			145	138
Agropyron smithii			100	112
Agropyron trachycaulum	88	99	125	125
Agropyron trichophorum			147	141
Bromus anomalus			95	94
Bromus biebersteinii			127	134
Bromus carinatus (Don Frederico)	131	133	89	97
Bromus inermis	118	118	128	136
Chenopodium album	72	106	92	66
Circium species			94	96
Dactylis glomerata			124	130
Desurainia sophia	94	95	108	98
Elymus dahuricus	94	114	142	136
Festuca rubra			50	
Galeopis tetrahit	57	87	75	74
Lychnis alba	87	87	96	90
Medicago sativa species	64	81	69	79
Phleum pratense	77	80	112	107
Secale cereale	56	54	135	132
Setaria viridis	70	74		
Sonchus asper	67	104		
Stipa curtiseta			117	109
Stipa viridula	84	64	144	144
Thlaspi arvense			52	67
Trifolium hybridum			77	64
Vicia americana	33	50	77	76

Table 2.16. 1995 and 1996 tillered plants per quadrat by mix as affected by mowing.

	Fall 1995		Spring 1996				Fall 1996			
	NM	ME	NM	ME	ML	MEL	NM	ME	ML	MEL
Mix 1	2	1	4	3	4	4	2	2	2	2
Mix 2	2	3	4	4	4	4	4	4	3	4
Mix 3	1	1	3	3	4	4	2	3	3	2
Mix 4	1	2	3	3	2	4	3	3	2	4
Mix 5	3	2	4	3	4	5	3	4	4	4
Mix 6	4	4	2	2	3	2	4	3	4	5
Mix 7	5	6	2	2	3	2	4	3	5	4
Mix 8	2	3	2	3	3	3	3	3	3	3
Mix 9	3	3	2	2	3	3	3	3	3	4

NM: no mow
ME: mow early
ML: mow late
MEL: mow early and late

III. EMERGENCE AND SURVIVABILITY OF SELECTED NATIVE AND INTRODUCED PLANT SPECIES IN RESPONSE TO HERBICIDES IN THE ESTABLISHMENT PERIOD

1. INTRODUCTION

Reduced forage yield due to weeds and the cost of weed control constitute a substantial economic loss to forage producers. Losses due to weeds on pastures and hayland include lower yields, lower livestock gains, livestock poisoning and reduced meat, milk, wool and hide quality. Understanding weed control methods and timing could lead to efficient financial resource allocation. Chandler et al. (1984) estimated average annual losses from weeds in western Canada to be $723 million. Approximately 10% of the losses occurred in hay crops and less than 1% in forage seed crops, with 29% of the total loss occurring in Alberta. Researchers were unable to quantify losses due to weed competition in pasture and rangelands as some weeds provide fodder and some pasture plants have weedy characteristics.

Duebbart et al. (1981 - cited by Kerr et al. 1993) stated that inadequate weed suppression is the leading cause of grass seeding failures. A controversy exists whether annual weeds should be controlled in new plantings or whether the use of herbicides will suppress or harm desired plant growth. Little information is readily available to the public on the effects of herbicides on introduced plant species and even less information and scientific data are available on the effect of herbicides on native plant species. Herbicide guides list few grass and legume species, using more general terms as hayland and pasture weed control, while some labels distinguish between seedling and established species (Alberta Agriculture 1997).

Weed control is usually necessary for new seedling establishment to reduce competition for light, nutrients and water. Managing competition may lead to increased ground cover and higher yields in some forage species (Klingman and McCarty 1958 - *Agropyron intermedium* and *Bromus inermis*). Ducks Unlimited (1995) found prompt post-plant weed control is required during the establishment year, generally through a broadleaf herbicide application. In general, native grasses had to reach the two to three leaf stage to survive the application. Response of several native species to various common herbicides is listed in this publication.

2. OBJECTIVES AND HYPOTHESES

2.1. Objectives

The objectives of this research were to:

1. Evaluate the survivability of selected native and introduced plant species and plant species mixes in response to selected herbicide treatments during the establishment period.
2. Evaluate the response of these selected native and introduced plant species mixes to selected herbicide treatments during the establishment period.

2.2. Hypotheses

The hypotheses to be tested were:

1. There is no difference in the response of the selected native and introduced plant species and mixes to selected herbicides in the establishment period.
2. Canopy cover, ground cover and productivity develop the same in selected native and introduced plant species through suppression of weed growth by selected herbicides.

3. MATERIALS AND METHODS

3.1. Site Description

The study site is located at the Agriculture and Agri-Food Canada Lacombe Research Centre (52° north latitude and 113° west longitude). The climate is continental prairie and is mildly affected by chinook winds most winters (Environment Canada 1991). The moisture regime is sub-humid with 446.9 mm of annual precipitation (de St. Remy 1990). Mean annual air temperature is 2.3 °C with average high temperatures ranging from -13.8 °C in January to 16.1 °C in July.

The soil on this site is classified as an Eluviated Black Chernozem (Malmo series), developed from fine glaciolacustrine parent material of loam to sandy loam texture. Soils are black silt loam at 0 to 30 cm, dark brown silty clay loam at 30 to 71 cm and dark brown loamy clay at 71 to 107 cm (Agriculture Canada unpublished data). The site is located on a low slope ranging from 1 to 6 degrees with a slight northerly aspect. Average elevation is 870 m above sea level.

3.2. Experimental Design

Nine plant species mixes (four native, four introduced, one mixed) were each replicated four times in a randomized split block (Figure 1, Appendix A). Treatment plots were 2.5 by 2.3 m in size. Total area per treatment was 2.5 m x 2.3 m x 36 plots = 207 m^2 or 0.0207 hectares. Two sections as described above were established for spraying in each of 1995 and 1996, located at the south end of the mowing treatments described in Chapter II. Plant species and herbicide treatments are as discussed in sections 3.4 and 3.5.

3.3. Site Preparation And Seeding

The plot area was summerfallowed in 1994 and cultivated, harrowed and packed in the week prior to seeding in 1995. Each of the species mixes was seeded with a four row plot seeder with hoe-type openers and packing wheels. Soil moisture conditions were optimum at the time of planting. Replicates were seeded in a north-south direction with the blocks aligned west-east. Seeding depth was approximately 1.3 cm. After seeding on May 23 to 25, 1995, the plots were packed with a Brillion grass seeder run at right angles to the seeded rows to pack the seed and minimize row ridging. *Agropyron pectiniforme* L. Gaertn. (crested wheatgrass) was seeded in the roadways.

3.4. Plant Species Treatments

Mixes were of introduced species commonly used in the area and native species present in the area. Each mix consisted of four grasses, one legume and an annual or short-lived species. It was anticipated annual or short-lived species would deter weeds and provide rapid cover for erosion control. The other species would provide a layered canopy to enhance cover. The nine mixes consisting of six species each (thirty-five species) were selected and developed, based on percentages and criteria in Table 1 (Appendix A). Mix compositions are listed in Tables 2 and 3 (Appendix A); mixes 1 through 4 were native, mixes 6 through 9 were introduced and mix 5 was of introduced and native species.

Seed analysis certificates were obtained and germination, tetrazolium and purity tests were conducted where no information was available from the supplier. Certified varieties and ecovars were used, if available. Alfalfa, clover and sainfoin inoculants were added to the seed at packaging for alfalfa, alsike clover and American vetch seed, respectively. American vetch seed was scarified with sand paper. Seeds were weighed based on 1000 seeds and prepackaged prior to seeding. Seed distribution was based on 22.9 cm row spacing at 350 live seeds m^{-2}. This number was a compromise between agricultural productivity and reclamation ground cover requirements. Reclamationists use 175 to 250 plants m^{-2} while agriculturalists use 250 to 800 plants m^{-2} based on the species selected. Seed numbers were based on the following formula: [350 seeds m^{-2} x plot area (10 x 40 m) x % of the mixture divided by number of seeds kg^{-1} x germination rate x % pure live seed (PLS)]. Calculations for native and introduced species seed mixes are presented in Tables 4 and 5 (Appendix A), respectively. Seeded species are listed in Table 6 (Appendix A).

3.5. Herbicide Treatments

Treatments consisted of three broadleaf herbicides: Pardner (bromoxynil at 28g a.i./L), Embutox (2,4-DB at 625g a.i./L) and Banvel (dicamba at 480g a.i./L) and a control (no herbicide). These herbicides were selected as they have the largest weed spectrum and crop registrations and are the most commonly utilized for weed control in forage stands (Alberta Agriculture 1995).

Embutox, Pardner and Banvel are post-emergent foliarly applied herbicides. Embutox (4-(2,4-dichlorophenoxy) butyric acid) is foliar absorbed and readily translocated (Beste 1983). It moves principally to meristematic areas of high metabolic activity. Herbicide injury is evidenced by differential growth rates causing bending and twisting of stems and leaves. Thickening of leaves and stems may also occur. Pardner (3,5-dibromo-4-hydroxybenzonitrile) is a photosynthetic and respiratory inhibitor with little movement once absorbed (Beste 1983). Banvel (3,6-dichloro-o-anisic acid) is readily absorbed by leaves and roots and translocated throughout the plant and may accumulate in mature leaf tips (Beste 1983). It has properties of an auxin-like growth regulator and may result in cell membrane disruption. Most legumes are sensitive to Banvel applications.

Manufacturer recommendations for each herbicide were adhered to: Banvel at 290 ml ha^{-1}, Embutox at 0.9 L ac^{-1} and Pardner at 0.485 ml ac^{-1}. Spraying was conducted with a spray bug (custom made compressed air plot sprayer) equipped with 8001 5 gallon per acre nozzle tips, sprayed at 2.5 mph for Pardner and Banvel and 1.25 mph for Embutox (Table 3.1). Spraying was at 50 cm nozzle spacing and compressed air delivered the spray at 45 psi.

Post emergent spraying was conducted July 14, 1995 when grasses were in the 2 to 4 leaf stage, alfalfa was in the 3 to 4 trifoliate stage and vetch had 3 to 4 stems per plant. Average heights of nonseeded plants at the time of spraying are given in Table 3.2. Spraying was conducted in winds of 5 to 8 km h^{-1} at 16 °C under overcast conditions. On June 22, 1996 spraying was conducted in winds of 0 to 10 km h^{-1} at 11 °C under overcast conditions.

3.6. Preliminary Soil Sampling And Analysis

In year one (1995), prior to seeding, soil was sampled at eight locations per block in sample depth increments of 0 to 5 and 5 to 15 cm then composited. Samples were analyzed by Norwest Labs for sodium adsorption ratio (SAR), pH, electrical conductivity (EC), nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) according to M^c^Keague

(1978). Fertilizer was not added as initial soil fertility was at the optimum recommended level for introduced species (Table 7, Appendix A).

3.7. Vegetation Field Measurements

A 1 m buffer was unsampled around each treatment to eliminate edge effects. Vegetation measurements were made in three randomly placed 0.1 m^2 (20 x 50 cm) permanent quadrats per treatment. Quadrats were placed lengthwise at right angles across two rows. Quadrats were marked with a washer and 15 cm spike in the top left and right hand corners and a flag in the top left hand corner. Each pin and washer was sprayed with fluorescent paint for long-term location. A magnetic pin finder was used to locate pins.

3.7.1. Plant density and survivability

Density by species was determined in each fixed quadrat (3 per herbicide treatment per mix) from 21 to 30 of August 1995 and 6 to 16 August 1996. Average emergence and survivability were based on [number of plants per 0.1 m^2 quadrat x 10 / number PLS planted of that species per m^2 x 100]. Survivability of an individual species was limited to 100% to minimize the effect of seed recruitment from seeded sources of a given species (this affected <2% of quadrats). To standardize plant counts, only two seeded rows were included in the quadrats.

3.7.2. Ground cover

Ground cover was visually assessed in each fixed quadrat as percent live vegetation, litter, bare ground, rock and moss cover. All vegetation on the ground and growing in the frame as well as vegetation lying on the ground, even if it originated outside the frame, was included. Any vegetation with direct ground contact was classified as ground cover. Leaves from forbs, which had fallen on the ground, were categorized as ground cover. Live vegetation (any vegetation without signs of green) was assessed by drawing the stalks and leaves loosely together at approximately 5 cm from the ground surface and comparing this circumference to a known measured cross section. Litter (dead material, vegetation which had no signs of green), bare ground, rock and moss cover were assessed as that present within 2 cm of the ground surface and compared to a known measured cross section (.1m^2 quadrat).

3.7.3. Canopy cover

Canopy cover was assessed in each quadrat by looking directly down on the vegetation and assessing percent live vegetation, litter, bare ground, rock and moss cover and comparing the area to a measured cross section. Vegetation in the frame was included whether it was rooted in the frame or not.

3.7.4. Plant height

Plant height was determined by measuring the longest portion of a plant and averaging the height of the plant species present. Average canopy height, based on three levels (if present), was measured with a meter stick and recorded in each of the fixed quadrats at the end of each growing season

3.7.5. Tillering

The number of tillered plants per species was counted at the beginning of the second growing season and at the end of each growing season (fall 1995, spring 1996, fall 1996).

3.8. Statistical Analyses

SPSS Release 6.1.3 (August 24, 1995) was used for K-means cluster classification on the survivability data to determine if there were group associations. Survivability of each species in each mix for each mowing treatment was computed with Excel 5.0. Four clusters were analyzed per treatment per sampling date. Cluster centers of native and introduced species were analyzed to determine if significant differences existed. All zero values were replaced with 0.9 to allow the program to run without discarding any values or interactions. All species percentages used for percent survivability of mix data were adjusted based on 100% to minimize the effect of reseeding from the first year's seed production.

Ground cover and canopy cover data were converted to a value of 1 and analyzed with a custom model within the general linear model (ANOVA, SPSS 7.0) after square root of square root transformations as determined after normality (Montgomery and Peck 1982, Kuehl 1994) (Table 11). Residuals were plotted against a normal distribution curve. Bar charts were also used to plot the uniformity of the means among groups. Normal Q-Q plots were used to pair observed values against expected values from a normal distribution (Taerem 1997). Density and survivability data were transformed using natural log transformation (Prasad 1997). LAI, disc meter and height measurements did not require transformation as they are discrete data (Prasad 1997). Tukey's HSD was used to statistically rank treatment means at 95% confidence.

3.9. Air Temperature And Precipitation

A meteorological station adjacent to the study site included a Sierra-Misco Inc. Model RG2501 tipping rain gauge to measure precipitation and a Campbell Scientific Co. Model 101 temperature probe to monitor air temperature. This equipment was mounted on a Campbell Scientific Model CM10 tripod and connected to a Campbell Scientific Inc. Model CR21 micrologger. Data collected form 1908 to 1992 were used for the long term normals. Measurements were recorded hourly then converted into daily minimum and maximum temperatures and daily precipitation. Data are presented as mean minimum and maximum monthly air temperature (°C) and monthly precipitation.

4. RESULTS

4.1. Air Temperature And Precipitation

Precipitation for the research period (1995, 1996) was generally higher than the long term average (Table 8, Appendix A). Precipitation for September 1995 was very low (21% of the long term average). Mean monthly temperatures were near the long term average.

4.2. Plant Density And Survivability

4.2.1. Plant density

There were few significantly consistent differences in seeded or nonseeded species densities among herbicide treatments in fall 1995, spring 1996 and fall 1996, regardless of whether spraying was done in 1995 or 1996 (Tables 3.3 and 3.4). Spraying in 1995 with Banvel appeared to decrease density of both seeded and nonseeded species more than the other herbicides, with significant density declines of seeded species in mixes 2 and nonseeded species in mixes 7 and 8. Spraying with Pardner decreased seeded plant density in mixes 3 and 6 and nonseeded plant density in mixes 7 and 8 if sprayed in 1995. Pardner treatments in 1996 decreased nonseeded plant density in mix 2. 1995 spraying with Embutox reduced seeded plant densities in mix 2 and nonseeded plant densities in mixes 3, 7 and 8.

For 1995 spraying, there were few significant differences in seeded plant densities between native and introduced mixes. Mixes 2 and 3 generally had high plant density of seeded species across time, decreasing during 1996. Mixes 1, 3, 4, 5 and 7 had relatively constant seeded species density across time, while mix 8 increased dramatically in 1996.

For 1995 spraying, plant density for nonseeded species increased markedly from fall 1995 to spring 1996, then decreased again except for mix 5, which had a slightly increasing plant density across time. The relatively low nonseeded plant densities for mix 1 across time was notable. Significant differences among mixes were observed at all three measurement times. Generally plant densities for the nonseeded species were lower for introduced than native mixes.

In fall 1996, for spraying in 1996, there were generally no significant differences in plant density among herbicide treatments with the exception of mix 2 (Table 3.4). Mix 1 generally had the lowest plant density of seeded species, while mix 8 had the highest. In fall 1996, for spraying in 1996, there were no significant differences in plant density of nonseeded species among herbicide treatments. Mixes 2, 3, 4 and 5 generally had the highest plant densities for these species.

4.2.2. Plant survivability

The interpretation of the results of the survivability cluster analysis, with r-squared and adjusted r-squared values of less than 0.1 (based on 5% level of significance) indicate that even though 19 of the 28 treatments showed a significant difference between the cluster centers, the factors block, mix and native or introduced explained less than 10% of the variation shown.

Plant survivability appeared to be species dependent; species with large seeds had the highest survivability. Of particular note are *Bromus*, *Agropyron* and *Medicago* species, *Elymus dahuricus*, *Festuca elatior*, *Lolium perenne*, *Secale cereale*, *Stipa viridula* and *Vicia americana* (Table 3.5). No species had consistent responses to any of the herbicides.

For 1995 spraying, there were few significant differences in survivability among herbicide treatments on the three measurement dates (Tables 3.6 and 3.7). Significant differences among mixes were evident on each date, but there was no clear trend in these differences. Mixes 2, 3, 7 and 8 had consistently highest survivability across dates, while mix 1 generally had the lowest survivability. Survivability of mixes 1 and 7 consistently declined over time. In fall 1996 mix 8 had the highest survivability, although not always significant.

For 1996 spraying, in fall 1996, there was only one significant difference in survivability among herbicide treatments (mix 2) (Table 3.7). Mixes 1 and 2 had the lowest survivability while mix 8 had the highest. Generally the survivability for introduced species was higher than that for native species, although differences among mixes 3, 4, 6, 7 and 9 were minor.

4.3. Ground Cover

For 1995 spraying, bare ground was generally high in fall 1995 and decreased dramatically by fall 1996 (Table 3.8). There were a few significant differences in bare ground among herbicide treatments, but no trend. Significant differences among mixes occurred with relatively low values for mixes 5 and 9 notable in fall 1995 and 1996. Very large decreases in bare ground occurred between fall 1995 and 1996 for mixes 3 and 8.

For 1996 spraying, there were significant differences in bare ground in fall 1996 among herbicide treatments in four of the nine cases, but as in 1995 no clear trend was evident (Table 3.8). Significant differences among mixes also occurred at this time, with mixes 1 and 7 having the highest bare ground. Mixes 3, 5, 8 and 9 had notably low bare ground. For 1995 spraying, there were few significant differences in litter due to herbicide treatments (Table 3.9). Litter increased dramatically between fall 1995 and fall 1996 for all mixes, least so for mixes 5 and 9 which had significantly higher litter in fall 1995 than the other mixes. In fall 1996 mixes 4, 6 and 7 had the lowest litter, in some cases significantly.

For 1996 spraying, in fall 1996, there were only 2 cases of significant differences in litter among spraying treatments (Table 3.9). Mixes 1 and 7 had notably low litter at this time, while mix 9 clearly had the highest litter, with mixes 3, 4 and 5 also having high values.

4.4. Canopy Cover

Bare ground in fall 1995 for 1995 spraying had several significant differences among spraying treatments, but no clear trend (Table 3.10). Bare ground was generally significantly higher for native mixes than introduced mixes at this time. Mix 5 had values similar to those for the introduced species. Bare ground by fall 1996 had decreased to near zero in almost all treatments.

For 1996 spraying, bare ground in fall 1996 had only minor significant differences among herbicide treatments. Significant differences in bare ground occurred among mixes, but all values in 1996 were very low (maximum 5%).

Litter for 1995 spraying and 1996 spraying was low for all treatments (maximum 14%) with most values under 3% (Table 3.11). Few instances of significant differences among herbicide treatments occurred; likewise for mixes with no clear trends for either evident. Mixes 5, 7 and 9 had the greatest increases in litter between fall 1995 and fall 1996 for 1995 spraying, unlike the other mixes which had very small increases.

Percent canopy cover composition for spraying in 1995 and 1996 had few significant differences among spraying treatments in seeded and nonseeded species (Table 3.12). For 1995 spraying, native mixes generally had lower canopy cover for seeded species in fall 1995 and 1996 than the other two mixes. Canopy cover for seeded species for introduced mixes was generally > 96% in fall 1996. Mix 5 generally had similar values to those of the introduced species. The much greater values for seeded species for introduced mixes was also evident in fall 1996 for 1996 spraying, except for mix 5, which was intermediate between native and mixed species at this time. Mix 3 had rather low canopy cover for seeded species at this time, while mix 1 had the highest cover of the four native mixes.

Differences in canopy cover among mixes for nonseeded species for 1995 spraying were generally significant, with values for native mixes generally greater than for introduced mixes. Mix 5 had low canopy cover for nonseeded species in fall 1995 and 1996. Trends for canopy cover for nonseeded species sprayed in 1996 were similar to those in 1995.

Response to herbicides was species specific (Table 3.13). *Bromus* and *Agropyron* species, *Dactylis glomerata*, *Elymus dahuricus*, *Lolium perenne*, *Secale cereale*, *Stipa viridula*, *Festuca elatior* and *Vicia americana* had high cover. Canopy level development was not affected by herbicide treatment (Table 3.14). Some species that were planted in multiple mixes performed better in certain mixes. *Agropyron smithii* and *Bromus anomalus* performed best in mix 4, *Stipa viridula* in mix 2, *Vicia americana* in mix 3, *Dactylis glomerata* and *Medicago sativa* (Anik) in mix 8, *Festuca rubra* in mix 7 and *Secale cereale* in mix 9 (Table 3.15). There was no trend among herbicide treatments.

4.5. Tillering

The 1995 spraying had no effect on number of tillering plants the following year (Table 3.16). The spraying of established native plants in 1996, and, to a lesser degree introduced plants, appears to have increased tillering over the control levels.

5.0. DISCUSSION

5.1. Survivability

Although herbicide spraying affected individual species density and survivability it did not have an overall significant effect on mix density. Some species declined under herbicide treatments but the density of other species that increased under herbicide treatments balanced the overall mix density. Herbicide injury was apparent on some plants and numerous seedlings were killed by herbicide application. Generally, except for *Agropyron* species, *Stipa viridula*, *Vicia americana* and *Secale cereale*, there was more of a decline in seeded species survivability when sprayed was conducted in the seedling stage (1995) than in the established stage (1996). Spraying in 1996 on established plant species mixes showed a statistically higher density of nonseeded species in the native species mixes. Nonseeded species had two years to become established in the 1996 sprayed plots accounting for their higher density. Plants were considered live if they retained green coloring. Many herbicide injured plants were counted as live, thus potentially affecting density counts if they died later due to the herbicide applications. There was more bare ground in the native species mixes in year one than in introduced species mixes, providing more ideal sites for nonseeded species germination and emergence. Nonseeded species may also have emerged after the herbicide treatments.

5.2. Cover

Spraying in the first year of establishment versus the second had a more positive effect on canopy cover due to the higher amount of seeded species in the canopy when sprayed in the first year. Most of the litter composition in all treatment plots was *Galeopsis tetrahit* leaves and *Thlaspi arvense* pods. Live *Galeopsis tetrahit* plants were present at high densities in control and Embutox plots indicating a lack of control of this weed at that stage. *Vicia americana* and *Chenopodium album* leaves made up a large portion of the remaining ground cover. *Monolepis nuttalliana*, where present, contributed largely to live ground cover as this plant's growth form is prone. Embutox treatments had a large portion of live ground cover attributed to *Vicia americana* which may have been affected the least by this herbicide treatment. *Vicia americana* was entangled with the forbs, making ground cover assessments difficult. Of the herbicides, Pardner had the least harmful effect on the larger forbs. Ground cover composition varied greatly in mixes 5 and 8 due to the varied stage of decomposition of the *Secale cereale* plants on the ground. Live *Galeopsis tetrahit* plants were present at high densities in control and Embutox plots.

Percent plant canopy cover did not directly relate to individual species survivability. Many plants had a larger growth form in 1996 and with more plants germinating there were physiological differences among seeded species. *Dactylis glomerata* plants were very large in 1996 compared to 1995. Many of *Agropyron* species had reached maturity and lodged, making it difficult to conduct canopy and ground cover assessments. Also, percent canopy cover by species within mixes was highly variable. For 1996 spraying mixes 1, 2, 4 and 6 were lodged. In 1996 large dead weeds present from the previous year added to litter percentages.

5.3. Other Considerations

Low pH may increase the possibility of herbicide persistence in the soil. Lode and Skuterud (1983) showed that raising soil pH from 5 to 7 resulted in a large, significant increase in the breakdown of the herbicide EPTC. As the soil at the research site had an average pH of 5.3, there may have been some residual activity of the Pardner and Embutox treatments on the seedling grasses and legumes, although this was not assessed in the current study. Soil persistence of Banvel is not affected by pH. Soil persistence may have led to lower than expected survival rates for some species with the average field half life for Pardner and Embutox is 7 days and 1-2 weeks respectively.

Sprayed grasses and legumes appeared to have reduced seed yield or delayed maturity which may be attributed to herbicide injury. Some injury may be due to absorption of herbicides by roots. As well as being foliarly absorbed, 2,4-D formulations may be absorbed by roots (Crafts 1975). When [^{14}C]dicamba and bromoxynil were applied at 1 kg ha^{-1} to a clay loam, the bromoxynil achieved 80% breakdown after 7 days, while it took 16 days for the [^{14}C]dicamba to achieve 50% breakdown at 85% of field capacity and at 20°C (Smith 1984) and [^{14}C]2,4-D 7 days to achieve 50% breakdown under the same conditions (Smith 1980).

Many of the control plots were trampled by deer, thus affecting canopy and ground cover measurements. As well, Richardson's ground squirrel and pocket gopher activity occurred in the plots. Mouse and gopher activity resulted in additional straw increasing the litter percentage. Aphids present on the *Secale cereale* plants also increased litter percentages in those plots seeded to *Secale cereale*.

5.4. Species And Mix Assessment

The *Agropyron* and *Bromus* species along with *Stipa viridula*, *Vicia americana*, *Elymus dahuricus*, *Secale cereale Festuca elatior*, *Festuca rubra*, *Lolium perenne*, *Medicago* species, *Phleum pratense* and *Dactylis glomerata* had the highest percent survivability.

Mixes 2 and 8 had the highest survivability of seeded native and introduced species respectively in fall 1996 from 1995 spraying and mixes 4 and 8 had the highest percent survivability for 1996 spraying.

For 1995 spraying, mixes 2 and 7 had the largest density for seeded plants in fall 1995 and spring 1996. In fall 1996 mixes 3 and 8 had the largest densities for both 1995 and 1996 spraying. Mixes which included species with the highest survivability had the highest density. Of these seeded species, mix 2 included *Agropyron smithii*, *Bromus anomalus*, *Vicia americana* and *Stipa viridula*, mix 7 included *Agropyron elongatum*, *Agropyron intermedium*, *Lolium perenne*, *Bromus inermis*, *Festuca rubra* and *Medicago sativa* (Algonquin). Mix 3 included *Agropyron dasystachyum*, *Bromus anomalus*, *Dactylis glomerata* and *Vicia americana* while mix 8 *included Agropyron trichophorum*, *Bromus inermis*, *Poa pratensis*, and *Medicago sativa* (Anik).

Mixes 3 and 9 had the highest litter for 1995 spraying for native and introduced species mixes, respectively, with the composite mix 5 being highest overall. Mixes 3 and 7 had highest litter cover for 1996 spraying. In fall 1996 the high ground cover litter for mixes 5, 8 and 9 was due to *Secale cereale* and *Bromus inermis* which also had highest canopy cover. *Secale cereale* made up most of the ground cover in mixes 5 and 9. *Agropyron smithii* composed most canopy cover in mix 4, *Stipa viridula* in mix 2, *Bromus inermis* in mixes 5 and 7, *Dactylis glomerata* in mix 8 and *Secale cereale* in mix 9.

Based on survivability, bare ground and litter cover, mixes 2 and 3 and 8 and 9 performed the best of the native and introduced mixes, respectively.

6. CONCLUSIONS

1. Herbicide treatments did not affect survivability of seeded native or introduced species after two years.
2. There were few significantly consistent differences in seeded or nonseeded species densities among herbicide treatments regardless of spraying date.

3. Response to herbicide application was similar in native and introduced plant species mixes for ground and canopy cover, with the litter portion of ground cover being high for all herbicide treatments.
4. Although not statistically significant, introduced species mixes had a higher percent canopy of seeded species than that of the native species mixes.
5. Spraying at the seedling stage of plant growth negatively affected seeded species; by the end of year two, these differences were no longer present.

7. REFERENCES

Alberta Agriculture. 1997. Crop protection with chemicals. Shaffeek Ali (editor). Alberta Agriculture, Food and Rural Development, Edmonton, AB. 347 pp.

Beste, C.E. 1983. Herbicide handbook of the Weed Science Society of America - 5th Edition. Weed Science Society of America. Illinois, U.S.A. 515 pp.

Chandler, J.M., A.S. Hamill and A.G. Thomas. Crop losses due to weeds in Canada and the United States. Weed Science Society of America. Champaign, IL. 22 pp.

Crafts, A.S. 1975. Modern weed control. University of California Press. Berkeley, CA. 440 pp.

Duebbert, H.F., E.T. Jacobson, K.F. Higgins and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat for the prairie porthole region. U.S. Department of Interior. Fish and Wildlife Service. Special Scientific Report - Wildlife No. 234. Washington, DC. 20 pp.

Ducks Unlimited Canada. 1995. Revegetating with native grasses. Native Plant Materials Committee. D.B. Wark (chair), W.R. Poole, R.G. Arnott, L.R. Moats and L. Wetter. Stonewall, MB. 133 pp.

Kerr, D.S., L.J. Morrison and K.E. Wilkinson Environmental Management Associates. 1993. Reclamation of native grasslands in Alberta: a review of the literature. RRTAC Report #93-1. 246 pp.

Klingman, D.L. and M.K. McCarty. 1958. USDA Bulletin 1180: 1-49.

Lode, O. and R. Skuterud. 1983. EPTC persistence and phytotoxicity influenced by pH and manure. Weed Res. 23:19-25.

Prasad, N.G.N. May 1, 1997. Personal communication. Associate Professor, Department of Mathematical Sciences, University of Alberta. Edmonton, AB.

Smith, A.E. 1984. Soil persistence studies with bromoxynil, propanil and [^{14}C]dicamba in herbicidal mixtures. Weed Res. 24:291-294.

Smith, A.E. 1980. Persistence studies with [^{14}C]2,4-D in soils previously treated with herbicides and pesticides. Weed Res. 20:355-359.

Table 3.1. Herbicide rates expressed as active ingredient.

Herbicide	Rate total	g ai/acre	Spray Volume	ml herbicide/ liter water
Banvel	290 ml/ha	56.36	110 L	2.64
Embutox	2232 ml/ha	564.8	80 L	11.25
Pardner	1203 ml/ha	136.4	40 L	12.12

Table 3.2. Average height (cm) of plants on spray date (July 15, 1995).

Species	Height
Brassica campestris	33
Capsella bursa-pastoris	12
Chenopodium album	24
Cirsium arvense	6
Desurainia sophia	13
Galeopsis tetrahit	15
Thlaspi arvense	14

Table 3.3. 1995 and 1996 plant density (per m^2) of seeded and nonseeded species as affected by spraying in 1995.

	Fall 1995					Spring 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Seeded										
Mix 1	32 aA	20 aA	30 aA	17 aA	6 *2	26 aA	25 aA	29 aA	19 aA	5 *2
Mix 2	80 cBC	104 bC	72 cdB	53 bcA	12 *1	93 bB	90 cB	82 cdB	53 dA	10 *1
Mix 3	63 cC	27 aA	57 bcdBC	33 abAB	7 *2	77 bAB	48 abA	77 dB	52 bcdAB	14 *2
Mix 4	17 aA	23 aAB	37 abcB	18 aAB	5 *2	33 aA	33 aA	43 bcA	30 abcdA	5 *1
Mix 5	28 abA	21 aA	20 aA	27 abA	3 *1	26 aA	24 aA	21 aA	30 abcdA	3 *1
Mix 6	49 bcB	33 aA	54 bcdB	57 cB	6 *1	59 bB	39 abA	50 cdAB	39 bcdAB	5 *1
Mix 7	58 cA	69 bA	82 dA	70 cA	9 *1	53 bA	60 bcA	54 cdA	47 cdA	6 *1
Mix 8	32 abA	21 aA	32 abA	23 aA	4 *1	30 aA	33 aA	23 aA	26 abA	8 *2
Mix 9	21 aA	27 aA	26 aA	22 aA	4 *1	28 aA	33 abA	30 abA	23 abcA	3 *1
SE of Mix	6 *1	5 *2	5 *1	5 *1		5 *1	6 *1	4 *1	5 *2	
Nonseeded										
Mix 1	9 aA	4 abA	3 aA	7 aA	2 *1	65 abcA	87 bcdA	63 aA	127 cdA	24 *3
Mix 2	13 aAB	6 abA	17 bAB	28 abAB	5 *2	215 deA	68 bcdA	53 aA	128 bcA	35 *3
Mix 3	13 aA	18 cA	9 abA	14 abA	3 *1	769 eB	217 dA	511 aAB	391 dAB	111 *2
Mix 4	7 aA	13 bcB	3 aA	7 aAB	2 *1	368 deB	238 cdAB	118 aA	124 cAB	72 *2
Mix 5	7 aA	1 aA	7 abA	3 aA	2 *1	13 aA	8 aA	23 aA	11 aA	8 *2
Mix 6	8 aA	5 abA	4 aA	11 aA	3 *1	60 abA	126 abcA	47 aA	35 aA	19 *3
Mix 7	11 aA	2 aA	3 aA	6 aA	2 *1	126 bcAB	67 abAB	68 aAB	8 aA	33 *3
Mix 8	8 aA	5 abA	3 aA	4 aA	2 *1	104 bcBC	94 bcdBC	30 aA	70 abAB	18 *2
Mix 9	12 aB	3 abA	10 abAB	5 aAB	2 *1	85 abcA	52 abA	48 aA	21 aA	23 *3
SE of Mix	3 *1	2 *1	2 *1	3 *1		78 *2	44 *3	30 *3	27 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.4. 1996 plant density (per m^2) of seeded and nonseeded species by mix as affected by spraying in 1995 and 1996.

	Fall 1996, Sprayed 1995					Fall 1996, Sprayed 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Seeded										
Mix 1	23 aA	16 aA	18 aA	14 aA	2 *1	13 aA	15 aA	13 aA	21 abA	2 *1
Mix 2	44 abB	38 bAB	40 bAB	28 abA	4 *1	18 abA	23 abAB	41 bcB	18 aA	5 *1
Mix 3	41 abA	33 abA	44 bcA	32 abcA	6 *2	49 cdB	28 abcAB	40 bcAB	23 abA	6 *2
Mix 4	26 aA	33 abA	34 bA	36 abA	3 *1	36 cA	52 cdA	29 abA	33 abA	8 *2
Mix 5	39 abA	36 bA	32 abA	40 abA	5 *1	27 bcA	29 bcA	27 abA	20 aA	3 *1
Mix 6	28 aA	25 abA	28 abA	32 abA	3 *1	38 cA	43 cdA	31 bcA	33 abA	4 *1
Mix 7	33 abA	37 bA	41 bcA	29 abA	3 *1	37 cA	33 bcA	35 bcA	32 abA	2 *1
Mix 8	77 bA	103 cA	111 cA	48 cA	27 *2	83 dA	74 dA	71 cA	71 cA	15 *2
Mix 9	38 abA	37 bA	37 bcA	34 abA	4 *1	30 bcA	35 bcA	31 bcA	40 bcA	4 *1
SE of Mix	8 *2	8 *1	15 *1	4 *1		6 *1	6 *1	8 *1	5 *1	
Nonseeded										
Mix 1	2 aA	15 abcA	9 abA	8 abA	2 *1	88 bcB	19 abA	8 aA	31 abAB	16 *3
Mix 2	22 abB	3 aA	11 abAB	18 abcAB	3 *1	138 cA	58 cdeA	141 bA	69 bcA	22 *2
Mix 3	76 cAB	57 dA	85 cA	139 dA	15 *2	163 cA	113 eA	140 bA	159 dA	22 *2
Mix 4	28 abA	27 bcA	21 abA	40 cA	3 *2	94 cA	83 cdeA	63 bA	187 cdA	21 *3
Mix 5	29 bA	36 cdA	37 bcA	23 bcA	3 *2	55 abcA	132 deA	80 bA	174 cdA	27 *3
Mix 6	2 aA	6 abA	3 aA	2 aA	1 *1	13 aA	1 aA	8 aA	16 aA	7 *2
Mix 7	2 aA	1 aA	3 aA	0 aA	1 *0	16 abAB	36 abcB	7 aA	8 aA	5 *2
Mix 8	23 abA	39 bcA	38 bcA	46 bcA	4 *2	19 abA	7 abA	31 aA	34 abA	12 *2
Mix 9	37 bcA	33 cdA	37 abcA	28 bcA	2 *2	96 cA	59 bcdA	79 bA	42 abA	27 *3
SE of Mix	8 *2	8 *2	10 *2	10 *2		20 *3	16 *2	17 *2	23 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.5. 1995 and 1996 percent survivability by species as affected by spraying in 1995 and 1996.

	Sprayed 1995				Sprayed 1995				Sprayed 1995				Sprayed 1996			
	Fall 1995				Spring 1996				Fall 1996				Fall 1996			
	C	P	E	B	C	P	E	B	C	P	E	B	C	P	E	B
Introduced Species																
Agropyron elongatum	7	14	22	16	3	5	12	3	5	6	9	8	1	0	0	1
Agropyron intermedium	22	18	24	21	24	33	24	27	13	18	24	16	16	14	29	14
Agropyron trichophorum	2	3	3	2	14	16	13	18	41	16	22	37	21	11	11	5
Alopecurus arundinaceus	0	0	0	0	3	3	3	0	2	2	0	0	6	0	0	0
Alopecurus pratensis	5	0	0	0	0	0	0	0	0	0	0	0	0	0	27	5
Bromus biebersteinii	23	15	29	26	38	18	25	22	21	14	18	17	23	24	15	23
Bromus carinatus (Don Frederico)	52	14	29	27	38	18	25	22	21	13	18	17	23	24	15	23
Bromus inermis	14	12	21	14	27	26	20	24	38	28	22	26	29	34	25	36
Dactylis glomerata	3	0	1	1	5	2	5	3	5	3	6	4	6	5	4	4
Elymus dahuricus	26	19	36	45	29	36	43	26	24	26	26	21	19	31	29	26
Festuca elatior	18	16	25	13	19	11	19	14	2	3	5	11	8	5	3	5
Festuca rubra	2	5	6	2	3	2	2	5	2	3	3	1	6	6	2	5
Lolium perenne	55	59	49	62	24	21	19	7	5	5	9	0	5	2	2	0
Medicago falcata (Anik)	5	2	2	1	3	1	0	0	1	3	0	0	4	2	1	2
Medicago sativa (Algonquin)	11	15	11	11	10	13	2	1	7	11	6	2	13	6	6	2
Medicago sativa (Rangelander)	12	5	5	10	7	5	2	4	0	4	0	1	6	8	5	1
Phleum pratense	5	3	0	6	2	3	3	2	3	0	0	5	6	5	6	2
Poa compressa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa pratensis	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Secale cereale	48	54	45	52	43	46	41	49	39	51	48	51	25	21	18	19
Trifolium hybridum	0	1	1	0	0	1	1	0	0	1	2	4	0	0	0	0
Native Species																
Agropyron dasystachyum	35	18	30	38	43	44	54	56	24	30	41	30	37	35	46	29
Agropyron smithii	35	48	42	37	49	47	57	47	36	39	40	44	30	44	45	31
Agropyron trachycaulum	37	27	40	30	43	43	56	35	43	30	35	25	24	29	25	38
Bromus anomalus	8	7	13	1	14	21	10	8	4	3	10	6	8	3	4	8
Danthonia parryi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	3	3	0	0	3	2	0	0	0	0	0	2	0	0	0	0
Festuca campestris	0	1	0	0	0	0	0	0	0	3	1	0	1	0	0	0
Festuca hallii	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Festuca idahoensis	0	0	0	3	0	0	2	2	2	2	0	6	0	0	5	2
Koeleria macrantha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petalostemon purpureum	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Stipa curtiseta	0	0	0	1	1	1	0	0	3	1	0	2	8	6	1	2
Stipa viridula	13	25	18	23	16	17	17	24	13	22	14	14	9	11	10	10
Vicia americana	61	38	46	15	66	37	58	18	26	12	19	4	13	14	16	2

C: Control

P: Pardner

E: Embutox

B: Banvel

Table 3.6. 1995 and 1996 percent survivability of seeded species by mix as affected by spraying in 1995.

	Fall 1995					Spring 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	11 abA	6 aA	10 aA	5 aA	2 *24	9 aA	8 aA	9 abA	6 aA	2 *26
Mix 2	22 cB	28 bB	21 abAB	15 cdA	2 *16	40 cB	27 cB	24 bcA	17 cA	8 *12
Mix 3	16 bcB	7 aA	15 abB	10 abcAB	2 *20	17 abcA	13 abA	19 cA	15 bcA	2 *23
Mix 4	5 aA	7 aAB	11 abB	6 abAB	2 *27	10 abA	11 abA	14 bcA	10 abcA	1 *19
Mix 5	12 bcA	9 aA	9 aA	11 cdA	1 *15	11 abA	10 abA	9 abA	12 bcA	1 *15
Mix 6	14 bcA	10 aA	16 abB	17 cdB	2 *13	16 abcA	12 abA	15 bcA	11 bcA	1 *14
Mix 7	20 cA	23 bA	25 bA	23 dA	2 *9	17 bcA	19 bcA	17 bcA	15 bcA	2 *9
Mix 8	14 bcA	9 aA	14 abA	10 bcA	2 *20	12 abA	9 aA	9 aA	10 abA	2 *25
Mix 9	9 bA	12 abA	10 aA	10 bcA	2 *19	11 abA	14 abcA	13 bcA	10 bcA	1 *12
SE of Mix	2 *19	1 *20	2 *17	2 *19		2 *18	2 *19	2 *15	2 *20	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.7. 1996 percent survivability of seeded species by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995 Fall 1996					Sprayed 1996 Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	7 aB	5 aAB	6 aAB	5 aA	1 *14	4 abA	5 aA	4 aA	7 aA	1 *17
Mix 2	13 abB	12 bcdB	13 abAB	9 abA	1 *12	6 aA	6 abAB	12 bcB	6 aA	1 *22
Mix 3	12 aA	9 abA	13 bcdA	10 abA	2 *25	13 cdA	8 abA	12 bcA	7 aA	2 *25
Mix 4	8 aA	10 abcA	11 bcA	11 bcA	1 *14	12 cdA	14 deA	9 bA	11 abcA	2 *14
Mix 5	14 abA	13 bcdA	13 bcdA	16 cA	2 *20	10 bcA	10 bcA	9 bA	7 abA	1 *16
Mix 6	8 aA	8 abA	8 abA	9 bcA	1 *13	10 cA	12 cA	9 bA	9 abcA	1 *11
Mix 7	10 aAB	11 bcdAB	13 bcdB	9 bcA	1 *13	11 cA	11 cA	11 bcA	10 abcA	1 *9
Mix 8	23 bA	26 dA	20 dA	17 cA	4 *16	24 dA	28 dA	20 cA	22 cA	3 *11
Mix 9	15 abA	15 cdA	15 cdA	14 cA	2 *11	12 cdA	14 cA	12 bcA	15 bcA	2 *12
SE of Mix	2 *18	2 *18	1 *11	1 *15		2 *16	2 *15	2 *14	2 *14	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.8. 1995 and 1996 bare ground percentage of ground cover by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995					Sprayed 1995					Sprayed 1996				
	Fall 1995					Fall 1996					Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	92 bA	96 bB	93 bA	95 bAB	1 *0	19 bcA	20 bcA	12 bcA	24 dA	4 *4	40 eAB	35 cAB	47 dB	21 cA	5 *4
Mix 2	90 bA	96 bB	90 bA	91 bA	1 *0	15 abA	17 abB	3 aA	20 cdB	2 *2	22 cdAB	20 cA	29 cdB	17 bcA	4 *3
Mix 3	90 bAB	96 bB	91 bAB	86 bA	1 *0	5 aA	25 bcB	7 abA	20 cdB	3 *2	9 abcA	8 bcAB	9 abA	32 cB	3 *4
Mix 4	93 bA	94 bA	94 bA	94 bA	1 *0	33 cA	25 bcA	25 cdA	10 bcdA	5 *4	15 cdeA	27 cA	18 bcA	31 cA	4 *3
Mix 5	37 aA	46 aA	59 aA	48 aA	7 *4	2 aA	3 aA	2 aA	9 abA	4 *4	10 abAB	3 abAB	4 aA	21 abcB	5 *4
Mix 6	91 bAB	91 bAB	93 bB	88 bA	1 *0	35 cA	39 cA	29 cdA	32 dA	7 *4	17 bcA	27 cA	54 cdB	14 abcA	6 *5
Mix 7	91 bAB	88 bA	91 bB	90 bAB	1 *0	33 cA	40 cA	40 cA	31 dA	6 *3	42 deAB	31 cA	54 dB	29 cA	6 *4
Mix 8	91 bA	91 bA	91 bA	93 bA	1 *0	6 aB	5 aB	1 aA	6 abcB	1 *2	16 abcA	2 aA	8 abA	4 abA	3 *3
Mix 9	67 aA	61 aA	57 aA	52 aA	6 *3	3 aA	3 aA	5 aA	3 aA	2 *3	2 aA	2 aA	3 aA	4 aA	1 *2
SE of Mix	4 *2	3 *2	3 *1	4 *2		4 *3	4 *3	3 *3	5 *4		4 *3	4 *4	4 *4	5 *4	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.9. 1995 and 1996 litter percentage of ground cover by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995					Sprayed 1995					Sprayed 1996				
	Fall 1995					Fall 1996					Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	3 aA	2 aA	3 aA	3 abA	1 *2	73 bcA	73 bcA	78 bcdA	63 aA	5 *2	53 aAB	54 aAB	38 aB	60 aB	5 *3
Mix 2	4 aB	1 aA	4 aB	4 abAB	1 *2	78 bcAB	75 bcAB	90 dB	70 aA	3 *2	72 abA	76 abcA	66 bA	76 abA	4 *2
Mix 3	4 aAB	2 abA	4 aAB	6 abB	1 *2	89 cB	68 abcA	85 dB	71 aA	3 *2	87 bB	85 bcB	82 bA	57 aA	3 *1
Mix 4	4 aA	3 abcA	3 aA	3 aA	1 *2	59 aA	67 abcAB	65 abAB	83 aB	5 *3	75 bA	64 abA	73 bA	59 aA	5 *2
Mix 5	47 bA	37 eA	32 bA	31 cA	7 *3	90 cA	89 cA	80 cdA	80 aA	4 *2	84 bA	94 cA	92 bA	74 abA	5 *3
Mix 6	5 aAB	5 bcdAB	3 aA	6 bB	1 *1	60 abA	57 aA	66 abcA	63 aA	7 *4	78 bB	72 abcB	43 aA	82 abB	6 *3
Mix 7	5 aA	6 dA	4 aA	4 abA	1 *2	63 abA	55 abA	54 aA	64 aA	6 *3	55 aAB	67 abB	42 aA	67 abB	6 *3
Mix 8	5 aA	6 cdA	5 aA	4 abA	1 *1	87 cA	86 cA	93 dB	86 aA	2 *1	77 bA	88 bcA	81 bA	78 abA	4 *2
Mix 9	24 bA	27 eA	35 bA	34 cA	5 *3	87 cA	87 cA	82 cdA	84 aA	2 *1	93 bA	94 cA	93 bA	91 bA	1 *0
SE of Mix	3 *3	3 *2	3 *2	3 *2		4 *2	5 *2	4 *2	5 *3		4 *2	4 *2	5 *2	5 *3	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.10. 1995 and 1996 bare ground cover percentage of canopy cover by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995					Sprayed 1995					Sprayed 1996				
	Fall 1995					Fall 1996					Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	31 deA	47 eA	35 eA	46 cA	6 *3	0 aA	1 aA	0 aA	0 aA	1 *2	2 aA	1 aA	1 abA	1 aA	1 *2
Mix 2	15 cA	48 eC	17 cdAB	42 cBC	4 *3	0 aA	1 aA	0 aA	1 aA	0 *1	1 aA	0 aA	3 abA	1 aA	1 *2
Mix 3	18 cdA	54 eC	34 deAB	45 cBC	4 *3	0 aA	1 aA	0 aA	3 aB	0 *1	1 aA	2 abA	1 aA	12 cAB	2 *2
Mix 4	53 eA	57 eA	64 fA	50 cA	6 *3	0 aA	1 aA	0 aA	0 aA	0 *1	0 aA	1 aA	0 aA	0 aA	0 *1
Mix 5	1 aA	0 aA	0 aA	0 aA	0 *1	0 aA	0 aA	0 aA	0 aA	0 *1	0 aA	0 aA	0 aA	0 aA	0 *1
Mix 6	6 bcA	9 dA	8 bA	4 bA	2 *2	2 bAB	2 aB	0 aA	1 aAB	1 *2	0 aA	1 aA	0 aA	3 abA	1 *1
Mix 7	2 abA	3 bcA	11 bcB	2 abA	1 *2	2 bA	2 aA	4 bA	4 aA	1 *3	3 bA	3 bA	5 bA	3 bcA	1 *2
Mix 8	12 bcA	6 cdA	2 aA	3 abA	4 *3	0 aA	0 aA	0 aA	1 aA	0 *1	0 aB	0 aA	1 aAB	0 aA	0 *1
Mix 9	3 abB	0 abA	1 aAB	0 aA	0 *1	0 aA	0 aA	1 bA	1 aA	0 *1	0 aAB	0 aA	3 aA	0 abB	1 *1
SE of Mix	4 *3	3 *2	3 *2	4 *2		0 *1	1 *2	0 *1	1 *2		1 *2	1 *2	1 *2	2 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.11. 1995 and 1996 litter percentage of canopy cover by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995 Fall 1995					Sprayed 1995 Fall 1996					Sprayed 1996 Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Mix 1	1 aA	1 abcA	1 abA	1 aA	0 *1	2 aA	1 aA	1 aA	2 abcA	1 *3	7 bcdA	1 aA	2 abA	0 aA	2 *3
Mix 2	1 abAB	1 aA	2 abB	1 aAB	0 *2	1 aA	1 aA	1 aA	1 abA	0 *1	3 abcdAB	5 abAB	5 bcB	2 aA	1 *3
Mix 3	1 abA	1 abA	1 abAB	2 bB	0 *2	3 abA	2 aA	2 abA	6 abcdA	1 *2	8 dA	10 bAB	7 cAB	14 cB	3 *3
Mix 4	1 abA	2 bcA	2 bB	1 aA	0 *2	1 aA	2 aA	1 aA	1 aA	1 *2	0 aA	2 aA	4 abcA	7 bB	2 *2
Mix 5	0 abA	0 abcA	0 abA	0 aA	0 *0	11 bA	14 bA	12 cA	7 bcdA	3 *4	1 abA	1 aA	1 aA	3 aA	1 *2
Mix 6	1 abAB	1 bcB	0 abA	0 aAB	0 *1	2 aA	3 aA	3 abA	2 abcA	1 *2	1 abcA	1 aA	2 abcA	1 aA	0 *1
Mix 7	0 abB	0 abcB	0 aA	0 aB	0 *0	5 abAB	4 abAB	6 bcB	2 abcA	1 *2	5 cdA	4 abA	5 abcA	3 abA	1 *2
Mix 8	0 abA	0 abcA	0 abA	0 aA	0 *0	1 aA	0 aA	4 abAB	9 cdB	2 *2	2 abcdA	3 abA	3 abcA	3 abA	1 *3
Mix 9	1 bA	1 cA	0 abA	0 aA	0 *1	9 bA	10 bA	10 cA	13 dA	3 *3	1 abcdA	2 aA	2 abcA	2 aA	1 *2
SE of Mix	0 *0	0 *1	0 *2	0 *1		2 *3	2 *2	2 *2	2 *3		2 *3	1 *3	1 *3	1 *2	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.12. 1995 and 1996 percent canopy cover composition by mix as affected by spraying in 1995 and 1996.

	Sprayed 1995					Sprayed 1995					Sprayed 1996				
	Fall 1995					Fall 1996					Fall 1996				
	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat	C	P	E	B	SE of Treat
Seeded															
Mix 1	50 abA	67 abcA	95 bA	54 abA	11 *8	95 bcA	82 bA	96 cA	79 abc	7 *4	70 abA	69 abc	85 bcA	76 bcA	10 *7
Mix 2	65 abA	88 bcB	67 aA	59 abA	6 *2	61 abA	94 bB	70 aA	64 abA	6 *3	50 aA	38 aA	43 abA	45 aA	8 *5
Mix 3	47 abA	31 aA	72 abA	41 abA	10 *6	50 aA	34 aA	60 abA	39 aA	9 *7	37 aA	49 abA	28 aA	38 abA	7 *5
Mix 4	46 aAB	50 abAB	83 abAB	44 aA	12 *7	66 abA	73 bAB	83 abB	75 bcA	6 *3	60 abA	49 abA	69 bcA	57 abcA	7 *3
Mix 5	90 bA	100 cA	82 abA	91 bA	6 *4	91 bcA	86 bA	89 cA	93 cA	8 *4	73 abA	71 bcA	81 bcA	87 cA	9 *5
Mix 6	77 abA	75 abcA	92 bA	72 bA	7 *3	98 bcA	87 bA	96 cA	98 cA	5 *3	97 cA	93 cA	99 cA	95 cA	2 *1
Mix 7	75 abA	94 cA	95 bA	89 bA	5 *2	100 bcA	99 bA	98 cA	100 cA	1 *0	98 cA	92 cA	94 cA	96 cA	2 *1
Mix 8	69 abA	73 abcA	96 bA	80 bA	10 *6	88 bcA	89 bA	85 bcA	77 bcA	8 *4	79 cA	87 cA	91 cA	89 cA	5 *2
Mix 9	66 abA	95 cA	80 abA	88 bA	7 *3	99 bcA	98 bA	96 cA	96 cA	2 *1	96 cA	86 cA	98 cA	99 cA	4 *2
SE of Mix	10 *6	8 *5	6 *3	10 *6		6 *4	6 *4	5 *3	7 *4		7 *5	7 *3	6 *4	7 *4	
Nonseeded															
Mix 1	50 aA	33 abA	5 abA	29 aA	0 *1	5 abA	18 abcdA	4 abcA	13 abA	7 *9	13 abA	31 bcA	15 abcA	24 abA	10 *9
Mix 2	36 aA	12 abA	34 bA	41 aA	6 *11	39 deB	7 abcA	30 bcdAB	36 bAB	*1	50 cA	62 cA	57 deA	47 cdA	9 *6
Mix 3	53 aAB	70 cB	28 abA	59 aAB	0 *1	50 eA	66 cA	40 dA	61 dA	9 *7	63 cA	51 cA	72 eA	62 dA	7 *5
Mix 4	38 aA	50 bcA	17 abA	48 aA	3 *1	34 cdeA	27 deA	17 abcdA	25 bcA	6 *8	40 cA	51 cA	32 cdeA	43 cdA	7 *7
Mix 5	10 aA	0 aA	18 abA	10 aA	6 *9	1 abA	14 bcdA	11 abcdA	7 abA	7 *7	27 bcA	29 bcA	19 bcdA	14 bcA	9 *8
Mix 6	23 aA	26 abA	8 abA	28 aA	7 *11	2 aA	13 abA	4 aA	2 aA	5 *7	3 aA	7 aA	1 aA	5 abA	4 *7
Mix 7	25 aB	6 abA	5 abA	11 aAB	5 *9	0 aA	1 aA	2 abA	0 aA	1 *4	2 aA	8 abA	6 abA	4 aA	2 *7
Mix 8	31 aB	18 abAB	4 aA	20 aAB	10 *1	12 bcdA	11 cdA	15 cdA	23 bA	8 *9	21 abA	13 abA	9 abA	11 abA	5 *7
Mix 9	27 aA	5 aA	20 abA	12 aA	6 *9	1 abcA	2 abcA	4 abcA	4 abA	2 *5	4 abAB	14 bB	2 abcAB	1 abA	4 *6
SE of Mix	10 *12	8 *10	6 *9	9 *12		5 *7	6 *7	5 *8	7 *8		6 *7	7 *6	6 *8	7 *7	

Means within a column for a given time period followed by the same lower case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Means within a row for a given time period followed by the same upper case letter are not significantly different ($p<0.05$) (based on Tukey's HSD).
Statistical analysis was done on transformed data and mean seperations were based on these data and not the untransformed means shown.
Standard error of means shown preceded by * are based on transformed data.
C: Control P: Pardner E: Embutox B: Banvel

Table 3.13. 1995 and 1996 percent canopy cover by species as affected by spraying in 1995 and 1996.

	Sprayed 1995				Sprayed 1995				Sprayed 1996			
	Fall 1995				Fall 1996				Fall 1996			
	C	P	E	B	C	P	E	B	C	P	E	B
Introduced Species												
Agropyron elongatum	10	13	25	18	14	13	5	18	1	0	0	1
Agropyron intermedium	12	14	22	12	23	33	40	27	21	13	14	20
Agropyron trichophorum	0	1	0	1	30	29	41	46	22	18	16	8
Alopecurus arundinaceus	0	0	0	0	0	2	0	0	1	0	0	0
Alopecurus pratensis	0	0	0	0	0	0	0	0	0	0	1	1
Bromus biebersteinii	27	28	41	27	60	38	48	47	71	51	33	56
Bromus carinatus (Don Frederico)	43	71	85	76	13	22	7	11	17	37	29	34
Bromus inermis	6	15	16	9	49	34	32	38	47	60	63	64
Dactylis glomerata	7	1	3	1	17	11	18	9	22	15	16	14
Elymus dahuricus	14	16	34	25	32	43	45	26	9	29	50	33
Festuca elatior	24	25	15	16	3	4	4	15	8	3	3	6
Festuca rubra	0	5	1	0	0	1	0	0	1	2	2	0
Lolium perenne	27	24	19	30	1	1	1	0	1	1	1	0
Medicago falcata (Anik)	4	1	0	0	1	2	0	0	2	3	3	1
Medicago sativa (Algonquin)	9	23	8	8	2	7	2	1	26	8	8	1
Medicago sativa (Rangelander)	11	0	3	4	0	1	0	0	6	15	5	0
Phleum pratense	2	6	0	1	0	0	0	9	1	2	1	0
Poa compressa	0	0	0	0	0	0	0	0	0	0	0	0
Poa pratensis	0	0	0	0	0	0	0	0	0	0	0	0
Secale cereale	75	76	66	84	47	62	61	59	28	27	19	19
Trifolium hybridum	0	2	1	0	0	0	0	4	0	0	0	0
Native Species												
Agropyron dasystachyum	14	20	18	34	23	23	22	26	18	27	40	15
Agropyron smithii	30	37	44	34	39	39	45	44	30	24	39	29
Agropyron trachycaulum	30	43	69	46	95	82	96	79	64	75	75	78
Bromus anomalus	2	3	3	0	4	2	7	4	7	3	2	7
Danthonia parryi	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	0	0	0	3	0	0	0	0
Festuca campestris	0	1	0	0	0	3	1	0	3	0	0	0
Festuca hallii	0	0	1	0	0	0	0	0	0	0	0	0
Festuca idahoensis	0	0	0	2	0	1	0	3	0	0	6	1
Koeleria macrantha	0	0	0	0	0	0	0	0	0	0	0	0
Petalostemon purpureum	0	0	1	0	0	0	0	0	0	0	0	0
Stipa curtiseta	0	0	0	0	1	0	0	1	2	2	0	1
Stipa viridula	10	23	15	18	18	37	22	20	10	21	8	15
Vicia americana	30	11	36	4	12	3	14	2	5	8	3	0

C: Control

P: Pardner

E: Embutox

B: Banvel

Table 3.14. 1995 and 1996 percent of quadrats with canopy levels as affected by spraying in 1995 and 1996.

	Control			Pardner			Embutox			Banvel		
	Canopy Level			Canopy Level			Canopy Level			Canopy Level		
	1	2	3	1	2	3	1	2	3	1	2	3
Sprayed 1995, Fall 1995												
Mix 1	100	100	50	100	100	58	100	100	33	100	75	17
Mix 2	100	100	50	100	100	42	100	92	67	100	100	8
Mix 3	100	100	75	100	75	58	100	75	33	100	83	8
Mix 4	100	58	25	100	58	25	100	67	33	100	75	17
Mix 5	100	8	8	100	17	0	100	25	0	100	8	0
Mix 6	100	92	33	100	50	17	100	92	17	100	83	25
Mix 7	100	100	58	100	92	17	100	100	33	100	67	42
Mix 8	100	100	83	100	92	83	100	100	75	100	100	75
Mix 9	100	33	17	100	25	8	100	0	0	100	8	0
Sprayed 1995, Fall 1996												
Mix 1	100	75	17	100	83	8	100	67	17	100	83	8
Mix 2	100	75	8	100	100	25	100	75	8	100	58	17
Mix 3	100	75	17	100	92	17	100	92	25	100	100	25
Mix 4	100	58	8	100	83	8	100	67	0	100	83	0
Mix 5	100	100	8	100	100	8	100	100	25	100	100	17
Mix 6	100	100	8	100	100	0	100	100	0	100	100	17
Mix 7	100	100	0	100	100	17	100	100	8	100	100	17
Mix 8	100	83	8	100	75	17	100	100	8	100	100	17
Mix 9	100	92	25	100	100	8	100	100	25	100	92	17
Sprayed 1996, Fall 1996												
Mix 1	100	75	0	100	33	0	100	33	0	100	58	17
Mix 2	100	67	8	100	83	25	100	75	8	100	50	0
Mix 3	100	42	0	100	75	25	100	58	17	100	75	17
Mix 4	100	92	8	100	83	8	100	58	0	100	67	0
Mix 5	100	92	42	100	92	50	100	100	50	100	100	17
Mix 6	100	100	8	100	100	33	100	100	8	100	100	17
Mix 7	100	92	8	100	100	8	100	92	0	100	100	8
Mix 8	100	67	0	100	67	8	100	58	8	100	50	17
Mix 9	100	100	42	100	100	42	100	100	33	100	100	67

Table 3.15. 1995 and 1996 percent canopy cover by species within mix as affected by spraying in 1995 and 1996.

		Sprayed 1995				Sprayed 1995				Sprayed 1996			
		Fall 1995				Fall 1996				Fall 1996			
	Mix	C	P	E	B	C	P	E	B	C	P	E	B
Native Species													
Agropyron smithii	2	14	25	9	24	13	12	18	19	10	2	32	6
	4	46	49	79	44	66	66	72	70	50	45	45	52
Bromus anomalus	1	3	7	0	0	0	0	0	1	7	0	0	2
	2	2	5	2	0	3	5	4	2	0	0	1	11
	3	2	1	8	2	12	3	12	7	3	3	4	7
	4	0	0	0	0	0	1	11	5	18	9	3	8
Danthonia parryi	1	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
Festuca hallii	1	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	3	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0
Koeleria macrantha	1	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0
Petalostemon purpureum	1	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	2	0	0	0	0	0	0	0	0	0
Stipa curtiseta	3	0	0	0	0	1	0	0	2	3	2	0	1
	4	0	0	0	0	1	0	0	0	1	2	1	0
Stipa viridula	2	19	45	29	31	37	73	45	39	20	42	12	30
	5	0	0	0	5	0	0	0	0	0	1	4	0
Vicia americana	2	29	12	27	4	8	1	3	2	0	5	2	0
	3	31	10	44	4	15	6	26	2	9	10	4	1
Introduced Species													
Bromus inermis	5	2	26	0	5	57	50	26	45	56	70	70	61
	7	16	18	19	21	60	44	50	54	44	66	70	75
	9	1	3	29	1	30	10	20	14	40	44	48	57
Dactylis glomerata	5	4	0	0	0	0	0	0	1	4	0	0	0
	8	18	0	9	3	42	32	37	21	46	33	38	31
	9	0	3	0	0	9	1	17	7	15	11	9	10
Festuca rubra	7	1	2	1	1	0	1	1	0	2	5	4	1
	9	0	8	0	0	0	0	0	0	0	0	0	0
Medicago falcata (Anik)	5	0	1	0	0	0	0	0	0	0	0	0	0
	8	8	2	1	0	3	4	0	0	3	6	6	2
Secale cereale	5	84	73	82	81	33	36	64	47	15	14	8	9
	9	65	80	50	88	60	88	59	72	41	41	31	30

C: Control
P: Pardner
E: Embutox
B: Banvel

Table 3.16. 1995 and 1996 tillered plants per quadrat as affected by spraying in 1995 and 1996.

	Sprayed 1995				Sprayed 1995				Sprayed 1995				Sprayed 1996			
	Fall 1995				Spring 1996				Fall 1996				Fall 1996			
	C	P	E	B	C	P	E	B	C	P	E	B	C	P	E	B
Mix 1	2	2	3	2	3	3	3	2	2	2	2	2	1	2	3	3
Mix 2	3	6	4	4	3	5	5	5	3	4	4	3	2	5	2	3
Mix 3	0	0	1	1	3	3	3	4	2	3	4	3	1	3	3	5
Mix 4	1	2	3	1	3	5	4	3	3	4	4	4	3	4	4	3
Mix 5	3	2	2	2	3	2	2	3	4	3	3	4	3	4	3	4
Mix 6	2	2	3	4	6	4	5	4	3	2	3	3	2	4	3	3
Mix 7	4	4	5	4	5	5	5	5	3	3	3	3	3	4	3	4
Mix 8	3	2	3	2	2	3	2	2	4	4	2	4	2	3	3	3
Mix 9	2	2	2	2	3	3	3	2	4	3	3	3	2	3	3	4

C: Control
P: Pardner
E: Embutox
B: Banvel

IV. SYNTHESIS

1. BACKGROUND

Native and introduced plant species have been attributed with many desirable characteristics. The objectives of this research were to evaluate selected native and introduced plant species emergence and survivability and their response to mowing and herbicides. The results of the study could be used to determine if selected native plant species will perform as well as introduced species in resource conservation and agricultural productivity.

2. NATIVE AND INTRODUCED SPECIES PERFORMANCE

Plant species survivability was species dependent with larger seeded species having a higher survivability than smaller seeded species. Plants of the same genus had similar survivability, whether they were native or introduced. As mixes were selected to be balanced for desired traits, they showed similar survivability and responded similarly to mowing and herbicide treatments. However, shading and decomposition of selected cover crop species may have reduced survivability of the non cover crop seeded species. There were more nonseeded species present in native species mixes than in introduced species mixes. However, they did not affect overall mix performance by the end of the two years of the study.

In general, native plant species were slower to emerge and become established resulting in more bare ground initially. The productivity of native plant species mixes were lower than introduced species mixes over a period of two years. This may be partially due to the fact that native species mixes did not attain the same heights as introduced species mixes. As introduced plant species are bred for productivity, this observation may be self evident. Early competition by the seeded introduced plants reduced the competition effects of the nonseeded species. In this research, plant species of the same genus performed similarly with respect to productivity.

In reclamation, a rapidly forming, sustainable ground cover is desirable for ground cover and erosion control. In areas prone to moderate or severe erosion, the selection of aggressive introduced plant species may be more appropriate. However, the more aggressive native *Agropyron* and *Bromus* species and *Stipa viridula* as well as *Vicia americana* should not be overlooked. The ability for these native species to reseed themselves is an important consideration. *Agropyron* species are subject to rusts and ergot, these species should not be seeded alone but in combination with other species. In this research *Agropyron* species were very aggressive and should not be seeded at higher rates than 15 to 20 % in a mix to allow other species to become established.

3. MOWING AND HERBICIDE IMPACTS

Mowing and the removal of the clipped material increased bare ground and reduced litter the following year. This could have negative implications for erosion due to decreased ground cover. Litter helps to reduce raindrop impact and to retain and conserve soil moisture providing protection to seedlings from desiccation and grazing. As well, litter removal would reduce nutrient cycling at a time when plant species are most vulnerable. Excessive litter has the negative effect of reducing plant germination.

Response to herbicide use was species specific. Although there was an initial decrease in seedling survivability, there was no long-term effect on survivability of seeded species mixes due to herbicide treatment. As injury to new seedlings is a major concern in the initial stages of establishment, early mowing may be more appropriate than spraying, particularly when plants undergo severe stress after herbicide application. Spraying visually delayed maturity in many of the seeded species. More research in this area is required as information on herbicide selection and rates for specific species is limited.

4. SPECIES MIX SELECTION

Based on this research, when considering survivability, canopy, litter and bare ground cover, mixes 2 and 3 and mixes 7 and 8 were considered to perform the best after two years for native and introduced species, respectively under both mowing and spraying treatments. Percent survivability of individual species appeared initially to be negatively affected by early (seedling) spraying and positively affected by early mowing. After two years there were no significant differences among mowing treatments and spraying treatments. If the initial concern is that of erosion control, mowing would be preferred to spraying in the first year. Native species mixes may be as suitable for reducing erosion as introduced species mixes, if nonseeded species are not a concern. Introduced species mixes were more competitive after two years as evidenced by lower nonseeded plant counts. Percent survivability was similar under mowing and herbicide regimes given high fertility and rainfall.

5. MANAGEMENT IMPLICATIONS

In this study, selected plant species were all seeded at the same depth. This may have resulted in smaller seeded species being buried too deep lowering expected germination. Smaller seeded species should be broadcast seeded and harrowed to provide increased soil to seed contact. Site preparation, seeding depth and seeding methods requires further investigation as this factor alone may be the main cause of seedling failure. A combination of methods may be more appropriate with the smaller seeded species being handled separately. This may increase the time required for seeding which may be more than offset with increased survivability, productivity and ground cover.

The term of this research had above average rainfall and the soil did not require supplemental fertilization. These factors, along with acidic soil conditions, may have served to minimize (mask) any negative effects from the treatments or any physiological differences between the native and introduced plant species. Individual species adaptability to acidity or other site specific considerations requires further investigation.

Annual or short lived perennial plants were used in the mixes as a cover crop to compete with the nonseeded species and reduce their competition. The *Secale cereale* and the *Bromus carinatus* (Don Frederico) were the best of the tested species for this purpose. These species may have been too competitive in this location given the above average rainfall and fertility. A more appropriate species selection may include *Aveneae* or *Hordeum* species which tiller less profusely and are able to reseed if allowed to reach maturity.

6. NATIVE AND INTRODUCED PLANT SPECIES CHARACTERISTICS

Although this study did not address all of the beliefs associated with native and introduced plant species, some can be supported and some contradicted with the data from this study. Native and introduced plants have been associated with several attributes:

1. Native plants are native and therefore more desirable. They grow under reduced (disturbed) soil conditions and require less inputs (nutrients, water). The study site chosen had adequate soil moisture and fertility for introduced species. The native species appeared to be as productive (based on LAI and disc meter measurements) as introduced species after two years. It would not appear that competition for available nutrients had negatively affected plant stands. Emergence and survivability data and density are similar for native and introduced plant species.
2. Native plant stands are more diverse and have greater longevity. The native plant mixes in this study had greater diversity (species richness). More species were present in the form of the nonseeded species (weeds and volunteer grasses). Seeded species comprised a lower proportion of canopy cover in the native mixes than seeded species in the introduced mixes. This study was not of a long enough duration to test the longevity theory.
3. Introduced plant species are too aggressive, resulting in monocultures. At 15% composition of native and introduced plant mixes, plants of the *Bromus* and *Agropyron* genera were aggressive as evidenced by their domination of live canopy cover.

4. Native plant species are too slow to germinate and establish. Although intially slower to germinate and reach maturity (in the first year), native plants had similar surviability rates after two years.

5. Native plants are later maturing. This was evident based on plant observations during the course of this study. Native plant species did not head out in the first year.

6. There is a lack of comercially available native seed and the seed that is available is too expensive. Certified varieties of native seed were 1.5 to 4 times as expensive on average. Some species were in limited supply and substantially more expensive.

7. FURTHER RESEARCH CONSIDERATIONS

The issue of weed control in new plantings needs to be researched further. Do the weeds provide needed ground cover for erosion control and nutrient cycling? Annual weeds may not cause the same long term competitive effects as the perennial weeds which may be more effectively controlled with herbicides than a limited mowing regime which may reduce seed production but not necessarily reduce the competitive effects of the weeds. Annual weeds may serve to reduce erosion caused by spring rains on bare ground. The density of the weed regime present may dictate the necessity for control, which may be site specific. In areas with reduced rainfall and fertility, this may be more critical than in an area with adequate fertility and rainfall.

Presently there is very little information justifying the number of species utilized in a mixture to provide a desired end land use. This research used six species in a mixture to provide data on species currently present or used in the parkland. More experimentation on seeding rates and species number is required.

This research may imply that with appropriate species selection (species that are adapted to a given ecosystem or end land use), native or introduced plant species may be used. This would provide new markets for the infant native seed industry which presently relies on the reclamation industry and its limited acreage for a market. This in turn has limited seeds supplies which increases the price of available seed. Research is presently being conducted at the environmental center at Vegreville to provide certified varieties of seed for the reclamation industry.

The controversy of how native is native and the use of varieties versus ecovars needs to be addressed in the reclamation industry which is leaning to a native only designation for those areas which are not privately owned. The reclamation community is still divided on this issue, which only serves to confuse the public as to the appropriate use of native species. Do the native ecovars provide superior genetics to selected, named native varieties?

8. CONCLUSIONS

In conclusion, given site conditions at the study site in the parkland area, native species mixes performed similarly to introduced species mixes under mowing and herbicide treatments. Response to selected treatments was species specific. Nonseeded species did not appear to adversely affect seeded plant species density or survivability. Introduced species generally were more productive than native species and provided greater initial protection from erosion. Native species were later to mature and may provide late season productivity. End land use may determine appropriate species selection, given that the requirements of the agricultural and reclamation industries are not mutually exclusive.

V. APPENDIX A

Figure 1. Research plot layout

Block 1	Block 2	Block 3	Block 4
rep	rep	rep	rep
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
trt	trt	trt	trt
6 4 7 3 2 9 8 5 1	9 8 3 7 6 2 1 4 5	6 2 7 5 9 3 8 1 4	5 7 6 2 4 9 3 1 8
mow	no mow	no mow	mow
mow	no mow	no mow	mow
mow	no mow	no mow	mow
no mow	mow	mow	no mow
no mow	mow	mow	no mow
no mow	mow	mow	no mow
spray 1995	spray 1995	spray 1995	spray 1995
spray 1996	spray 1996	spray 1996	spray 1996

Table 1. Species selection criteria.

% in Mix	Category	Category Description
25	Bunchgrass	Low growing species for ground cover, erosion and productivity
15	Rhizomatous	Wheatgrasses are found throughout Alberta and are adapted to climate, aggressive creeping-rooted plants fill bare areas faster
10	Annual or short-lived perennial	Initial ground cover, erosion prevention and weed competition
20	Legume	Source of nitrogen for fertility and long term sustainability
15	Shorter species	Understory development, erosion control, productivity
15	Other (tall, short full season grazing)	Productivity

Table 2. Listing of species comprising the native and introduced species mixes.

Native Pasture	Native Hay	Native Mix
Mix 1	Mix 2	Mix 3
Festuca hallii	*Festuca campestris*	*Stipa curtiseta*
Agropyron trachycaulum	*Agropyron smithii*	*Agropyron dasystachyum*
Bromus anomalus	*Bromus anomalus*	*Bromus anomalus*
Petalostemon purpureum	*Vicia americana*	*Vicia americana*
Koeleria macrantha	*Stipa viridula*	*Festuca idahoensis*
Danthonia parryi	*Deschampsia caespitosa*	*Danthonia parryi*
Alternate Native Mix	**Native-Improved Mix**	**Introduced Pasture**
Mix 4	Mix 5	Mix 6
Festuca hallii	*Festuca hallii*	*Bromus biebersteinii*
Agropyron smithii	*Bromus inermis*	*Poa compressa*
Bromus anomalus	*Secale cereale*	*Elymus dahuricus*
Petalostemon purpureum	*Medicago falcata* (An)	*Medicago sativa* (Ra)
Koeleria macrantha	*Stipa viridula*	*Festuca elatior*
Stipa curtiseta	*Dactylis glomerata*	*Phleum pratense*
Introduced Hay	**Introduced Mix**	**Alternate Introduced Mix**
Mix 7	Mix 8	Mix 9
Agropyron elongatum	*Dactylis glomerata*	*Dactylis glomerata*
Bromus inermis	*Alopecurus arundinaceus*	*Festuca rubra*
Lolium perenne	*Bromus carinatus* (D F)	*Secale cereale*
Medicago sativa (Al)	*Medicago falcata* (An)	*Trifolium hybridum*
Festuca rubra	*Poa pratensis*	*Alopecurus pratensis*
Agropyron intermedium	*Agropyron trichophorum*	*Bromus inermis*

An: Anik
Al: Algonquin
Ra: Rangelander
D F: Don Frederico

Table 3. Selection criteria and species mixes.

Criteria	Native Pasture	Native Hay	Native Mix
	Mix 1	Mix 2	Mix 3
25% bunch grass	plains rough fescue	foothills rough fescue	western porcupine grass
15% rhizomatous	slender wheatgrass	western wheatgrass	northern wheatgrass
10% annual or short-lived perennial	nodding brome	nodding brome	nodding brome
20% legume	purple prairie clover	American vetch	American vetch
15% shorter species	june grass	green needle grass	Idaho fescue
15% other (tall,short, full season grazing)	Parry's oatgrass	tufted hairgrass	Parry's oatgrass

Criteria	Alternate Native Mix	Native-Improved Mix	Introduced Pasture
	Mix 4	Mix 5	Mix 6
25% bunch grass	plains rough fescue	plains rough fescue	meadow brome
15% rhizomatous	western wheatgrass	smooth brome	Canada bluegrass
10% annual or short-lived perennial	nodding brome	fall rye	dahurian wildrye
20% legume	purple prairie clover	alfalfa (Anik)	alfalfa (Rangelander)
15% shorter species	june grass	green needle grass	meadow fescue
15% other (tall,short, full season grazing)	western porcupine grass	orchard grass	timothy

Criteria	Introduced Hay	Introduced Mix	Alternate Introduced Mix
	Mix 7	Mix 8	Mix 9
25% bunch grass	tall wheatgrass	orchard grass	orchard grass
15% rhizomatous	smooth brome	creeping foxtail	creeping red fescue
10% annual or short-lived perennial	perennial ryegrass	brome (Don Frederico)	fall rye
20% legume	alfalfa (Algonquin)	alfalfa (Anik)	alsike clover
15% shorter species	creeping red fescue	Kentucky bluegrass	meadow foxtail
15% other (tall.short. full season grazing)	intermediate wheatgrass	pubescent wheatgrass	smooth brome

Table 4. Calculations for native seed requirements.

Species	Variety	Supplier	seeds/kg	Total seed required kg	P.L.S.	Seed 100% (based on PLS) gm	Percent in mix	Total seed/rep gm	Seed/row gm	Total seed (160 rows) gm
American vetch	n/a	PS	87,000	1.6092	46.5	3460.6	0.20	692.1	17.30	5536.8
Awnless wheatgrass	Revenue	PS	350,000	0.4000	81.0	493.8	0.15	74.1	1.85	296.3
Foothills rough fescue	n/a	PS	837,000	0.1673	47.0	356.0	0.25	89.0	2.22	356.0
Green needle grass	n/a	PS	288,000	0.4861	68.5	709.6	0.15	106.4	2.70	425.6
Hooker's oatgrass	n/a	DU	515,000	0.2718	13.8	1964.2	0.15	294.6	7.36	1178.4
Idaho fescue	Joseph	E	1,333,000	0.1050	16.0	656.3	0.15	98.4	2.46	393.6
June grass	n/a	PS	3,200,000	0.0438	46.0	95.1	0.15	14.3	0.36	114.1
Nodding brome	n/a	ESRS	385,000	0.3636	84.6	429.8	0.10	43.0	1.08	688.0
Northern wheatgrass	Elbee	PS	340,000	0.4118	81.5	505.2	0.15	75.8	1.89	303.1
Parry's oatgrass	n/a	E	373,000	0.3753	49.8	753.3	0.15	113.0	2.83	452.0
Plains rough fescue	n/a	DU	837,000	0.1673	57.4	291.4	0.25	72.9	1.82	874.8
Purple prairie clover	Kaneb	DU	293,000	0.4778	84.2	567.5	0.20	113.5	2.84	908.0
Tufted hairgrass	n/a	PS	2,500,000	0.0560	76.1	73.6	0.15	11.0	0.28	44.2
Western porcupine grass	n/a	E	350,000	0.4000	67.2	59.5	0.25	148.8	3.72	595.2
Western wheatgrass	Walsh	PS	242,000	0.5785	83.0	697.0	0.15	104.6	2.62	836.8

DU: Ducks Unlimited Canada

ESRS: Eastern Slopes Rangeland Seeds Ltd.

E: EnviroScapes

PS: Prairie Seeds Inc.

Table 5. Calculations for introduced seed requirements.

Species	Variety	Supplier	seeds/kg	Total seed required kg	P.L.S.	Seed 100% (based on PLS) gm	Percent in mix	Total seed/rep gm	Seed/row gm	Total seed (160 rows) gm
Alfalfa	Algonquin	H	440,000	0.3182	90.0	353.6	0.20	70.7	1.77	282.9
	Anik	Pick	440,000	0.3182	94.0	338.5	0.20	67.7	1.69	541.6
	Rangelander	H	440,000	0.3182	94.0	338.5	0.20	67.7	1.69	270.8
Alsike clover	Aurora	H	1,540,000	0.0909	96.0	94.7	0.20	18.9	0.47	75.8
California brome	Don Frederico	J	125,000	1.1200	95.0	1178.9	0.10	117.9	29.48	471.6
Canada bluegrass	Reubens	PS	2,500,000	0.0560	77.4	72.4	0.15	10.9	0.27	43.6
Creeping foxtail	Garrison (coated)	H	1,736,000	0.0806	85.0	94.9	0.15	14.2	0.36	227.2
Creeping red fescue	Boreal	H	1,353,000	0.1035	90.0	115.0	0.15	17.3	0.43	69.0
Creeping red fescue	Boreal	H	1,353,000	0.1035	90.0	115.0	0.15	17.3	0.43	69.0
Crested wheatgrass	Nordan	H	440,000	0.3182	92.7	343.3	1.00	343.3	8.58	1373.2
Dahurian wildrye	n/a	H	185,000	0.7568	94.0	805.1	0.10	80.5	2.01	322.0
Fall rye	Prima	H	30,500	4.5902	92.0	4989.3	0.10	498.9	12.50	3991.4
Intermediate wheatgrass	Chief	H	194,000	0.7216	93.0	776.0	0.15	116.4	2.91	465.6
Kentucky bluegrass	Troy	PS	4,800,000	0.0292	72.8	40.1	0.15	6.0	0.15	24.1
Meadow brome	Fleet	H	176,000	0.7955	88.6	897.8	0.25	224.5	5.61	897.8
Meadow fescue	Ensign	PS	506,000	0.2767	78.0	354.7	0.15	53.2	1.33	212.8
Meadow foxtail	n/a (coated)	H	895,000	0.6257	83.7	747.6	0.15	112.1	2.80	448.4
Orchard grass	Kay	H	1,439,000	0.0973	84.0	115.8	0.25	29.0	0.72	231.6
Orchard grass	Kay	H	1,439,000	0.0973	84.0	115.8	0.15	17.4	0.44	69.6
Perennial ryegrass	n/a	H	500,000	0.2800	91.0	307.7	0.10	30.8	0.77	123.1
Pubescent wheatgrass	Greenleaf	H	220,000	0.6364	84.0	757.6	0.15	113.6	2.84	454.4
Smooth brome	Carlton	H	300,000	0.4667	84.0	555.6	0.15	83.3	2.08	666.4
Smooth brome	Carlton	H	300,000	0.4667	84.0	555.6	0.15	83.3	2.08	333.2
Tall wheatgrass	n/a	H	174,000	0.8046	87.0	924.8	0.25	231.2	5.78	924.8
Timothy	Champ	H	2,710,000	0.0517	94.0	55.0	0.15	8.2	0.20	32.8

H: Hannas Seeds Ltd — Pick: Pickseed
J: Johnson Seeds — PS: Prairie Seeds Inc.

Table 6. Alphabetical listing of selected native and introduced plant species.

Species		
Agr das	*Agropyron dasystachyum*	northern wheatgrass
Agr elo	*Agropyron elongatum*	tall wheatgrass
Agr int	*Agropyron intermedium*	intermediate wheatgrass
Agr smi	*Agropyron smithii*	western wheatgrass
Agr tra	*Agropyron trachycaulum*	slender wheatgrass
Agr tri	*Agropyron trichophorum*	pubescent wheatgrass
Alo aru	*Alopecurus arundinaceus*	creeping foxtail
Alo pr	*Alopecurus pratensis*	meadow foxtail
Bro ano	*Bromus anomalus*	nodding brome
Bro bie	*Bromus biebersteinii*	meadow brome
Bro DF	*Bromus carinatus* (D F)	brome (Don Frederico)
Bro ine	*Bromus inermis*	smooth brome
Dac glo	*Dactylis glomerata*	orchard grass
Dan par	*Danthonia parryi*	Parry's oatgrass
Des cae	*Deschampsia caespitosa*	tufted hairgrass
Ely dah	*Elymus dahuricus*	dahurian wildrye
Fes cam	*Festuca campestris*	foothills rough fescue
Fes ela	*Festuca elatior*	meadow fescue
Fes hal	*Festuca hallii*	plains rough fescue
Fes ida	*Festuca idahoensis*	Idaho fescue
Fes rub	*Festuca rubra*	creeping red fescue
Koe mac	*Koeleria macrantha*	june grass
Lol per	*Lolium perenne*	perennial ryegrass
Med An	*Medicago falcata* (An)	alfalfa (Anik)
Med Al	*Medicago sativa* (Al)	alfalfa (Algonquin)
Med Ra	*Medicago sativa* (Ra)	alfalfa (Rangelander)
Pet pur	*Petalostemon purpureum*	purple prairie clover
Phl pra	*Phleum pratense*	timothy
Poa com	*Poa compressa*	Canada bluegrass
Poa pra	*Poa pratensis*	Kentucky bluegrass
Sec cer	*Secale cereale*	fall rye
Sti cur	*Stipa curtiseta*	western porcupine grass
Sti vir	*Stipa viridula*	green needle grass
Tri hyb	*Trifolium hybridum*	alsike clover
Vic ame	*Vicia americana*	American vetch

Table 7. Soil chemical properties of the study site.

Sample Depth (cm)	nitrate (ppm)	phosphate (ppm)	potassium (ppm)	sulphate (ppm)	pH	E.C.
0 to 5	>73	>60	>570	26	5.3	1.3
5 to 15	>57	>60	>545	12	5.3	0.7
total kg/ha	>290	>269	>1119	59		
avail. kg/ha	411	134	1251	83		

Table 8. Meteorological data for Agriculture Canada Lacombe Research Centre for the growing seasons of 1995 and 1996.

	Mean Max. Temp. (°C)			Mean Min. Temp. (°C)			Mean Temp. (°C)			Precipitation (mm)			Precipitation Days		
Month	1995	1996	85-yr av.	1995	1996	85-yr av.	1995	1996	85-yr av.	1995	1996	85-yr av.	1995	1996	85 yr av.
April	9.5	12.0	10.6	-2.7	-2.0	-3.2	3.4	5.0	3.6	21.6	64.0	27.8	9	11	7.6
May	17.8	13.3	17.3	2.6	1.7	2.4	10.2	7.5	9.8	61.0	80.0	50.3	9	14	10.8
June	22.2	19.6	20.6	8.1	6.0	6.6	15.2	13.1	13.6	83.0	110.0	81.7	10	13	14.0
July	22.3	23.0	23.5	9.4	9.7	8.7	15.9	16.4	16.1	112.0	114.0	77.6	16	15	13.6
August	19.4	24.1	22.4	5.9	7.4	7.3	12.7	15.8	14.8	104.0	61.0	63.5	13	6	11.8
September	20.7		17.5	1.7		2.5	11.2		10.0	9.0		41.8	4		10.1
October	10.6		11.9	-3.2		-2.9	3.7		4.5	17.0		19.4	7		6.4

Table 9. Alphabetical listing of nonseeded plant species.

Species		
Ama ret	*Amaranthus retroflexus*	redroot pigweed
Ave fat	*Avena fatua*	wild oats
Axy ama	*Axyris amaranthoides*	russian pigweed
Bra cam	*Brassica campestris*	canola
Cap bur	*Capsella bursa-pastoris*	shepherdspurse
Che alb	*Chenopodium album*	lamb's-quarters
Cir arv	*Cirsium arvense*	Canada thistle
Cir sp.	*Cirsium* species	Lacombe thistle
Cre tec	*Crepis tectorum*	narow-leaved hawk's-beard
Des sop	*Descurainia sophia*	flixweed
Ech cru	*Echinochloa crus-galli*	barnyardgrass
Gal tet	*Galeopsis tetrahit*	hempnettle
Hor jub	*Hordeum jubatum*	foxtail barley
Hor vul	*Hordeum vulgare*	barley
Lam amp	*Lamium amplexicaule*	henbit
Lat och	*Lathyrus ochroleucus*	peavine
Lyc alb	*Lychnis alba*	white cockle
Mal cri	*Malva crispa*	mallow
Mat mat	*Matricaria matricarioides*	pineapple weed
Mel sp.	*Melilotus* species	sweet clover
Mon nut	*Monolepis nuttalliana*	spear-leaved goosefoot
Pol con	*Polygonum convolvulus*	wild buckwheat
Pol per	*Polygonum persicaria*	lady's thumb/smartweed
Sal sp.	*Salix* species	willow sp.
Sen vul	*Senecio vulgaris*	common groundsel
Set vir	*Setaria viridis*	green foxtail
Sol tri	*Solanum triflorum*	wild tomato
Son asp	*Sonchus asper*	spiny sowthistle
Ste med	*Stellaria media*	common chickweed
Tar sp.	*Taraxacum* species	dandelion
Thl arv	*Thlaspi arvense*	stinkweed
Tri aes	*Triticum aestivum*	wheat
Tri pra	*Trifolium pratense*	red clover

Table 10. ANOVA table and transformation summary for mowing data analysis.

	Density	Survivability	Ground Cover	Canopy Cover	LAI	Disc Meter	Height
Source	df	df	df	df	df	df	df
Block	3	3	3	3	3	3	3
Mix	8	8	8	8	8	8	8
Treatment	3	3	3	3	3	3	3
Transformation	LN	LN	SQRT (SQRT)	SQRT (SQRT)	None	None	None

LN: natural log base *e*
SQRT: square root

Table 11. ANOVA table and transformation summary for herbicide data analysis.

	Density	Survivability	Ground Cover	Canopy Cover
Source	df	df	df	df
Block	3	3	3	3
Mix	8	8	8	8
Treatment	3	3	3	3
Transformation	LN	LN	SQRT (SQRT)	SQRT (SQRT)

LN: natural log base *e*
SQRT: square root