

Revegetating with Native Grasses in the Northern Great Plains

Professional's Manual

Canada | Ducks Unlimited Canada — Canada's Conservation Company | Fisheries and Oceans Canada | Proven Seed | Native Plant Solutions

D. B. Wark L. K. Gabruch C. Penner R. J. Hamilton T. G. Koblun

Acknowledgments

The authors wish to thank the following agencies and organizations whose staff provided helpful comments and advice in the development of this publication:

Agriculture and Agri-Food Canada
Alberta Agriculture, Food and Rural Development
Canadian Cattlemen's Association
Canadian Federation of Agriculture
Department of Fisheries and Oceans
Ducks Unlimited Canada
Manitoba Agriculture, Food and Rural Initiatives
Prairie Farm Rehabilitation Administration
Proven Seed
Saskatchewan Agriculture and Food
Soil Conservation Council of Canada

Revegetating With Native Grasses in the Northern Great Plains contains the most recent innovations for revegetating with native plant materials and is modelled after an earlier manual produced by Ducks Unlimited Canada (DUC) nearly a decade ago. That manual,"Revegetating with Native Grasses" was very well received with over 4,000 copies distributed throughout North America, Europe and Australia. That original body of work authored by DUC's Native Plant Materials Committee members **D.B. Wark, W.R. Poole (deceased), R. G. Arnott, L.R. Moats and L. Wetter,** is intertwined throughout this new manual.

This work is intended to provide guidelines to end users, based on decades of native revegetation experience gained by DUC staff across the Canadian portion of the Northern Great Plains. While the guidelines provided in this manual are time-tested, there is no substitution for local experience. Always consult with local agronomists, the Provincial Weed Control Guide and revegetation professionals in your area.

The authors wish to thank funding partners who underwrote the preparation and publication of this manual.

Agriculture and Agri-Food Canada's Greencover Canada Program
Department of Fisheries and Oceans
Ducks Unlimited Canada
Proven Seed

We also wish to thank our colleagues at the **USDA Natural Resources Conservation Service** with whom we have collaborated on advancing the science of revegetating with native plant materials for a quarter of a century. Thanks also to Mr. Paul Thoroughgood for helpful editorial comments and to Sandra Hall who spent many hours typing this document.

We dedicate this manual to the memory of one of
the builders of the native revegetation ethic in Canada…

Mr. W. R. (Bill) Poole

Table of Contents

List of Figures

Figure

List of Tables

Table

List of Appendices

Appendix

INTRODUCTION

Ducks Unlimited Canada (DUC), a private non-profit conservation organization, has been actively involved in wildlife habitat restoration for almost 70 years. Initially DUC was primarily involved in wetland restoration and management. However, as a result of research conducted over the past 20 years, DUC programs have steadily expanded into upland restoration and management as the value of these areas to waterfowl became increasingly known. Today, upland work is a major emphasis of DUC's conservation programs. As a result, DUC has invested considerable resources in developing long-term science-based sustainable programs to support the increased use of native plant species in revegetation programs.

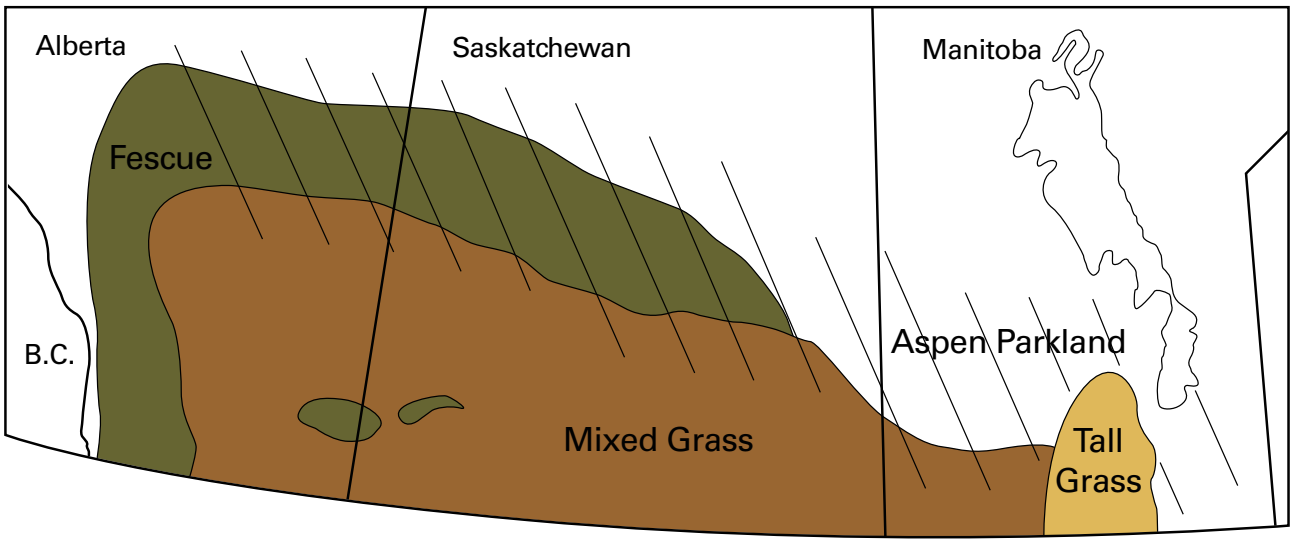
Although several excellent references exist describing the methods employed to establish grass stands (Duebbert et al. 1981, Thornburg 1982), a Canadian Prairies-specific summary would be useful. This report presents proven techniques for the establishment of native plant materials. The methods outlined apply to establishing plantings on formerly cultivated or disturbed sites, as opposed to rejuvenation of existing native cover. In fact, DUC strongly recommends that all remnant stands of native prairie be retained and managed according to sound ecological principles. This manual provides an outline of techniques and materials for revegetating extensive areas of former cropland in an attempt to approximate the species composition of natural communities using the most common species of native plants. It is not about prairie grassland restoration per se.

(note: For ease of reading, only the Canadian common names of plant species have been used in the text of this manual. Appendix A cross-references those names to one or more of the scientific names used in North America.)

BACKGROUND

Ducks Unlimited Canada (DUC) began seeding grass in 1976 using traditional forage mixtures. Typically, forage grasses are introduced varieties selected to produce large volumes of palatable, nutritious livestock feed. Such plantings are considered temporary (Duebbert et al. 1981) and within seven to eight years after the establishment of introduced cover plots, DUC professionals began observing declines in the ability of those stands to survive without significant input. As a result, DUC began looking for alternatives to traditional introduced forage grasses for long-term plantings. DUC's inquiries led them to the U.S. Soil Conservation Service (now known as the Natural Resources Conservation Service (NRCS), whose expertise is recognized in land reclamation. Based on their experience, it very quickly became apparent that native plant material would provide a long-lived, easily managed alternative to introduced grasses on long-term plantings. DUC has also learned that it is no more difficult to establish stands of native species provided certain techniques regarding site preparation, weed control, seed quality and seeding techniques are employed. This manual presents those techniques.

Figure 1 – Generalized prairie types in Western Canada



PLANTING OBJECTIVES

There are a wide array of native and introduced plant species for reclamation agencies and individuals to choose from when undertaking a revegetation project. Each species has attributes and limitations that must be considered. Selection of the most appropriate species should be based on a combination of criteria including the nature of the land base, purpose of the seeding, likely management regimes, seed availability, seed costs, longevity, ease of stand establishment and the attributes of available plant species (Wright 1994).

PLANTING/COVER TYPES

For short-term plantings of 10 years or less, DUC relies on mixtures of introduced grass and legume species such as tall wheatgrass, intermediate wheatgrass, pubescent wheatgrass, meadow bromegrass and alfalfa. These species provide excellent, albeit somewhat homogeneous, short-term wildlife cover. The added cost of using native seed in short-term plantings is unwarranted.

For permanent plantings, DUC's objective is to create diverse, long-lived, easily managed cover. Most of the fields converted to grass are only marginally suitable for annual cropping. These tracts have inherent fertility and soil structure limitations that challenge revegetation efforts.

Ducks Unlimited Canada believes that the best way to accomplish its objectives on such lands is to revegetate with native grass, forb and shrub species. Since adapted native species are virtually permanent, there is no need to reseed after several years, as was the case with introduced species. The additional cost of reseeding is avoided, as is the risk of exposing the land to erosion during stand establishment. Many agencies and regulators are now embracing the use of native plant materials for the same reasons. Most recently, there has been a great deal of interest in seeding native grasses for forage use from the agricultural and ranching industries.

Native plant materials are divided into two main categories – cool season and warm season. Cool season plants begin annual growth in early spring, grow rapidly through early summer and usually become dormant during the hottest, driest portion of mid- and late summer. In favourable environmental conditions, cool season grasses experience a second minor flush of growth in late summer and early fall. Cool season grasses usually produce most of their annual growth prior to mid-July.

Cool season grass species dominate the drier portions of the fescue, mixed and arid mixed prairies. Species such as green needlegrass, slender wheatgrass, northern wheatgrass, western wheatgrass, plains rough fescue, needle-and-thread, porcupine grass and June grass are common throughout the region. Seed of green needlegrass, needle-and-thread, Canada wildrye, northern, awned, slender and western wheatgrass is presently available in good supply for revegetation projects. Limited quantities of plains rough fescue, fringed brome and June grass are also available.

Warm season plants begin growth in late spring and continue active growth throughout the summer. Typically, warm season species produce the majority of their annual growth from July through early to mid-September. Tall warm season grasses dominated the true tall grass region of the eastern prairies. Several species of tall warm season native grasses are available for reclamation purposes in the prairie regions of mid-Canada. Big bluestem, little bluestem, Indiangrass and switchgrass are among the dominant grasses of the region. Good seed supplies exist for those species. One must be aware, however, that true tall grass species generally require relatively high annual precipitation (50 cm+) or run-on or sub-irrigated sites to develop vigorous stands.

Many other warm season native grasses thrive in semi-arid regions. Little bluestem, blue grama, side-oats grama, prairie sandreed and sand dropseed are locally important species. Suitable commercial seed is available for little bluestem, side-oats grama, blue grama and prairie sandreed. Canadian Ecovar™ selections of little bluestem and blue grama are available.

RANGE SITE CHARACTERISTICS

A range site is a distinctive area of land with specific physical characteristics that enable it to produce a specific native plant community. Plant species composition and biomass production vary among range sites due to differences in soil, water and topographic features. Major range site factors influencing plant species composition and biomass production include topsoil depth, soil texture, available soil moisture, land slope and exposure, precipitation, soil fertility and salinity (Sedivec et al. 1991).

DUC's experience with the establishment of native grass on cultivated fields has shown that seeded native grass success is closely correlated with range site factors. Realizing that site effects cause differences in natural plant communities, it seemed only logical to design seeding mixtures that approximate the relative composition occurring naturally on the planting site. For this reason DUC recommends adoption of a sculptured seeding methodology.

SCULPTURED SEEDING

The longevity and diversity of re-established grasslands can be greatly enhanced by a technique known as sculptured seeding (Jacobson et al. 1994). Sculptured seeding is an ecological approach to revegetation based on a knowledge and understanding of the natural vegetation of the eco-climatic region of the site. The objective is to establish a diverse native plant community capable of regeneration and long-term plant succession. It is intended to match plant species with the site conditions under which they are known to persist in different regions of the Prairies. Seed mixtures are developed to match soil and climatic conditions, not only within a region but also within a specific field. While DUC is not attempting to replicate or restore true prairie, it is producing a rough approximation of what occurs in a natural situation within the constraints of current technology and seed availability. This technique was developed by DUC in conjunction with the USDA Natural Resources Conservation Service.

Many species occurring naturally in a "high prairie" situation are generally shorter than those found growing in the "mid" and "low prairie" zones. This is a result of complex interactions between soil texture, nutrients and moisture regimes which create varying plant height and growth form. This, in turn, provides diverse vegetative cover. The sculptured seeding methodology tries to duplicate these effects to produce sustainable cover of varying height, density and structure. Native forbs, shrubs and half shrubs can also be planted to further enhance stand longevity and structural diversity, providing habitat for a wider array of wildlife species. A detailed description of the sculptured seeding methodology, including sample seed mixes for high, mid- and low prairie situations, is presented as Appendix B.

Figure 2 – "High", "Mid" and "Low" Prairie Landscape Positions

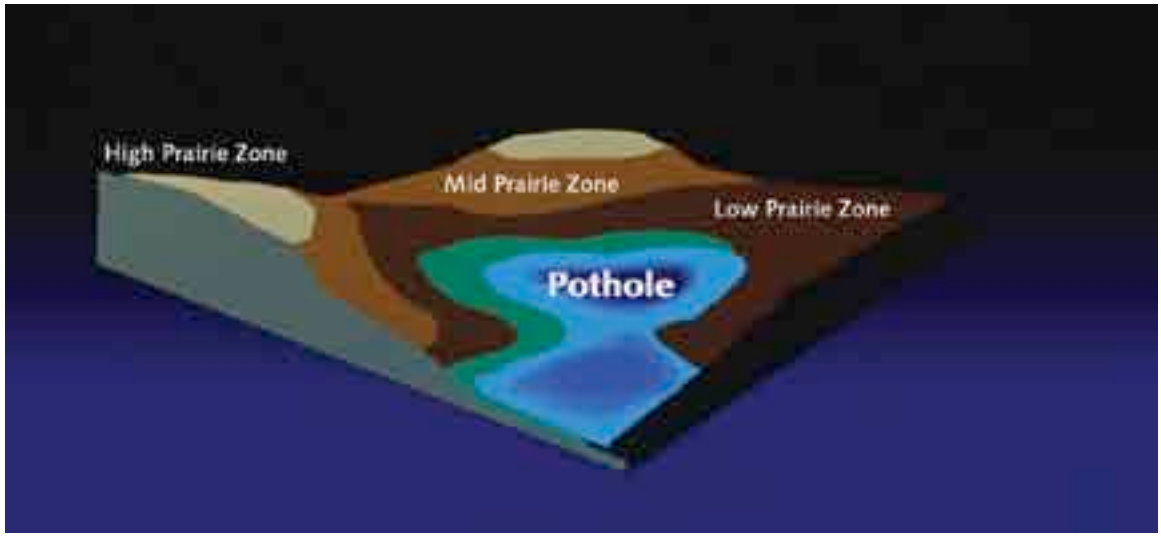


Figure 3 – Avian Species Associations with Grassland Habitat Types

PRE-SEEDING PREPARATIONS

A thorough plan provides an excellent opportunity to undertake weed control activities required on the planting site before seeding. Activities should be planned well in advance of the planting. Proven establishment procedures must be followed from the outset. Shortcuts or attempts to reduce costs can lead to establishment failures. A flow chart of standard procedures (Figure 4) presents the path a typical planting should take.

References to specific herbicides and rates of application are based on preliminary research data and field experience. Unless stated otherwise, they should NOT be construed as recommendations. For herbicide recommendations for your area, always refer to experienced local personnel, a provincial weed control publication and to herbicide label information. Herbicides are identified by their Canadian trade name.

All references to glyphosate are based on the 356 g/L formulation (as a solution).

PRE-SEEDING YEAR WEED CONTROL

Pre-seeding weed control is a critical step in the establishment of native plants. Duebbert et al. (1981) indicate that inadequate weed suppression causes more grass seeding failures than any other single factor. Weeds compete with seedlings for moisture, light and nutrients. They must be controlled to promote successful stand establishment. Since seedling native grasses and legumes are for the most part, weaker competitors, pre-seeding weed control is particularly important. If effective weed control procedures are not followed prior to seeding, the resulting stand may be substandard. Subsequent rehabilitation efforts are often costly and time-consuming.

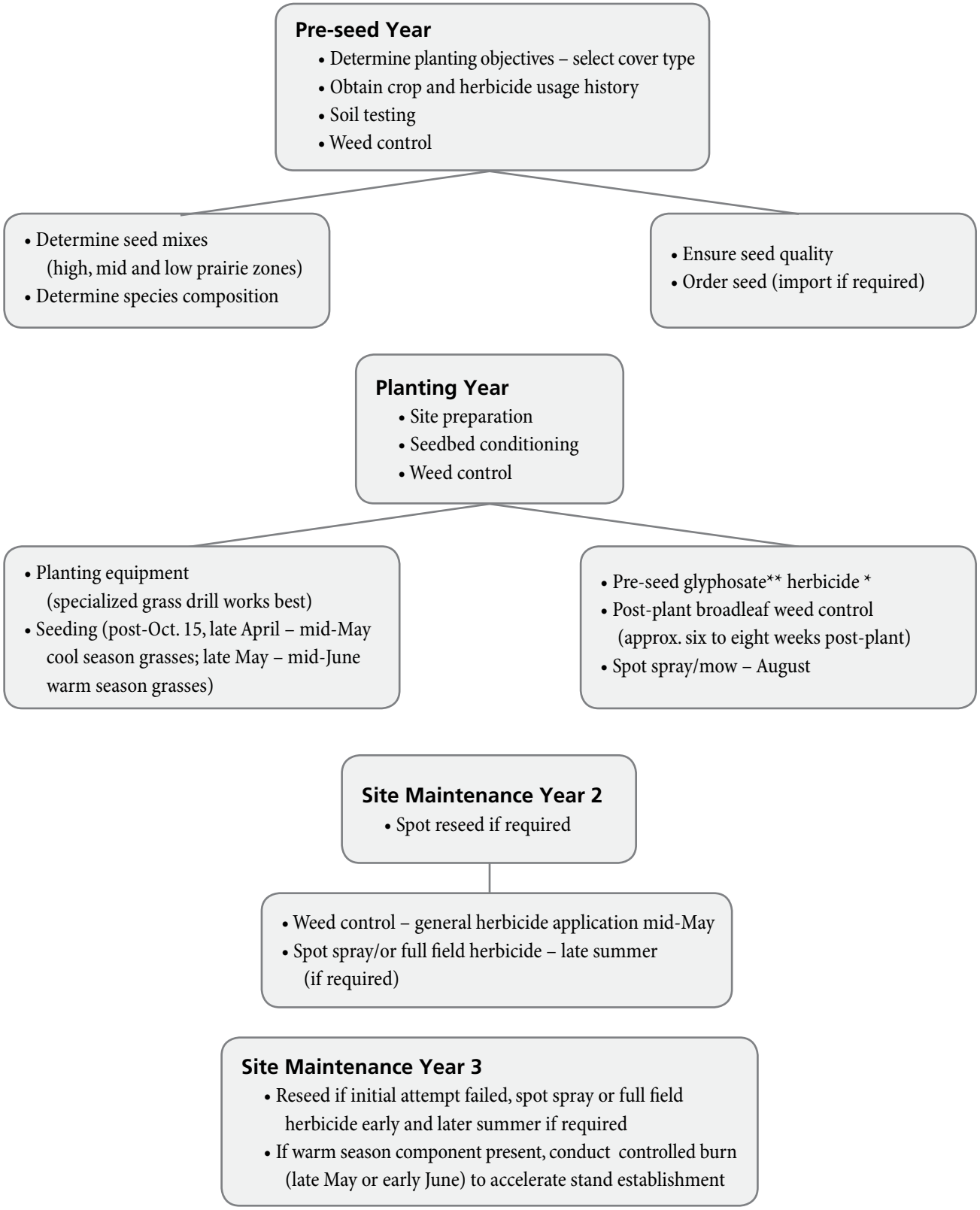
Once a site has been selected for revegetation, thoroughly inspect the field to determine the type, density and distribution of weed species. The accuracy of this information is critically important to the development of an effective weed control strategy. The most effective method of scouting a field for weeds is to walk through it in a "W" or zigzag pattern. This provides an objective assessment of weeds throughout the field. Readily available guides such as Weed Seedling Identification Guide (2000), Weeds of the West (1992), Weeds of Alberta (1988), Weeds of Canada (1987) or Common Weeds of Canada (1989) are useful when identifying weed seedlings.

At the time of site assessment, it is also important to obtain previous herbicide usage on the site from its recent cropping history. Volunteer plants from previous herbicide-tolerant crops have recently become a challenge and may require additional herbicides to provide adequate control. Residues of some herbicides, such as the Group 2 herbicides (Odyssey and Sundance), Group 3 (e.g. Edge and Treflan); Group 5 (atrazine, Velpar, etc.) and Group 8 (Avadex) may prevent the establishment of some native plants for up to two years. Information on these herbicides is provided in weed control guides published annually by provincial agriculture departments. Herbicide residues may affect grass establishment, so delay planting until after the recommended interval to allow residue levels to dissipate. Herbicide manufacturers recommend that a field bioassay be conducted the year before growing any crop other than those listed on the label under "recropping restrictions".

The most commonly used options for pre-seeding weed control include summerfallow, combined tillage and chemical summerfallow, chemical summerfallow and weed control in the preceding crop. An effective strategy often involves the integrated use of two or more during the same growing season. The development of an appropriate weed control strategy depends on site-specific factors such as the species and level of weed infestation, the range site characteristics, the acceptable level of soil disturbance (degree of soil erosion risk) and planting objectives. Regardless of the planting technique to be used, the year prior to the planting of native species should be considered an intensive pre-seed weed control year. If time permits, special attention to achieving a high level of weed control even two years prior to revegetating is recommended. During these years, a concerted effort should be made to control persistent perennials such as smooth bromegrass, quack grass and Canada thistle.

If present, old fence lines should be removed and field boundaries graded and reshaped during this time. Old fence lines are often sources of unwanted species such as smooth brome, crested wheatgrass and perennial weeds. The disturbed areas can then be seeded with the rest of the planting, reducing the potential number of sites from which invasive species plants like smooth bromegrass can escape and move into the native planting.

Figure 4 – Establishment flow chart



* Herbicide-tolerant volunteer crops may require additional herbicide tank mixes for control

**Glyphosate formulation: 356g/L

Candidate sites for revegetating plantings should be inspected to determine weed population distribution and density.

If not controlled, persistent perennial weeds like Canada thistle will cause continuing problems in revegetation plantings.

Smooth bromegrass (left) and downy bromegrass (right) can become serious problems in native grass plantings.

Tillage and Herbicide Summerfallow

The primary objective of a pre-seeding weed control strategy is to control weed species, particularly the perennials, which cannot be controlled with herbicides after the native plant seedlings have emerged. Although tillage has historically been the most commonly used weed control technique in prairie agriculture, it is not the most effective method to control persistent perennial weeds like Canada thistle and quack grass.

In addition, the development of new herbicides and crop varieties allows increased levels of in-crop weed control. There are also agronomic and environmental risks associated with tillage fallowing. Given the nature of many of the fields that are candidates for revegetation plantings, tillage often increases the potential for serious soil erosion. **As a result, in most areas, tillage should not be used unless absolutely necessary.**

Herbicide treatments combined with tillage can result in excellent control of persistent perennial weeds. Use tillage equipment that controls weeds with minimum surface residue loss. Rod weeders, wide blade cultivators or cultivators equipped with low crown sweeps and/or trailing rod attachments can meet those objectives. To reduce the risk of soil erosion, these should be operated at four miles per hour or less, at shallow depths and without harrows. Weed kill will be maximized if tillage occurs when the soil surface is dry and is followed by several days of dry weather.

On soils where it is appropriate, the number and frequency of tillage operations will depend on site characteristics: soil type, topography, precipitation and weed populations. Tillage is not recommended on erosion-prone soils.

On planting sites with low risks of soil erosion and in areas where low spring moisture levels do not normally affect germination, a pre-seeding summerfallow year that combines both tillage and herbicide treatments can provide excellent perennial weed control.

Canada thistle is an aggressive perennial that must be controlled prior to seeding. J.H. Hunter, Agriculture and Agri-Food Canada (pers .comm.), indicates that effective Canada thistle control involves an integrated approach combining tillage and non-selective herbicides. Spring cultivation followed by periodic tillage (or an application of a low rate of a non-selective herbicide) ending in mid- to late July, will force the thistle to produce a rosette when eight- to 10 inches in size) by mid- to late August.

A fall (mid-August to early September) application of glyphosate provides good control of Canada thistle and quack grass if the plants are green and actively growing. If drought, cool temperatures or other adverse conditions have slowed weed growth, ensure that the target weeds have resumed active growth before applying the herbicide. See the Provincial Weed Guide for glyphosate rates to control perennials such as quack grass and Canada thistle.

Frost may affect the success of herbicide applications after early September. For best results, at least one week of frost-free weather is required prior to spraying. (The other option is to wait until plant growth has resumed.) After a fall frost, wait two or three days and recheck the field to evaluate the effect on Canada thistle and quack grass. Frost-damaged quack grass typically exhibits a darker green colour, more evident on the lower leaves. Wilting may also be evident at this time. Frost damage on Canada thistle is easier to assess. Plants typically exhibit a darker green colour and damaged leaf edges with lower leaves showing more evidence of damage. If 60 per cent or more of the plant is still green and actively growing, apply herbicides. Frost damage will not be uniform, so assess each field carefully. If weeds show significant damage, wait one or two days to allow the weeds to begin regrowth before applying herbicides. If the weeds have not begun regrowth, the herbicide will not be translocated to the roots and its effectiveness will be sharply reduced. After a minimum of two weeks, cultivate and pack the seedbed to achieve adequate packing. Figure 5 presents a tillage and herbicide summerfallow weed control procedure for an area receiving more than 15 inches of average annual precipitation.

Chemfallow

Over the past several decades, the use of herbicides by prairie farmers has increased as a primary method of weed control. Similar techniques can be effective for revegetation plantings provided that the herbicides used do not have residual effects that may reduce the germination and establishment of native plant species. Like tillage, improperly used herbicides can be hazardous to the environment. These potential hazards can be minimized by proper calibration of spraying equipment, careful application practices in accordance with label directions and the safe storage and disposal of herbicide containers. Successful chemical summerfallow begins with an application of 2,4-D amine 500 or MCPA amine 500 in the fall or early spring to control winter annuals such as stinkweed and flixweed. Literature (Kirkland 1993) indicates that a fall-application provides more effective winter annual control (Table 1).

Once winter annuals are controlled, annual grassy and broadleaf weed control can be achieved with subsequent applications of glyphosate. If perennials are present, rates of 1.9 to 2.8 litres per acre of fall applied glyphosate are required. Figure 6 presents a typical herbicide summerfallow procedure.

Table 1 – Effect of application timing on control of winter annuals

Application Date	Stinkweed Plants/Square Foot	Flixweed Plants/Square Foot
Untreated	1.1	0.8
September 25	0.1	0.1
October 27	0	0
April 28	0.1	0.1
May 13	0.6	0.5

Weed Control in the Preceding Crop

If the soil is erosion-prone or the level of weed infestation is light, consider a more intensive in-crop weed control for one or possibly two years prior to planting revegetation. Seeding into weed-free standing stubble with a low-disturbance opener can be especially valuable in drier areas where the snow-catch in the stubble can improve surface moisture conditions for germination.

Oats, barley and canola are the preferred annual crops to be seeded for in-crop weed control. They are highly competitive and provide cultural weed control, and have a variety of effective registered herbicides. The cereal crops should be harvested as green feed whenever possible to minimize the presence of volunteer growth in the planting year, and to maximize the retention of soil moisture. Also, removing these crops as green feed also provides a seed bed ready to plant into with minimal amounts of potentially troublesome crop residues. Effective in-crop herbicides for annual weeds should be applied with the objective of preventing seed set of these weeds. Keep in mind that using a clopyralid-based product may prevent thistle regrowth in fall, which may eliminate fall regrowth and therefore comprimise the preferred fall treatment for thistle control. Another option for fall weed control is the use of a pre- or post- harvest glyphosate application. Glyphosate is applied at the hard dough stage of the crop, typically three or four days before normal swathing would occur. An example of an in-crop weed control scenario is presented in Figure 7.

Removal of Invasive Plants

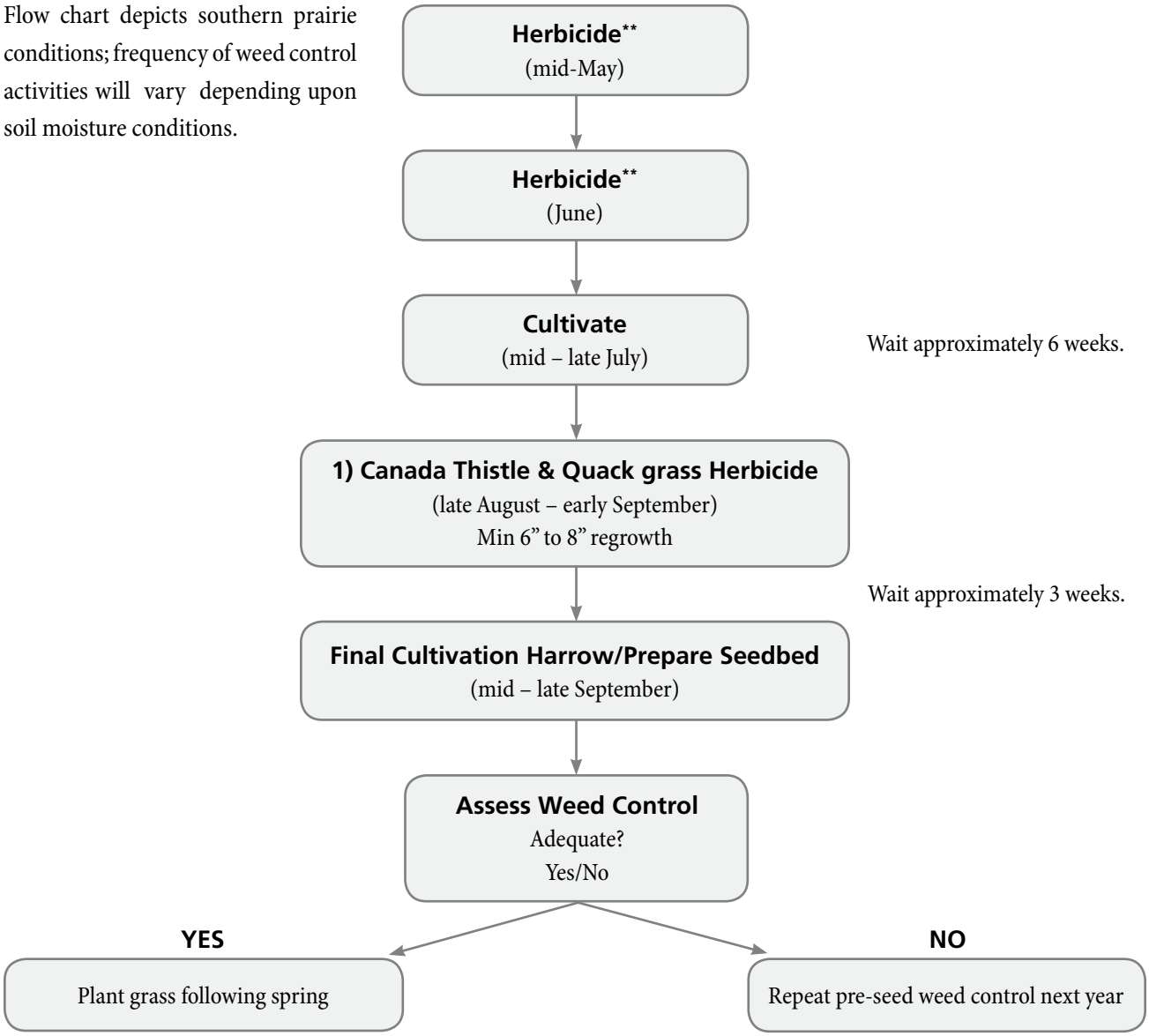
Removal of existing perennial vegetation found in old hayfields and adjacent headlands requires an integrated approach with repeated herbicide applications and tillage treatments for best results. Smooth bromegrass, quack grass and Canada thistle are typically found in these areas. Efforts must be made to ensure maximum effectiveness of non-selective herbicide applications. The herbicide treatments should be applied only to actively growing plants and should be followed by timely tillage operations. The flow chart in Figure 5 can be used as a guideline for removal of invasive plants.

Evaluating Weed Control Effectiveness

To ensure adequate weed control during the pre-seeding year, the site should be inspected several times during the growing season. The effectiveness of the weed control strategy should be evaluated following the final treatment in the site preparation year. DUC does not usually seed a field if remnant perennial weed populations cover more than five per cent of the area, especially if the remaining weeds occur as scattered plants throughout the field. If the remaining weeds are primarily perennial grassy weed patches, they may be controlled by a non-selective herbicide application immediately prior to planting followed by spot treatments as necessary.

Figure 5 – Pre-seeding year tillage and herbicide summerfallow

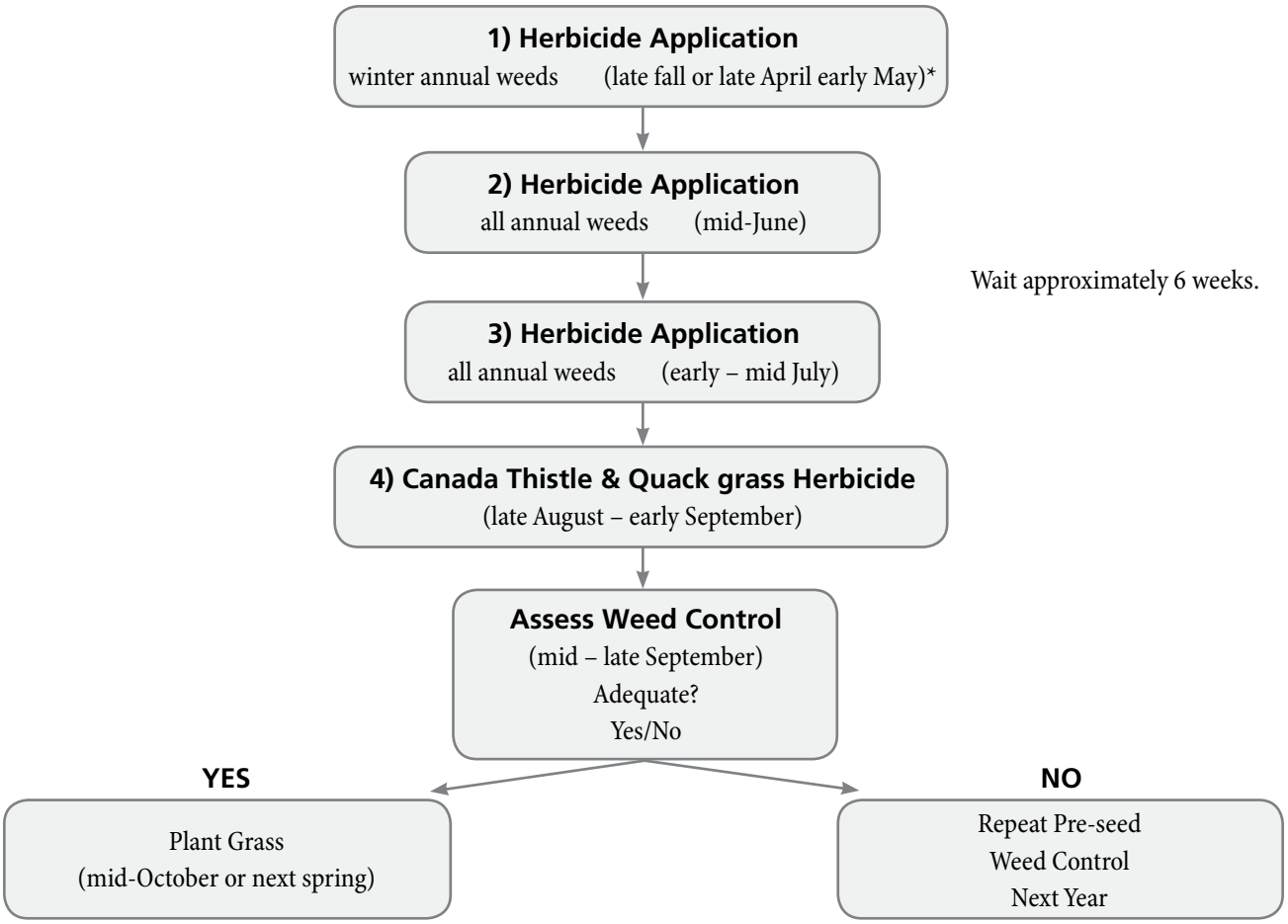
Flow chart depicts southern prairie conditions; frequency of weed control activities will vary depending upon soil moisture conditions.



Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	Canada thistle, quack grass	Late Aug. early Sept.	Banvel + Roundup	0.5+ 0.7 - 1.0+	dicamba glyphosate	480 356	n/a	Quack grass: 3 to 4 actively growing leaves. Canada thistle – fall rosettes. 8-10 inches new growth.
			Roundup	1.0 1.9 - 2.8	glyphosate	356	n/a	Quack grass: 3 to 4 actively growing leaves. Canada thistle – fall rosettes. 8-10 inches new growth.

** Depending upon site conditions, this herbicide may be replaced by a cultivation operation.

Figure 6 – Pre-seeding year chemfallow



Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	winter annuals broadleaf weeds	Late fall or late April – early May	2, 4-D amine	0.48-0.74	2, 4-D	500	n/a	Fall or spring rosettes. Use higher rate in spring prior to plants bolting.
			Roundup	0.51-0.77	glyphosate	356		
2)	annual grass, broadleaf weeds	Various	Rustler	1.0	glyphosate dicamba	194 46	n/a	Less than 6 inches. Use higher rate for wild buckwheat 3-4 leaf less than 6 inches.
3)	grass, broadleaf weeds	Various	Roundup	0.4	glyphosate	356		Not including glyphosate-tolerant volunteer canola varieties.
			2, 4-D amine	0.5	2, 4-D	500	n/a	
	perennial weeds		Roundup	1.0	glyphosate	356		Less than 6 inches.
4)	Canada thistle, quack grass	Late Aug. – early Sept.	Roundup	1.9-2.8	glyphosate	356	n/a	Quack grass: 3 to 4 actively growing leaves. Canada thistle – fall rosettes.

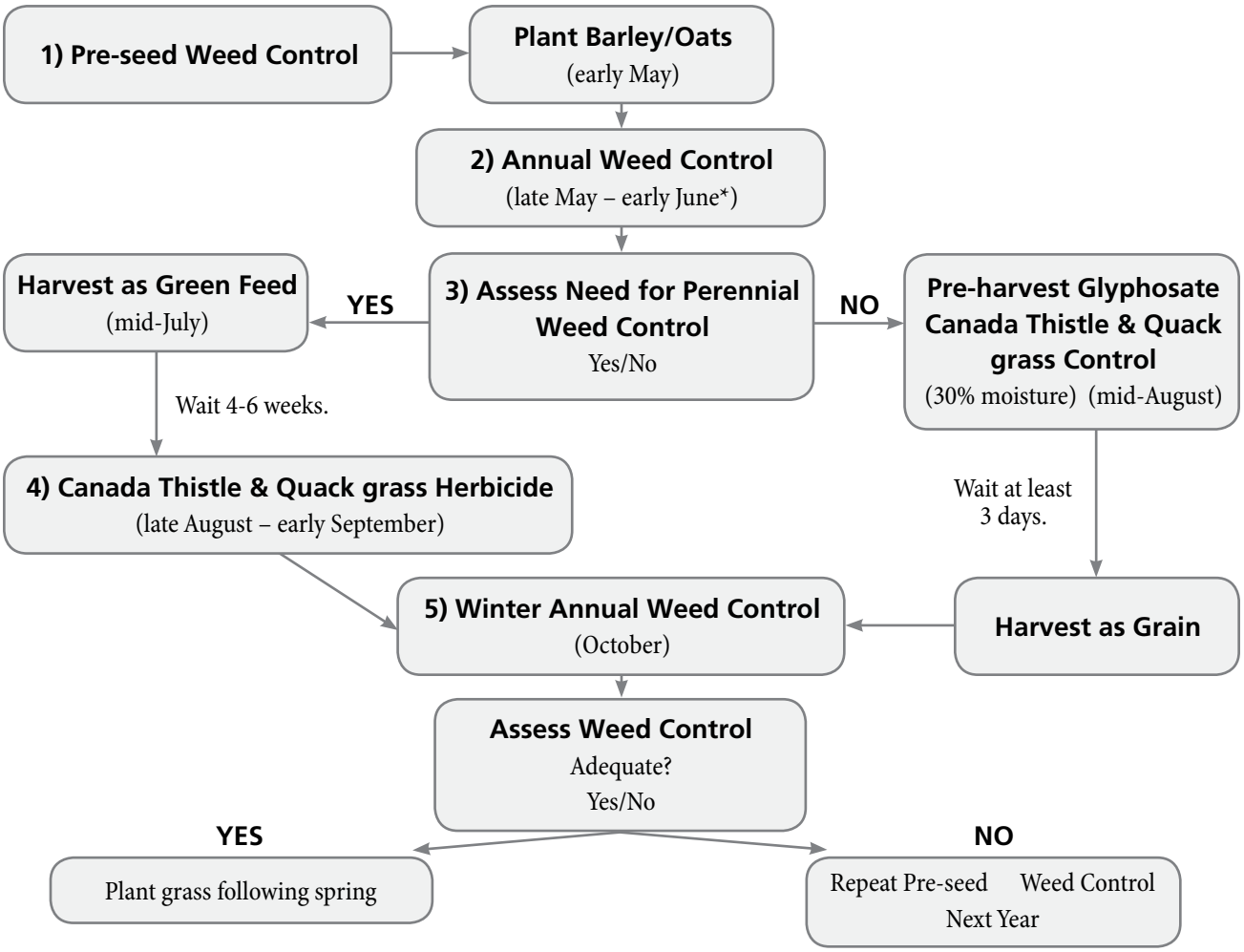
*For control of volunteer herbicide-tolerant crops additional herbicides may be required.

Carefully timed tillage can force Canada thistle to form rosettes. At that growth stage, herbicides are readily translocated into the root system.

Photo courtesy: Brandt Industries

A suitable field sprayer is an important part of a weed control strategy for large-scale native grass revegetation plantings.

Figure 7 – Weed control in the preceding crop **



Weed (crop type)		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	annuals weeds quack grass	pre-seeding	Roundup	1.0	glyphosate	356	n/a	Annuals less than 6 inches. Quack grass 3-4 growing leaves.
2)	annual broadleaf,	early June	Buctril M	0.4	Bromoxynil+ MCPA ester	280 280	2 to flag	Annual weeds up to 4 inches. Canada thistle top growth only.
	Canada thistle (barley, oats)		Refine Extra Toss-N-Go Agsurf	8g/acre 0.2L/100L of spray solution	Thifensulfuron Tribnuro methyl Surfactant	50% 25%	2 to flag	Annuals less than 4 inches. Canada thistle top growth only.
3)	Canada thistle, quack grass	late Aug. – early Sept.	Roundup	1.9-2.8	glyphosate	356	n/a	Quack grass – 3 to 4 actively growing leaves. Canada thistle – fall regrowth.
4)	winter annual, broadleaf weeds	late fall	2, 4-D amine	0.34-0.45	2, 4-D	500	n/a	Fall or spring rosettes.
			MCPA amine	0.28-0.45	MCPA	500		Fall or spring rosettes.
			Roundup	0.5	glyphosate	356		

* Only herbicides that allow for Canada thistle regrowth in fall (e.g. Buctril M). ** A green feed crop is the best management practice for weed control in the preceding year.

SOILS

The process of soil assessment and testing to determine physical and chemical properties and nutrient levels will contribute valuable information on a revegetation site and aid in preparing the revegetation plan. Soils information can be derived from soils maps, which can usually be obtained from government soil survey departments. Soil survey maps have been published for most of the agricultural areas of Canada and the U.S. In addition to soils maps, obtaining aerial photos of the site to be revegetated is recommended. Depending on the type of photo obtained, differences in soil types can be interpreted. These areas, once identified, can be further investigated on the ground. The assessment of soil physical factors in the field will help determine erosion risks and draw attention to adverse soil characteristics such as hardpan layers (solonetzic soils). Field inspections to obtain soil samples and soil textures should occur well in advance of planting.

Although fertilizer is usually not required when establishing native plants, soil testing is recommended to determine soil properties, significant nutrient deficiencies and areas of high conductivity. Sites known to be extremely infertile (e.g. knolls) or those that soil test results indicate phosphorus deficiencies may benefit from an application of a phosphate fertilizer. Phosphorus encourages root development.

Soil test parameters should include basic nutrient contents, soil pH, conductivity, organic matter estimates, and if required, a soil particle size analysis. Reliable information can be obtained only if the samples submitted are representative of the field from which they were taken. Proper sampling procedures include using proper equipment and supplies, obtaining samples from correct soil depths, taking samples fully representative of average field conditions and proper handling of soil samples to ensure their nutrient status remains constant. Soil test laboratories located in each province can provide the supplies and technical advice needed to ensure accurate sampling.

Those with expertise in soil science and plant ecology can make objective observations of soils by studying the soil profile and plant growth/presence, in the field and on sites (with similar soils) adjacent to the revegetation project. Soil areas subject to flooding and/or poor internal drainage should be mapped out and delineated. Areas having significant topographical features that differ from the rest of the site should also be identified.

If the revegetation site contains significant areas of two or more distinctly different soil types or conditions, those areas should be sampled and treated as separate units. These differences in soil type may warrant the use of the sculptured seeding technique. For example, a quarter section with two distinct soil types, one moderate to severely saline and the other non-saline with all other conditions the same, should be planted to two different seed mixes.

SEED QUALITY

The Canadian native seed industry has developed to a point where many site-appropriate native species are available from local seed suppliers. Most Canadian seed suppliers can custom blend, bag and import (if necessary) for the consumers. This section provides an overview of recent quality control developments within the industry. A section on seed importation is also presented, for those interested in sourcing U.S. seed.

An essential first step toward ensuring successful revegetation with native plants is to purchase certified seed of adapted varieties. Certified seed provides superior results when planting either native or introduced grass varieties. If certified seed is not available, it may be necessary to purchase common stock. While common seed cannot be sold by variety name in Canada, the purchaser should determine its genetic origin. As a safeguard, seed buyers should also request that the point of origin be indicated on the seed analysis report for common seed. It is recommended that seed purchasers source seed from a reputable seed supplier that can provide and blend high quality seed and mixtures. Many varieties now available have been developed for western Canadian regions.

DUC, several Agriculture and Agri-Food Canada research stations and the Universities of Saskatchewan and Manitoba have launched and continue to expand the "Ecovar" development program in an effort to offset the lack of commercial seed production of the many native species required for Canadian revegetation projects.

An Ecovar™ (ecological variety) is a selection that is developed with equal emphasis on maintenance of a broad genetic base and certain agronomic characteristics. It differs from a "cultivar" (cultivated variety) which is rigidly selected for uniformity of agronomic characteristics. This unique approach to plant breeding yields seed that is closer to its native origin than are the cultivars currently in use. Seed production of these varieties and the development of new ones are ongoing.

Most recently, a Native Plant Certification Program (NPC) is being implemented in Canada through the Canadian Seed Growers' Association (CSGA). This is a voluntary quality control process provided by the CSGA for native plant seed identification. Although legally separate from pedigreed seed crop certification, similar CSGA documents and procedures are used to verify the origin of collection or production of native plant reproductive materials that have not been released as a variety (Appendix C, Circular 6). This program documents the identity of plant material and verifies that it is from a designated geographical location (Source Identified Class) or selected for specific characteristics (Selected Class). See Figures 11 and 12.

The following definitions apply to the NPC program:

Pre-Variety Germplasm:	This category of "Association of Official Seed Certifying Agencies" (AOSCA) certification standards is used for the collections and selections of plants, usually perennial native forage grasses, legumes and forbs, that are not sufficiently distinct, uniform or stable to be certified as varieties. In Canada, separate from pedigreed seed crop certification, these standards are used in the CSGA's NPC program for Source Identified and Selected class seed crop certification.
Source Identified (SI):	This seed certification class of pre-variety germplasm provides third party assurance of geographical origin, usually for perennial native grasses, legumes and forbs produced from parent populations which have not been selected. SI seed labels issued by the CSGA identify the original geographic location of the collection or production that has been declared by the responsible Plant Breeder.
Selected:	This seed certification class of pre-variety germplasm provides third party assurance of identity, usually for perennial native grasses, legumes and forbs produced from selected parent populations with distinctive, identifiable characteristics or potential genetic improvement. Selected class seed labels issued by the CSGA identify the name assigned to the selection by the responsible Plant Breeder.

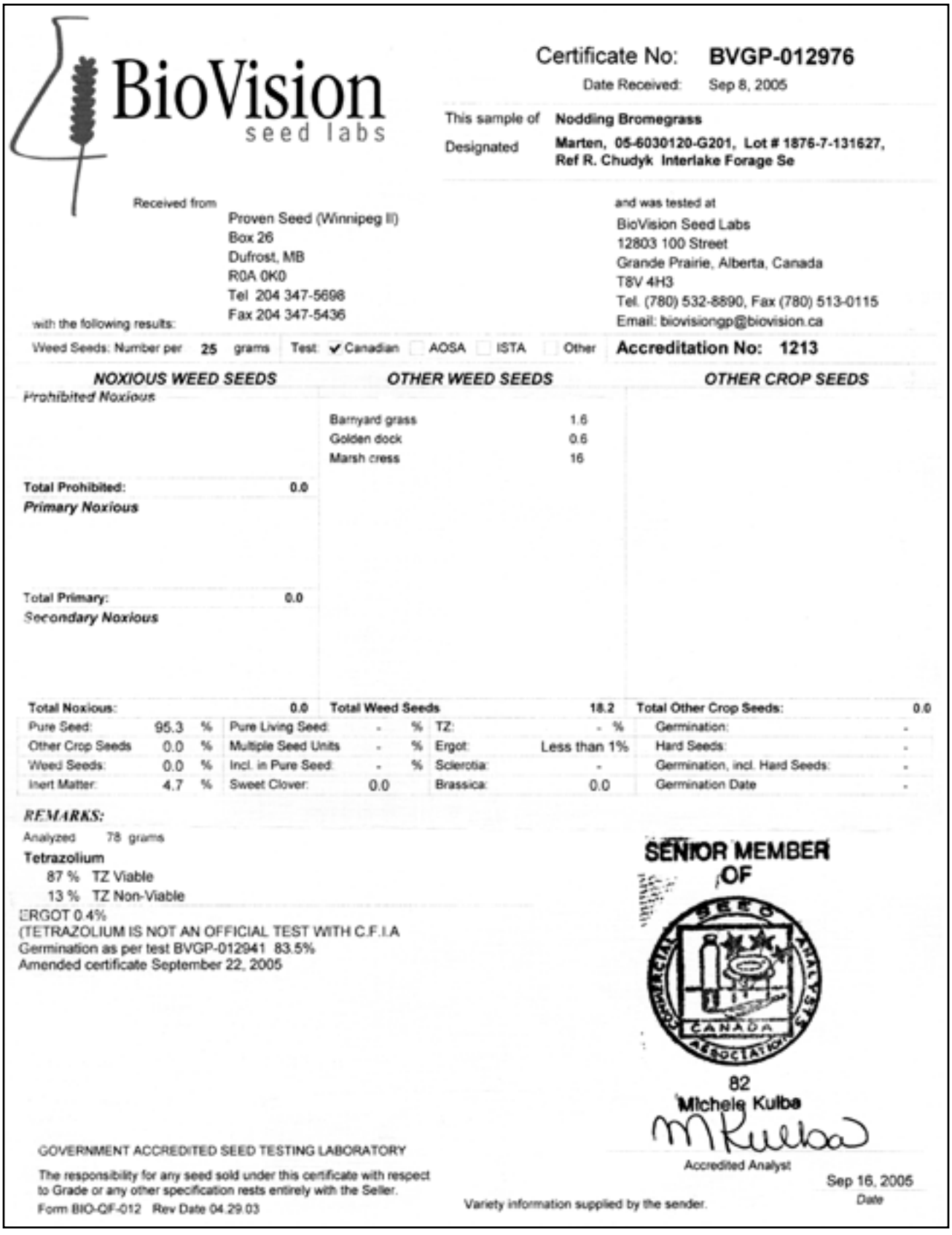
In addition, a new system for the designation of multiplication generations in the NPC program replaces pedigreed class names. For example, Generation 1 (G1) is equivalent to Breeder status and Generation 2 (G2) is equivalent to Foundation status in the SI and Selected classes of pre-variety germplasm certification.

Thornburg (1982) suggests native seed should not be moved more than 300 miles north or 200 miles south of its point of origin as problems with winter hardiness, longevity and disease may result. Movement east or west is affected by changes in precipitation and elevation. An increase of 1,000 feet in elevation is equal to a move of approximately 175 miles north. Adherence to Thornburg's guideline is strongly recommended. As a general rule, only certified seed of varieties originating in western Canada, North Dakota, Montana, Wyoming and Idaho should be used in western Canadian revegetation projects. Varieties originating south of that area generally will not persist in Canada. Bags of certified seed will bear a certified tag. Certified seed tags from the U.S. will list the following characteristics: per cent pure seed, per cent inert, per cent germination, and per cent dormant seed.

Bags not bearing a certified tag contain common seed. In Canada these bags generally display a tag marked Canada #1, or Canada #2, which refers to the level of weed seed contamination. If certified seed is not available, insist on Canada #1 common seed. Always order species individually. Mixtures should be blended following delivery.

When purchasing either certified or common seed, request that the distributor provide a seed analysis report for each species. This report provides information similar to that listed on the U.S. certified tag, as well as per cent of other crop seed, per cent of hard seed, and a list of types and amount of weed species present. Avoid distributors who will not provide a seed analysis report. Always review the seed analysis report before ordering or accepting seed shipments. Typical Canadian and U.S. seed analysis reports are presented as Figures 8 and 9.

Figure 8 – Canadian seed analysis report



BioVision seed labs

Certificate No: **BVGP-012976**

Date Received: Sep 8, 2005

This sample of **Nodding Bromegrass**

Designated **Marten, 05-6030120-G201, Lot # 1876-7-131627, Ref R. Chudyk Interlake Forage Se**

Received from
Proven Seed (Winnipeg II)
Box 26
Dufrost, MB
R0A 0K0
Tel 204 347-5698
Fax 204 347-5436

and was tested at
BioVision Seed Labs
12803 100 Street
Grande Prairie, Alberta, Canada
T8V 4H3
Tel. (780) 532-8890, Fax (780) 513-0115
Email: biovisiongp@biovision.ca

with the following results:

Weed Seeds: Number per **25** grams Test: ✔ Canadian ☐ AOSA ☐ ISTA ☐ Other **Accreditation No: 1213**

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS
Prohibited Noxious		Barnyard grass	1.6	
		Golden dock	0.6	
		Marsh cress	16	
Total Prohibited:	0.0			
Primary Noxious				
Total Primary:	0.0			
Secondary Noxious				
Total Noxious:	0.0	**Total Weed Seeds**	18.2	**Total Other Crop Seeds:** 0.0

Pure Seed:	95.3 %	Pure Living Seed:	- %	TZ:	- %	Germination:	-
Other Crop Seeds	0.0 %	Multiple Seed Units	- %	Ergot:	Less than 1%	Hard Seeds:	-
Weed Seeds:	0.0 %	Incl. in Pure Seed:	- %	Sclerotia:	-	Germination, incl. Hard Seeds:	-
Inert Matter:	4.7 %	Sweet Clover:	0.0	Brassica:	0.0	Germination Date	-

REMARKS:

Analyzed 78 grams

Tetrazolium

87 % TZ Viable

13 % TZ Non-Viable

ERGOT 0.4%

(TETRAZOLIUM IS NOT AN OFFICIAL TEST WITH C.F.I.A

Germination as per test BVGP-012941 83.5%

Amended certificate September 22, 2005

SENIOR MEMBER OF SEED ANALYSTS ASSOCIATION CANADA

82

Michele Kulba

Accredited Analyst

Sep 16, 2005

Date

GOVERNMENT ACCREDITED SEED TESTING LABORATORY

The responsibility for any seed sold under this certificate with respect to Grade or any other specification rests entirely with the Seller.

Form BIO-QF-012 Rev Date 04.29.03

Variety information supplied by the sender.

Figure 9 – U.S. seed analysis report

Seed Analysis Report

ND State Seed Department
PO Box 5257
Fargo, ND 58105-5257
(701) 239-7210 Fax: (701) 239-7214
Seed Lab Director: Mark Hafdahl

Date Received	Date Printed	Sample Number
12/12/2001	01/17/2002	L2104089

Lot #: 013017

NATIVE PLANT SOLUTIONS
1255 CLARENCE
WINNIPEG MANITOBA
CANADA, R3T 1T4

Kind: BIG BLUESTEM
Variety: Variety Not Stated
Bin Ref:

204-953-8200

Copy Sent To:

Rules Followed: AOSA

WARNING - It is unlawful to use the name of the State Seed Department or the name of the Official Laboratory for advertising purposes in connection with this report, except in the case of Registered or Certified Seed.
IF THIS SEED IS TO BE SOLD, IT MUST BE LABELED TO COMPLY WITH EXISTING NORTH DAKOTA SEED LAWS AND REGULATIONS UNLESS SPECIFICALLY EXEMPT. FOR SEED LABELING INFORMATION CONTACT THE STATE SEED DEPARTMENT.

The letter 'x' means the test will not be conducted. Varietal purity guaranteed by labeler.
The analysis report show below is accurate only for the sample received at the laboratory. Whomever makes use of this information for labeling purposes is guaranteeing that the sample is representative of the lot of seed from which it was drawn.

Seed Component(s)		Percent	Germination	Dormant
BIG BLUESTEM	Pure Seed:	**84.93%**	**87%**	**1%**
	Other Crop Seed:	**3.65%**		
	Inert Matter:	**11.36%**	Comment:	Germ Date: 01/2002
	Weed Seed:	**0.06%**		

Total Grams Analyzed: 7.036 G

OTHER CROP SEED

SWITCHGRASS	Panicum virgatum
FLAX	Linum usitatissimum
INDIANGRASS	Sorgastrum spp.
SMOOTH BROME	Bromus inermis subsp. inermis
SLENDER WHEATGRASS	Elymus trachycaulus subsp. trachycaulus
SIDE-OATS GRAMA	Bouteloua curtipendula
DURUM	Triticum durum
LITTLE BLUESTEM	Schizachyrium scoparium

WEED SEED

YELLOW FOXTAIL	Setaria pumila
GREEN FOXTAIL	Setaria viridis

NOXIOUS WEED

None Found

Noxious Working Weight: 70 G

Figure 10 – Sample: Canadian Seed Growers' Association "Source Identification Seed" tag

Front

Back

Figure 11 – Sample: Canadian Seed Growers' Association "Selected Class Seed Identification" tag

Front

Back

The seed analysis report is usually the buyer's only opportunity to exercise quality control on seed lots. Each component within a mixture should have a seed analysis report made available to the purchaser, prior to blending. Specify to the dealer that seed analyses must be reported at the 0.01 per cent level. This way, all other seed found in the lot will be reported and lots with trace amounts of nuisance weed seeds can be rejected. If there are any questions regarding a seed analysis report, do not hesitate to phone the seed laboratory where the analysis was done and ask for a complete listing of other seed found in the lot.

DUC recommends zero tolerance in seed lots for species such as downy bromegrass, hairy chess, rattailed fescue, Japanese bromegrass, smooth bromegrass, quack grass and other invasive species that will present management challenges within plantings or may escape onto neighbouring land. DUC has a clear understanding with its distributors that all seed lots failing to meet those standards will be rejected.

Certified seed may not be available for some species. For others, seed increased from native harvest is currently the only commercial seed available. This seed can be used with confidence, provided it has been tested for purity and germination and that it was harvested in the vicinity (within 100-150 miles) of the area proposed for revegetation. For example, native seed harvested and increased in northern Minnesota would be suitable for use in southern Manitoba.

PREPARING A SEED MIX

When preparing a seed mixture or ordering seed, always think in terms of pure live seed (PLS). Pure live seed is a single expression for the percentage of live seed or viable seed that potentially will germinate and produce a seedling. It is calculated by multiplying the purity of a seed lot by the germination and dividing by 100.

Example:

A seed analysis report for a lot of western wheatgrass shows 98 per cent pure seed and 89 per cent germination. To determine PLS: multiply pure seed (98 per cent) by germination (89 per cent) and divide by 100. (98 x 89/100 = 87.22 per cent PLS)

This calculation shows that 87 per cent of the material in the seed lot is viable western wheatgrass and that 13 per cent is other seeds or inert matter.

When buying native grass seed, be aware that many native species tend to have high levels of seed dormancy. For this reason, when determining germination for a seed lot, it is acceptable to combine per cent germination and per cent dormant to get a measure of total viable seed. The total viable seed number then replaces per cent germination in the above example. Another acceptable method of determining total viable seed is to use the TZ or tetrazolium test. The TZ test is used on certain cereal crop seed lots and is arguably at least as accurate as a standard short-term germination test for determining total viable seed.

Determining the PLS content allows quality comparison of various seed lots. Whenever possible, buy the seed lot with the highest PLS content as this reduces the volume of material handled when seeding. Reducing volume can also save on shipping charges. Ordering seed on a PLS versus bulk pound basis can save the first-time buyer a considerable sum since seed viability can be low in some native species.

Seeding a known amount of live seeds also enhances planting success. Seeding on a bulk seed basis with no knowledge of seed viability can contribute to an establishment failure if to few live seeds are planted. An example may serve to illustrate the importance of this point:

DUC plants a combination of rhizomatous and bunchgrass species. The objective is to quickly establish a dense grass stand with a good root network. To achieve this objective, DUC has set a minimum target level of five to six established grass seedlings per square foot (one seedling every four inches of drill row with six inches spacing) by fall of the planting year. Due to relatively poor seedling vigour, native seedling establishment is normally estimated at 20-25 per cent of the PLS seeding rate. Therefore, to achieve five to six grass seedlings per square foot, a PLS planting rate of 30 seeds per square foot is required if one assumes a 20 per cent seedling establishment rate.

Recommended PLS seeding rates vary with climate. A planting rate of 40 PLS seeds per square foot quickly provides dense stands of cover in the relatively moist climate of the eastern prairies. Moving west into drier regions, planting rates should be reduced to reduce seedling competition for moisture and nutrients. Some suggested planting rates are presented in Appendix E.

DUC recommends basing all calculations on a square foot basis when preparing a seed mixture. It is much easier to visualize how the established planting will appear if one considers a square foot rather than an entire field. For example, a mixture comprised of eight grass species is planned for Manitoba. A planting rate of 40 PLS seeds per square foot is suitable for that climatic zone. If equal amounts of each species were planted, it would be a simple matter of planting five seeds per square foot of each species. However, the components within a mix are often adjusted to achieve a specific planting objective. One may wish to roughly approximate the species density found in remnant prairies or to establish a heavy sod to prevent erosion. While species composition may be the same for both objectives, the relative proportions of individual species in the seed mix could be much different.

If the planting objective aims to have big bluestem as the dominant species post-establishment, ensure that the planting rate allows this to happen. For example, at a 40 PLS per square foot seeding rate consider planting 10 big bluestem seeds. Allowing for a 20-25 per cent seedling establishment rate, the end product should provide 2-2.5 big bluestem plants per square foot. All other species in the mixture should be considered in the same fashion to gain some perspective of how the established planting will appear.

A WORD OF CAUTION: When preparing a seed mix that is intended to provide a diverse planting, seed a light rate of western wheatgrass and northern wheatgrass if those species are included in the mixture. Under moist mixed prairie climatic conditions, because of their strongly rhizomatous nature they will dominate a stand if planted at rates exceeding one PLS pound per acre. Likewise, when undertaking a mixed cool season/warm season planting, ensure the cool season component is under 50 per cent of the total mix. Due to greater seedling vigour, cool season species can outcompete warm season species at the seedling stage. Some suggested mixtures are presented in Appendix C.

Once the PLS seeding rate per square foot is determined by species, determine the PLS seeding rate per acre. If 10 PLS seeds of big bluestem are to be planted per square foot, multiply 10 x 43,560 (square feet/acre) = 435,600 seeds per acre. Consult Table 3 to determine the number of big bluestem seeds per pound (165,000). Dividing 435,600 seeds/acre by 165,000 seeds/lb. gives a planting rate of 2.64 PLS pounds per acre. Similar calculations would be performed for all other species in the mix. Once completed, multiply the pounds per acre PLS rates by the acres to be seeded to determine the PLS seed requirements by species for the site.

With the desired seed quantities determined, convert the PLS amounts to bulk pounds for seed mixing and drill calibration. Conversion from PLS to bulk pounds can be done quickly by consulting Table 4 and referring to the seed analysis reports for your seed lots. If, for example, green needlegrass was to be included in a planting at three pounds PLS per acre and the seed analysis report showed that the seed lot had 80 per cent purity and 60 per cent viability, the bulk seeding rate would be three pounds PLS times the conversion factor of 2.1, or 6.3 bulk pounds per acre. When preparing a seed mix, it is imperative that plant growth characteristics and adaptations be considered. Detailed descriptions for the majority of the native species available for revegetation programs in prairie Canada are presented in Appendix F.

Table 2 – Approximate number of seeds per pound

Common Name		Seeds per Pound	Seeds per square foot (at 1 lb. per acre)
Bluestem	big	165,000	3.8
	little	260,000	6.0
	sand	100,000	2.3
Dropseed	prairie	224,000	5.1
	sand	5,600,000	128.7
Fescue hard	hard	560,000	13.0
	plains rough	200,000	4.6
	sheep's	680,000	15.6
	tall	210,000	4.8
Grama blue	blue	725,000	16.7
	side-oats	191,000	4.4
Green needlegrass		181,000	4.2
Indiangrass		175,000	4.0
Indian ricegrass		160,000	3.7
June grass		2,000,000	45.9
Needle-and-thread		115,000	2.6
Porcupine grass		57,000	1.3
Prairie sandreed		274,000	6.3
Switchgrass		389,000	8.9
Wheatgrass	awned	122,702	2.8
	awnless	129,714	3.0
	northern	154,000	3.5
	slender	159,000	3.7
	streambank	156,000	3.6
	western	110,000	2.5
Wildrye	basin	150,000	3.4
	beardless	150,000	3.4

Table 3 – Conversion factors to determine pounds of bulk seed needed to obtain 1 pound of pure live seed
(adapted from Conservation Job Sheet ND-20, USDA-SCS 1980)

Per Cent Purity	Per Cent Germination										
	100	95	90	85	80	75	70	65	60	55	50
100	1.00	1.05	1.10	1.20	1.25	1.35	1.10	1.55	1.65	1.80	2.00
95	1.05	1.10	1.20	1.25	1.30	1.40	1.50	1.65	1.5	1.90	2.10
90	1.10	1.20	1.25	1.30	1.40	1.50	1.60	1.70	1.85	2.00	2.20
85	1.20	1.25	1.30	1.40	1.45	1.55	1.70	1.80	1.95	2.15	2.35
80	1.25	1.30	1.40	1.50	1.55	1.65	1.80	1.90	2.10	2.25	2.50
75	1.35	1.40	1.50	1.55	1.65	1.80	1.90	2.05	2.20	2.45	2.65
70	1.40	1.50	1.60	1.70	1.80	1.90	2.05	2.20	2.40	2.60	2.85
65	1.55	1.65	1.70	1.80	1.90	2.05	2.20	2.40	2.55	2.80	3.10
60	1.65	1.75	1.85	1.95	2.10	2.20	2.40	2.55	2.80	3.05	3.35
55	1.80	1.90	2.00	2.15	2.25	2.45	2.60	2.80	3.05	3.35	3.65
50	2.00	2.10	2.20	2.35	2.50	2.65	2.85	3.10	3.35	3.65	4.00

SEED IMPORTATION

As a result of advances within the Canadian native seed industry commercial seed is available for many common native species. Several regional seed suppliers provide native plant materials and can import seed lots of appropriate varieties from the northern states. However, should a reclamation agency wish to source U.S. seed lots independently, the process must be initiated well before the planting date. Sourcing should begin in late fall, with supplies secured at least three months in advance of planting. Clearly specify species required and seed quality minimum standards and request copies of seed analysis for weeds reported at the 0.01 per cent level prior to accepting delivery. In addition, all seed analysis reports must be marked "tested to meet Canadian import standards". Complete and detailed information regarding seed imports can be obtained by contacting the Canadian Food Inspection Agency website (www.inspection.gc.ca) or from the regional office numbers listed below.

WESTERN AREA
Room 654 - 220 4th Ave SE Calgary, Alberta T2G 4X3
Tel: (403) 292-4301 Fax: (403) 292-5707

Alberta North
Room 205 - 7000 113 St.
Edmonton, Alberta T6H 5T6
Tel: (780) 495-3333
Fax: (780) 495-3359
Local Offices – Operations

Alberta South
Floor 1, Room 102
110 Country Hills Landing NW
Calgary, Alberta T3K 5P3
Tel: (403) 299-7660
Fax: (403) 221-3296
Local Offices – Operations

BC Coastal
4321 Still Creek Dr., Suite 400
Burnaby, British Columbia V5C 6S7
Tel: (604) 666-6513
Fax: (604) 666-1261
Local Offices – Operations

BC Mainland/Interior
4321 Still Creek Dr., Suite 400
Burnaby, British Columbia V5C 6S7
Tel: (604) 666-6513
Fax: (604) 666-1261
Local Offices – Operations

Manitoba
Room 613 - 269 Main St.
Winnipeg, Manitoba R3C 1B2
Tel: (204) 983-2200
Fax: (204) 984-6008
Local Offices – Operations

Saskatchewan
Room 300 - 3085 Albert St.
Regina, Saskatchewan S4P 4E3
Tel: (306) 780-5180
Fax: (306) 780-5177
Local Offices – Operations

PLANTING YEAR ACTIVITIES

In addition to the planning and preparation of the pre-seeding year, a number of other factors must be considered before the seed actually goes in the ground. These factors include planting date, seedbed condition, pre-seeding weed control, selection of seeding equipment and fertilization.

PLANTING DATE

Cool season grass mixtures can be planted in early spring or late fall. Spring plantings typically occur between late April and May 20, fall seedings generally after October 20. In very arid areas and/or on soils highly prone to crusting, early spring plantings into moist soil is recommended, however, the importance of pre-seeding weed control cannot be minimized. Late fall (dormant) plantings of cool season mixes must wait until soil temperatures fall below 5 C to avoid seed germination and seedling mortality, due to frost. It is important to ensure that all seedbed preparations and residue managements are complete during the season prior to a planned dormant planting. In southwest Saskatchewan, dormant planting dates generally range between October 15 and November 15. Planting dates closest to the onset of winter will have the greatest chances of success. In the western prairies, planting can extend into December.

Warm season grasses, alone or in mixtures with cool season grasses, require soil temperatures of at least 10 C before they will germinate. Warm season plantings normally occur between mid-May and mid-June. Fall or dormant seeding of warm season species is not recommended. It is important that mixes are planted into a seedbed that has a high probability of having adequate moisture after seeding. Moisture conditions are considered to be ideal if the soil can be readily formed into a ball in the palm of the hand.

Spring seeding dates may be extended two or three weeks past the normal dates when moisture conditions are favourable. In spring when growing conditions cause a delay in pre-seeding weed control, it may also be necessary to delay seeding until after the normal date. When planting into fields that historically are flooded or very wet in spring, consideration should be given to dormant planting, as the likelihood of the site supporting heavy equipment and achieving accurate seed placement and packing is greater in the fall.

SITE PREPARATION

Seedbed Condition

A firm seedbed is important when seeding native grasses. A firm seedbed conserves moisture and ensures good seed to soil contact. Recently tilled ground should be packed with a coil or roller packer prior to seeding. Pre-seeding packing can also be accomplished by traversing the field once or twice with an empty press drill. The seedbed is considered firm enough when a footprint penetrates ¼ to ½ inch deep (Duebbert et al. 1981). Packing is rarely necessary when seeding into standing stubble as soil firmness is usually adequate. Seedbed condition may influence the choice of seeding equipment, a factor that is discussed in a later section.

Pre-Seeding Weed Control

Weed control procedures during the pre-seeding year will have eliminated most of the major weed problems in a field, but weed populations should be re-evaluated prior to seeding. Weeds, volunteer cereal or broadleaf crops present at seeding time will have a competitive advantage over the less aggressive native seedlings, and must be controlled prior to seeding.

An application of a non-selective herbicide is required immediately prior to seeding or up to four days after seeding. If winter annual weeds such as flixweed and stinkweed and annual broadleaf weeds such as wild buckwheat and smartweeds are present, apply a higher rate of glyphosate. Applications of non-selective herbicides that occur more than four days after planting may cause seedling damage and should be avoided.

Glyphosate application can occur more than four days after planting, if less than two seedlings per foot of drill row have emerged. The treatment will cause some seedling mortality, but the result may be less harmful than heavy weed competition, particularly if perennial weeds are present. If more than two seedlings per foot of drill row have emerged, do not apply glyphosate. Rather, immediately apply a broadleaf herbicide for broadleaf weed control and continue to monitor the planting to evaluate the need for further treatments.

Frost may affect spring weed control activities. After a spring frost, wait three or four days and recheck the field to evaluate the effect on Canada thistle and quack grass. A description of the symptoms of frost damage on these weeds was presented earlier in the site preparation section. If weeds show significant frost damage, wait one or two days for regrowth to begin before applying herbicides. When they have begun growing again the herbicide will be translocated to the roots, increasing its effectiveness.

PLANTING EQUIPMENT

The equipment to seed native plants should provide a consistent rate of seed flow and place the seeds at a uniform depth with good seed to soil contact. Given suitable moisture levels and temperatures, meeting all three of those conditions will result in optimum seedling germination and emergence. The flow characteristics of some native grass seeds require the use of specialized equipment or modifications to standard agricultural equipment or seeding practices to accomplish that objective.

Seeding equipment used for planting native grasses must be able to operate at a consistent shallow depth. Seed should be placed at 1/ 4 to ½ inch in fine textured soils and ½ to ¾ inch deep in sandy soils. Do not seed more deeply than one inch in an attempt to "seed to moisture". Incorrect seed placement can significantly reduce stand establishment. Depth bands or gauge wheels linked to the openers provide positive seed depth control on disc-type seeders. Packer/ gauge wheels are used to ensure depth control on seeders that use hoe or knife openers. If the seeding machine does not provide adequate on-row packing after the seed has been placed, the site should receive an additional packing operation to ensure good seed to soil contact.

Conventional Press Drills

Seeds of some species are awned or have sharply-pointed tips. Others are light and fluffy. Any of those characteristics can result in uneven rates of seed flow in standard gravity-fed grain drills and lead to undesirable skips in seed rows. To overcome that problem, a light rate of oats (5-10 pounds per acre) or, preferably, an inert carrier like cracked wheat or oat groats at half the bulk seeding rate per acre, can be mixed with the grasses to improve seed flow. If the inert carrier and seed are to be mixed in the drill box, be sure to mix some of the carrier and seed in a separate container first. Fill the seed cups with that mixture before starting to fill the drill box.

The use of oats as a carrier can be valuable when seeding soils subject to erosion or crusting. In the drier parts of the prairies, however, seedling native plants may have difficulty competing with even a light rate of oats. In some planting scenarios, the emergence of volunteer grains from the previous year's crop can be overly competitive with newly emerged grass seedlings. Fertilizer is generally not recommended as a carrier due to the possibility of damaging the seed or seedlings, but it can be used providing the following guidelines are adhered to:

- Mix only enough seed and phosphate-based fertilizer so that it can be seeded out the same day.
- Do not store blended product as seed damage may occur.
- Use only enough fertilizer to create a flowable blend.
- Clean seeding equipment (cups and tanks) after use to prevent corrosion damage caused by fertilizer.

The ratio of seed to fertilizer will depend on the flow characteristics of the blend. Blends with a large component of fluffy and/or awned seeds will require more fertilizer carrier. For simple cool season mixtures, use a minimum 1:1 ratio (by weight). For complex mixtures containing awned and or fluffy species, ratios as high as 1:8 seed to fertilizer have proven successful. Ammonium phosphate dry fertilizer products (e.g., 11-52-0) are recommended. Contact a revegetation specialist who has experience with this technique to help determine these ratios.

Specialized Grass Seeding Press Drills

Specialized grass seeding drills usually have seed box agitators and/or specially designed seed cups to help ensure a uniform flow without carriers. Those adaptations are particularly important when seeding mixtures containing more than 50 per cent warm season grasses, and/or species of awned or poorly flowing cool season species.

Air Drills

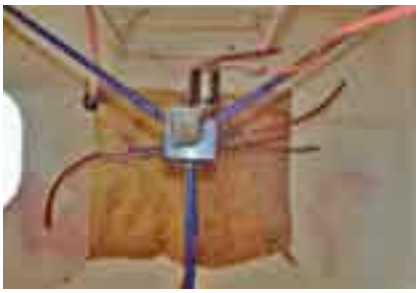
Air drills can be successfully used to seed native grasses if attention is paid to three basic functions: seed metering, seed placement and packing. Recent work at the Semiarid Prairie Agricultural Research Centre in Swift Current showed that a Bourgault air seeder could be successfully used to seed a diverse mixture of native grass species into standing stubble (Iwaasa et al. 2004). With most seed delivery systems and for most native grass mixtures, the use of a carrier is advised to ensure a uniform flow of seed from the tank into the air stream. Use the loading auger on the air drill system to

blend the seed and carrier. Blend only enough seed to complete approximately 20 acres. This minimizes the length of time the product remains blended and contributes to better seed delivery. Never completely fill the product tank of an air drill with grass seed as the increased weight of product leads to a higher risk of bridging, and settling of smaller seeds while seeding. Purchasing quality seed that has been conditioned, scalped and debearded will result in more consistent delivery. Avoid using seed lots containing longer straws. Most seed lots can be conditioned to reduce bridging problems.

Some air drills are manufactured with a seed tank agitator when combined with a carrier at the appropriate ratio, can deliver seed uniformly. Carrier ratios presented in the conventional drill section hold for air drills, also. Regardless of drill make, a carrier to seed ratio (by weight) of 1:1 is recommended.

Prairie Agricultural Machinery Institute (PAMI) at Humboldt, Sask., studied seed delivery using meadow bromegrass seed (because it is prone to bridging) and developed prototypes of seed tank agitators in three makes of air seeders.

Figure 12 – Air drill seed tank agitators



This research update can be accessed on PAMI's website: www.pami.ca (Research Update # 733). Those modifications will make seeding native species with air drills more reliable. In addition to agitation, air flow speed settings should be high enough to deliver the seed mixture through the opener without "blowout" that will result in misplaced seed. Monitor the setting so that seed is adequately delivered through the openers without plugging in the air delivery system. Mixtures that include fertilizer will require a faster fan speed than one with a cracked wheat carrier.

Check that the seeding tool is level to ensure proper seed placement. On newer air disc drills, each opener will have individual settings or depth bands. Maintain a shallow seeding depth and check the settings when seeding in variable soil conditions or when moving to different fields, as soil and residue conditions can be quite variable between fields.

Disc or hoe openers with individual depth settings are likely to yield the most consistent depth. Choice of openers also requires some consideration. Shovels are not recommended as they create a great deal of soil disturbance and are not as precise with seed placement as knife or disc openers. Based on PAMI field trials, knife openers provided better emergence than spoon openers (PAMI, 1997). If using an air drill with double shoot openers designed to place fertilizer below the seed, seed the mixture through the fertilizer tank or switch the hoses so that the seed is delivered through the fertilizer opener. This adaptation results in less soil disturbance since the fertilizer point is now at the shallow seeding depth. In addition, cost savings related to less draft (reducing fuel consumption) are possible. Regardless of the type of air delivery system selected, packing of the seed rows is best achieved with equipment designed with on-row packers.

Tilled seedbeds and standing residue are the most common surface conditions encountered when undertaking a revegetation planting. Occasionally, plantings may also be made into existing sod.

Tilled Seedbeds

Sites that have been tilled during the pre-seeding year are normally in suitable condition for seeding with all types of equipment, providing the seedbed is firm enough to maintain desired seeding depth. The minimal amount of surface residue remaining should not interfere with the operation of seed drills with disc, knife or hoe openers. In the drier parts of the prairies, lack of surface residue may increase the risk of wind damage to emerging seedlings. In those areas, it is preferable to seed into standing residue.

A herbicide treatment should replace tillage for weed control immediately prior to planting. Avoiding spring tillage will leave a firmer seedbed, making depth control more precise. In addition, a tillage operation may accelerate loss of moisture from the surface soil, making conditions less suitable for rapid germination.

Standing Residue

Planning for planting into standing residue must include management of the residue from the harvest of the preceding crop. From the standpoint of seedbed preparation, removal of the crop as green feed, either in bales or as silage, represents the ideal situation. That treatment will remove most of the seed from weeds which may have escaped in-crop management. It also provides enough time for any remnant weeds to reach a growth stage where it can be more completely controlled by a post-harvest herbicide application.

In many cases, the preceding crop will be harvested for grain rather than greenfeed. When that occurs, both the straw and the chaff must be properly managed to minimize potential problems at seeding time. Straw should be baled and removed from the field or finely chopped and spread as widely as possible. The chaff can also be collected and removed, a practice that also collects weed seeds or waste grain coming through the harvesting machinery. Harrowing after harvest can help overcome unsatisfactory spreading of straw and chaff.

When the chaff is spread, it is very important to ensure that it is distributed as widely as possible. If that is not done, the resulting chaff row can interfere with seed placement and with seedling germination and emergence.

Disc, knife or hoe openers can all seed into standing stubble. To optimize their performance, especially in heavy residue, the openers are often preceded by a coulter which cuts through the residue or by a trash plow which clears the residue off a narrow strip to prevent hair-pinning of residue. A narrow band of blackened ground right over the seed row can hasten germination and emergence by creating somewhat warmer soil temperatures near the seed.

Provided residue is properly managed and the seed is well placed, clean standing stubble is an excellent seedbed for revegetation plantings. The soil is firm, allowing good depth control. The standing stubble reduces wind speed and evaporation at the soil surface, provides erosion protection to the soil and may provide some partial shade to tender, newly emerged seedlings.

Existing sod

Seeding into existing sod presents some special challenges. While the roots and top growth of the old vegetation provide excellent soil erosion protection and enhance moisture-holding efficiencies, they can make it difficult to achieve good seed placement.

Standard knife and hoe openers tend to tear existing sod, leaving a rough surface. Because of that tearing action, seed depth and seed to soil contact can be extremely variable, resulting in uneven seedling establishment.

Proper seed placement into existing sod requires the use of specialized equipment. Sod seeders usually have disc openers or very narrow knives and cutting coulters. The coulter makes a slot in the sod for the opener to follow. It is important for sod seeders to provide good on-row packing to ensure the slot is closed and the soil is firmly packed around the seed.

Existing sod will compete very strongly with new seedlings for moisture and nutrients. For that reason, a non-selective herbicide should be applied prior to planting to suppress competition. If the planting site contains a significant remnant native plant population, serious consideration should be given to a management program that would favour those remnant plants rather than eliminating them with a herbicide and then reseeding.

Sod seeding, particularly with native species, is still not well understood. The technique therefore represents the highest risk of the options considered. Since research into sod seeding is a continuing activity, anyone considering using this technique is urged to seek the most current information available.

Depth control bands ensure that disc openers maintain a uniform planting depth when seeding native grass revegetation plantings.

Agitators ensure an even flow of native grass seeds from the drill box to the furrow opener.

An example of an air drill with disc openers seeding native grasses at Swift Current, Sask.

SEEDING

Seeding rates for native grass stands usually vary from seven to 10 pounds PLS per acre. The lower seeding rates are normally used in drier prairie regions.

Before to planting, the seed drill must be serviced and repairs carried out. Regular maintenance such as greasing, checking seed cups and seed tubes for obstructions, and removing old seed from the seed box, cups and tubes should be done before each planting. It is advisable to disassemble and clean the distribution manifolds on an air seeder or air drill before each planting as they tend to be prone to blockages, resulting in seeding misses. The seed delivery system on all drills should be checked periodically during seeding to ensure that it is operating properly.

To ensure the desired PLS seeding rate is achieved, the drill must be calibrated for each seed mixture to be planted. Appendix G presents two methods of drill calibration, one based on the bulk weight of seed and one on seeds per row-foot. Calibration methods for air drills should follow the manufacturer's recommendations provided with the equipment. For gravity flow drills, the following method can be a time-saver on a windy day when drill calibration using the seeds per row-foot method may be difficult.

a) Jack up the drive-wheel end of the drill and measure the drive-wheel circumference in feet. Mark the side of the tire as a reference point.

b) Place containers under two or more seed spouts.

c) Rotate the drive-wheel a half-turn or one full turn and calculate the distance travelled by the circumference of the wheel.

d) Count the number of seeds in each container and divide by the number of feet of wheel travel to determine the number of seeds delivered per linear foot.

Broadcast seeding is not a recommended practice. If conditions dictate that it is the only possible method, however, the seeding rate should be at least double that used for a drilled planting. The site should be harrowed prior to broadcast seeding, then harrowed and very firmly packed after.

FERTILIZING

Fertilizer applications are not usually required for native species plantings in the establishment year (Ries et al. 1987). The results of the soil test taken in the fall of the pre-seeding year will give an accurate picture of the nutrient status of the planting site. Sites that have infertile soils or those that have been cropped in the pre-seeding year may benefit from fertilizer. In those cases, it is particularly important to ensure that adequate phosphorus levels are provided since that nutrient promotes root development. Nitrogen fertilizer applications are generally not recommended, as it tends to promote vigorous weed growth which may be excessively competitive with emerging seedlings.

Fertilizer may be applied either before or at the time of planting. If the application is a separate operation in late fall or early spring prior to seeding, it should be made with equipment that creates a minimum of soil disturbance. A spring pre-seeding application may loosen the seedbed to such an extent that a repacking operation is also required prior to seeding. Repacking at that time, however, may pulverize the soil surface and increase the risk of wind erosion.

If fertilizer is applied at seeding time, ensure that there is sufficient separation between the seed and fertilizer to minimize the risk of seedling injury.

All units in a multi-drill hitch must be calibrated to ensure accurate seeding rates.

Grass seeding drills can be calibrated by counting the seeds delivered per foot of row.

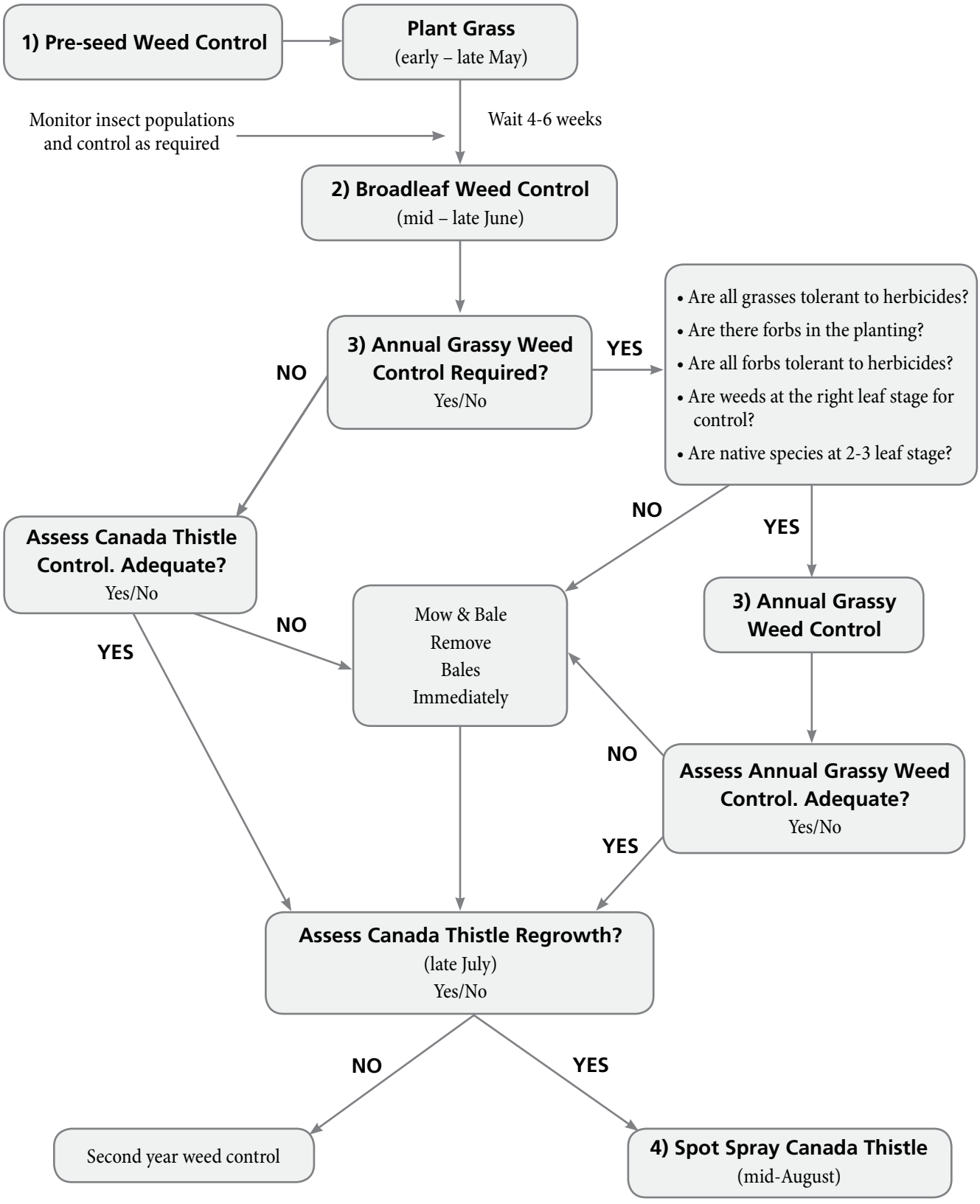
POST-SEEDING WEED CONTROL

PLANTING YEAR

Prompt attention to post-plant weed control is required on all sites during the establishment year. Generally this is achieved by a broadleaf herbicide application, control of annual grassy weeds by either mowing or herbicide application, followed by spot (or field scale) spraying of perennial weeds. Grassy weed control must be considered if the weed densities reach threshold levels. For example, under moist growing conditions, five wild oat plants, 15 green foxtail plants or a combination of three wild oats plus 10 green foxtail plants per square foot would require control measures. A native planting may fail if competitive annual grassy weeds such as wild oats, green foxtail and Persian darnel are not controlled. Techniques employed will depend upon the extent of weed infestation. A typical planting year weed control scenario is presented in Figure 13.

A field inspection must occur every two weeks post-planting to identify the weed species present and growth stage. Usually a broadleaf herbicide such as Buctril M or Target is applied to control broadleaf weeds for all sites. If Canada thistle is present, a more effective control option is to apply Curtail M when the majority of the them are four inches in height. If forbs are present in the mix, the selection of a broadleaf herbicide will require knowledge of potential negative impacts. As a general rule of thumb, do not apply herbicides developed to control cool season broadleaf weeds on native cool season forbs.

Figure 13 – Planting year weed control



Planting year pre-seeding weed control

Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	annuals weeds, quack grass	various	Roundup	1.0-1.5	glyphosate	356	n/a	Less than 6 inches. Wild buckwheat 3-4 leaf stage. Season long control quack grass. 3-4 actively growing leaves.

Planting year pos-emergent weed control

Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
2)	annual broadleaf	mid-late June	Dyvel DS	0.45	dicamba 2, 4-D mecoprop	110 295 80	2-4	2-3 leaf annuals
			Target	0.61	MCPA mecoprop dicamba	275 62.5 62.5	2-4	2-3 Russian thistle to 2 inches
	Canada thistle, annual broadleaf	mid-late June	Curtail M	0.8	clopyralid MCPA ester	50 280	2-4	Majority of Canada thistle are 4 inches – prior to bud stage, annual weeds 2-4 leaf
3)	Canada thistle	mid-Aug.	Curtail M	0.11-0.34+ 0.34-0.45	clopyralid MCPA ester	50 280		Fall regrowth spot treatment

The timing of the herbicide application for annual grassy weed control is a balance of crop tolerance, plant development and weed stage. Native grasses must have reached the two to three leaf stage to survive the herbicide application.

Application of herbicides for annual grassy weed control may not be possible for a variety of reasons. If, for example, native grass seedlings are not at the desired leaf stage or annual grassy weeds have advanced beyond the optimum leaf stage, or not all of the species planted have tolerance to annual grassy weed herbicides, the best option is to mow and bale. Mowing must be done before the wild oats set viable seed. Mower conditioners, swathers, rotary mowers or flail-type mowers are generally used. If a mower conditioner or swather is used, the mowed material must be baled and removed immediately as swath or bales remaining in the field for more than one week can cause seedling damage.

Some options do exist for herbicide control of annual grassy weeds in establishing native grass plantings. Consult the Provincial Weed Control Guide, agronomists with experience for these types of treatments and product labels for more information.

When a companion crop is used, it should be cut and baled after July 15 with bales removed by late July. **If the planting was sprayed prior to cutting, be sure to check the herbicide label for possible feeding restrictions.** Under no circumstances should the swath or bales remain in the field for more than one week as seedling damage may result. Mowing the companion crop in midsummer also serves as a weed control treatment. A field inspection should be done, usually in late July, to assess Canada thistle. A spot treatment of Curtail M should be applied to heavily infested areas just prior to bud development.

SECOND YEAR WEED CONTROL

Most native plantings will require a herbicide application for Canada thistle control the year following establishment. This treatment will normally consist of one application of Curtail M early in the season, if Canada thistles are scattered throughout, treat the entire field. Spot treatment should be adequate if they only occur in patches. Use the higher rate of Curtail M if moderate to high densities of Canada thistle are present (Table 4).

Herbicide applications should occur in mid-May when most Canada thistles are four inches in height and before buds have developed. Applications must occur before annual grass growth forms a canopy that screens the thistles from herbicides. Spot mowing may also be required in mid to late summer for Canada thistle control. If spot mowing is undertaken, use a rotary mower with guards removed which will scatter mowed vegetation, precluding the need to remove the swath.

Table 4 – Second year weed control

Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	Canada thistle	mid-May	Curtail M	0.8	clopyralid MCPA	50 280	to flag	Majority of Canada thistle are between 4 inches and pre bud stage

Photo courtesy: Brandt Industries

Pre-seeding and post-emergent herbicide applications will minimize the number of weeds competing with newly planted grass seedlings.

Spot-spraying of localized patches is an effective method of controlling problem weeds like Canada thistle in new revegetation plantings.

Photo courtesy: Schulte Industries

Rotary mowing is often effective in reducing the effects of patches of annual grassy weeds or Canada thistle that have not been adequately controlled with herbicides.

CONTROL OF INVASIVE PLANTS

Control of aggressive cool season invaders such as smooth bromegrass and quack grass is required to ensure the integrity of the planting and maximum diversity in the long term. Preliminary field research in Manitoba indicates that one of the options for cool season invader control is a controlled burn followed by an application of atrazine. The technique can only be applied to a native planting with a strong warm season component. A controlled burn must be done to promote warm season grasses when they are in the one to three leaf stage (one to three inches in height) in late May or early June. When the majority of invasive plants have resumed growth, usually two to three weeks after the controlled burn, spot apply Aatrex 480. The warm season grasses should spread to fill any voids created by the removal of cool season plants.

Preliminary field research in Saskatchewan indicates that another option for cool season invader control in newly planted native grass stands is a wick herbicide applicator. A 33 per cent solution of glyphosate (one part glyphosate: two parts water) is wicked onto the actively growing invading species which are usually several inches higher than newly seeded native grass seedlings. The higher rates are required for effective control of smooth bromegrass. When using a wick applicator, glyphosate must be applied when the majority of tillers are actively growing and before they reach the boot stage (Table 5).

Barrier plantings may prevent the invasion of aggressive grasses from the margins of fields and headlands or make control treatments more effective. Sheep's fescue, a long-lived native turf grass, has been planted in 30 to 40 foot wide strips around the perimeter of some plantings in Saskatchewan where the invasion of smooth bromegrass was a problem. The fescue's deep roots and tufted growth form resist invasion by weeds and rhizomatous grasses.

In areas where enough seed of adapted warm season species is available, a warm season barrier strip adjacent to potential sources of invasive plants can provide the basis for another control technique. Since most invasive species are cool season, they can be selectively controlled by applying Aatrex 480 herbicide to a warm season barrier strip.

Table 5 – Post-establishment control of invasive plants

Weed		Date	Herbicide (e.g.)	Rate (L/ac.)	Chemical Name	Active Ingred. (g/L)	Leaf Stage	
							Crop	Weed
1)	smooth bromegrass, quack grass	mid-June	*Aatrex Liquid	2.85-4.7	atrazine	480	1-2	Majority of invasive plants have resumed growth following controlled burns
		various	Roundup	33% solution (wick applicator)	glyphosate	356		Apply to actively growing invader species prior to the boot stage. Invading species are usually taller than newly seeded grasses.

* Aatrex Liquid can only be applied to plantings that contain warm season grasses. Use the higher rate on high organic matter, fine textured (clay) soils.
Not registered for use on grasses in Canada.

GRASSHOPPER CONTROL

In the arid mixed prairie, damage by grasshoppers can be a major cause of grass stand establishment failure. Grasshopper populations are cyclical. Outbreaks can last three to six years and have been known to last up to 20.

Lighter-textured, disturbed or bare soils are preferred egg-laying sites for many grasshopper species, especially the ones that cause the most economic damage. Hot and dry conditions usually favour rapid development of eggs and nymphs and increased egg-laying activity in adult females. Conversely, cool, moist conditions cause slow development and increase the incidence of disease, especially fungi.

Departments of agriculture produce annual grasshopper forecast maps, showing predicted levels of abundance and geographic distribution. Locations with a high potential for damage should be monitored closely in the year of grass establishment.

Agriculture and Agri-Food Canada has established action thresholds for grasshoppers (Table 6). A decision to proceed should be based on the cost of the control versus the amount of the expected loss, the life stage and type of grasshopper involved and the ecological sensitivity of the control site.

Table 6 – Threshold levels for grasshopper control (densities per sq. yd.)

Field	Roadside	Management
> 12	> 23	Control required
7-11	12-22	Control may be required
< 7	< 12	Conrol not required

Because grasshoppers are not usually distributed uniformly, counts should be taken in a number of locations within a field to determine the average density. Provincial agriculture department publications can provide the technical advice needed to ensure accurate sampling.

References to specific insecticides and rates of application are based on provincial crop protection or insect control guides. Wide coverage or aerial application should be avoided to minimize effects on non-target organisms. Application should be directed at the source of the infestation such as roadside ditches, field margins or other locations where egg-laying has occurred.

Wherever possible, less toxic insecticides such as Malathion, Cygon or Sevin XLR should be used. Bran-based baits like Eco Bran present the least risk to non-target organisms, and may be used in pastures while beef cattle are grazing. Refer to the product label for complete product use instructions.

Table 7 – Planting year – grasshopper control

Insect		Date	Insecticide (e.g.)	Rate (L/ac)	Chemical Name	Active Ingred. (g/L)	Application
1)	grasshopper various		Eco Bran	0.8-1.6 kg/ac	carbaryl	2%	ground only
			Sevin XLR Plus	0.5-1.4	carbaryl	480	ground only
			Cygon 480	0.17-0.34	dimethoate	480	aerial or ground
			Decis 5EC	0.04-0.06	deltamethrin	50	aerial or ground
			Guthion SC	0.44-0.70	azinfosmethyl	240	aerial or ground
			Lorsban	0.24-0.35	chlorpyrifos	480	aerial or ground
			Malathion	0.69	malathion	500	aerial or ground

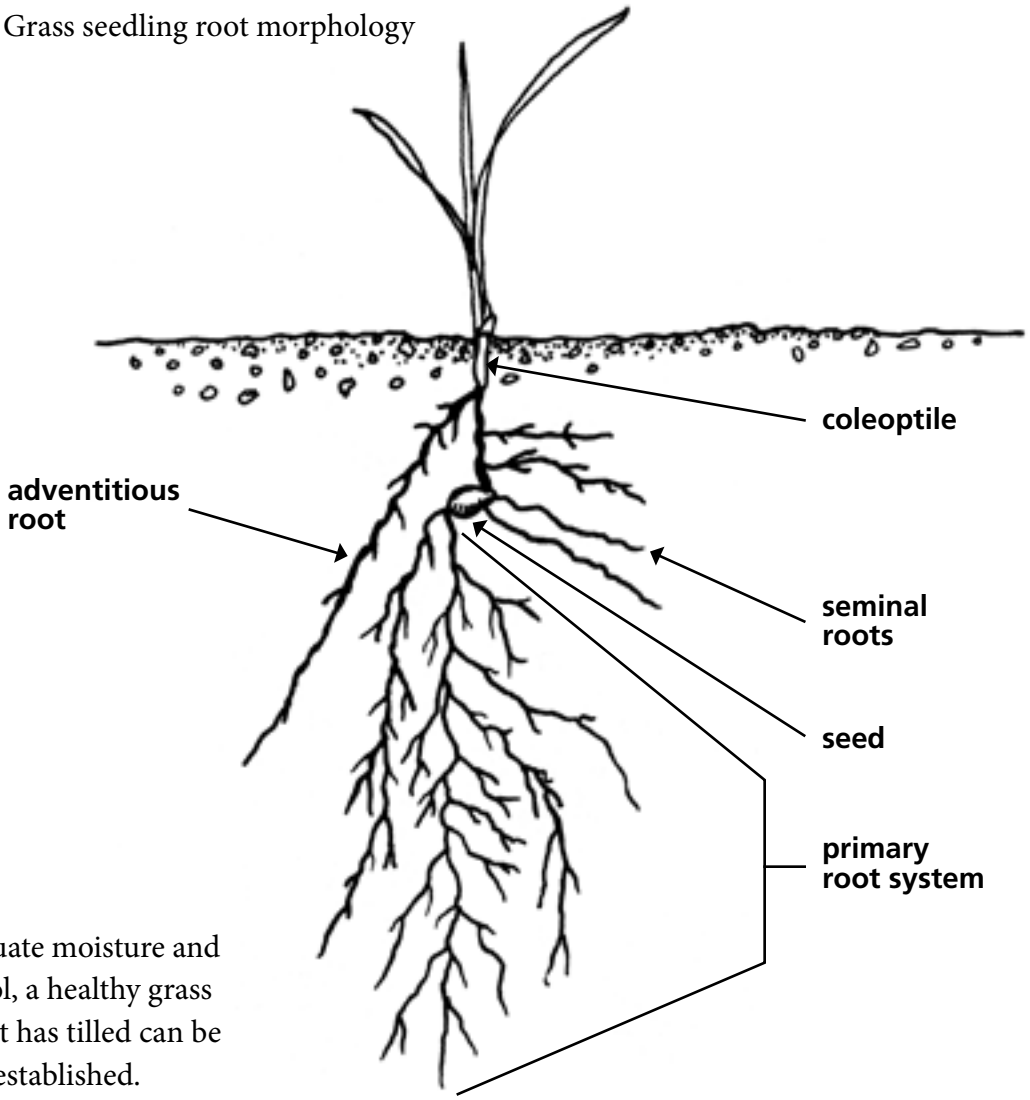
Cultural methods, such as eliminating annual weeds with herbicides or tilling nearby stubble land and field margins in the spring to destroy green growth, reduce the number of emerging grasshoppers by destroying their food supplies. During the year prior to planting, herbicides and/or tillage to keep the field free of green growth will make the site less attractive to grasshoppers for laying eggs. In droughty areas consider the impacts that tillage may have regarding loss of soil moisture and the increased risk of soil erosion. Seeding early will give the plants a chance to grow to a point where some defoliation can be tolerated. Older plants are much better able to withstand defoliation than young seedlings. Grasshoppers may be deterred from invading newly planted fields by planting non-preferred crops such as oats in strips 100 feet or wider around the field perimeter to act as barriers. Alternatively, planting a preferred crop like fall rye around the field edge can attract large numbers of grasshoppers. Carefully timed insecticide applications within the "trap" crop can help control damaging outbreaks.

STAND EVALUATION

To determine the overall success of the planting, a monitoring program should consider the number of seedlings, distribution of seedlings across field gradients, seedling vigour, height and growth stage and overall diversity of seeded plants (Clark and Redmann 1994). Preliminary evaluation of fall and spring planted native grasses should be made four to six weeks after germination. This inspection of seedling density and distribution can easily be combined with an inspection for post-plant weed control requirements. A second inspection late in the summer of the planting year will be necessary to evaluate stand adequacy based on density of established plants and their stage of development. However, the final establishment inspection should ideally be made after the stand has gone through at least one winter.

It is often difficult to decide when establishment occurs following grass seeding. Whalley et al. (1966) maintain that a grass seedling should be completely autotrophic (not reliant on seed reserves) before being considered established. Successful establishment of grass seedlings also requires the formation of adventitious roots (Hyder et al. 1971, Newman and Moser 1988) (Figure 14).

Figure 14 – Grass seedling root morphology



Given adequate moisture and weed control, a healthy grass seedling that has tilled can be considered established.

Sampling Techniques

The systematic collection of stand establishment data is especially important when an individual or organization first becomes involved with native grass revegetation or when new seed mixtures are being tested. As part of a comprehensive system of field records, establishment data can play a key role in determining the reasons for the ultimate success, or failure, of a planting.

Several methods can be used to collect stand establishment data. Density measurements, taken by counting the number of individual plants and species within a standard one square foot quadrate, are the most commonly used. The accuracy and usefulness of the data collected will depend on the number and location of the sites sampled. As a general rule, there should be at least one sample site per acre in fields of 40 acres or less. A minimum of 50 sites is required on fields larger than 40 acres.

The location of the sites within the field deserves special attention. Sample locations should reflect the nature of the field. If, for example, 25 per cent of the field has saline soils, about 25 per cent of the total number of samples should come from saline areas. If the sculptured seeding approach has been used, it would be advisable to sample separately each part of the field that received a different seed mixture.

Experienced personnel can usually determine by visual observation if plant emergence has been satisfactory. At the time of the first inspection, species with high rates of seed dormancy such as porcupine grass or needle-and-thread may not yet have emerged. When drill rows are clearly evident, emergence has been excellent.

Table 8 presents some suggested actions based on seedling densities in the planting year.

Table 8 – Seedling density for stand evaluation

Avgerage Seedings (per sq. ft.)	Action/Condition
< 1	Reseed
1-3	Wait and revaluate next year
4-5	Successful planting
> 6	Very good

Even germination and emergence results in clearly evident drill rows. This planting is well on the way to becoming successfully established.

POST-ESTABLISHMENT MANAGEMENT

Native plants are well suited for a number of planting objectives. Wildlife and reclamation agencies have used native plant species for decades. Their longevity and ability to thrive under adverse conditions with few inputs make them an obvious choice for long-term, low-maintenance plantings.

Native grass stands, like all grass stands, require that managers understand the growth habits of the plants and apply appropriate management at the proper time. Carefully considering the planting objectives and following through with sound management will greatly enhance the likelihood of keeping a native planting productive for a very long time.

Most of DUC's management experience with seeded native plants has focused on maximizing wildlife production. Therefore, most of the comments in the following pages reflect 20 years of experience in maintaining fields of idle cover for wildlife production. The guidelines presented will serve managers with similar objectives. The advice presented for "reclamation management" is applicable for producers interested in rejuvenating old pastures through natural management systems.

Wildlife Cover Priority

While native plantings may be considered permanent, periodic management is required (Duebbert et al. 1981). Management intervals will vary with soil, climate, plant species and other factors. In the wetter eastern prairies, management may be required every three or four years. The intervals may be six or seven years or more in the drier mixed prairie. It is important that management occurs before stand vigour declines dramatically. DUC has developed a systematic monitoring program of stand vigour attributes to help guide management decisions. Observations of characteristics such as litter (duff) accumulation, percentage of field lodged, culm and vegetation height and density, help a manager make management decisions. Recognizing changes in stand vigour characteristics over time allows a manager to determine when the management of a native stand is necessary.

Stand Vigour Indicies

Litter (duff) accumulation is probably the single best attribute managers can use to determine when to apply grassland treatments (Naugle et al. 2000). Duff is defined as accumulated dead plant material resulting from compaction of lodged materials that have begun decomposition.

Litter accumulation is a natural process in a grass sward. However, accumulation can reach a point where it impedes light and heat penetration to the soil surface and should be removed. For example, Forster and Entz (1999) found that in native plantings in Manitoba, spring duff thickness is inversely correlated with total culm production (including tillers). An even stronger inverse correlation between duff thickness and seed culm density was detected. When duff accumulations exceeded three inches, less than five seed-producing culms per square foot were found and the percentage of seed-producing culms was consistently below five percent. Seed culm production is an excellent indication

of stand vigour. Therefore, when duff accumulation exceeds three inches and less than five seed culms per square foot are observed, management may be needed.

Field lodging is also a natural process that occurs as dead stems and leaves from previous growth break and become lodged in the new growth. Lodging will increase as a stand matures. Lodged material is defined as dead plant material that is at an angle of less than 45 degrees but is not duff. Be advised, early spring is not the best time to inspect fields for lodged material. As the stand initiates growth, old material flattened by winter snow pack is lifted. A decreasing percentage of lodged material can be correlated to an increase in duff accumulations and forewarns of stand stress and the potential need for management.

Management Frequency

Management treatments on either planted or naturally occurring native sites may be undertaken for a variety of reasons. Chief among these is the removal of accumulated plant litter, as described earlier, that can impede light and moisture penetration. Exposing growth points to sunlight and recycling nutrients tied up in the old plant growth stimulates new growth. Native grass stands in arid regions will not accumulate duff as rapidly as in wetter areas. In fact, in arid areas native grass stands may never reach the critical levels necessary for management as outlined earlier. In these areas, haying or grazing to stimulate production is recommended. Conversely, sites that produce high annual biomass may require complete removal of the duff layer by burning or haying and harrowing to rejuvenate native stands on a fairly regular (three to four years) basis. Interestingly, these conditions may exist within the same field where knoll and other thin upland sites may not need management as frequently as the rest of the field. Management plans should accommodate these features. Management frequency will be influenced by monitoring stand vigour indices.

Management is also undertaken to control woody plants or invasive weed species that can overrun a planting. Properly timed management, especially a burn, can stimulate tillering in new plantings, accelerating the establishment of newly seeded native grasses. Timely litter management also reduces the risk of large and potentially damaging wildfires by removing accumulations of old growth.

Management Considerations

Accepted management techniques on seeded or native grasslands include burning, grazing and chemical weed control. In the Eastern regions a properly timed burn will reduce ground litter, suppress or eradicate woody or weedy species, change species composition and in most cases, increase forage production (Kjellsen and Higgens 1990). Care must be taken, however, when considering a burn in the drier western portions of the Great Plains as forage production can be hindered in the short term. Timing, weather, moisture conditions and firing techniques are important factors influencing the effectiveness of a managed burn. For example, during drought conditions burning should be avoided as native grasses are already stressed and management may have a detrimental effect. Also, try to vary your management timing and treatment to encourage stand diversity.

Timing, particularly for controlled burns, can have a significant effect on management outcomes. As discussed earlier, cool season plants (C3) grow actively in the early part of the growing season. Warm season plants (C4) initiate growth later in the season and put on most annual growth during the hottest, driest part of the summer. Given the different

start times of their annual growth, these species growing together in a native stand will respond differently to the same management treatment.

When plants have just started growth, they are using root reserves to produce new vegetation. They respond favourably to management at this stage. In fact, the species that the management is intended to encourage should be just starting to green up (about one to three inches of new growth) when they are burned (Kjellsen and Higgens 1990). Burning after that time, when plants have used up root reserves, can actually set them back. Usually, species actively growing (six to eight inches of new growth) when the area is burned are much more susceptible to injury and death than dormant species or those just initiating growth (Anderson et el. 1970).

Typically, early spring burns encourage cool season species. Late spring burns, when warm season species have one to three inches of new growth, encourage warm season species and can suppress cool season species. A management burn intended to shift species composition is referred to as a reclamation burn.

Fall burns tend to have a neutral effect on species shift. In fields where managers are content with species density and distribution, a fall burn that effectively removes accumulated litter is recommended. These treatments are referred to as maintenance burns.

Before undertaking a burn, consultation with experts and a review of the literature is recommended. Burning has been recognized as one of the simplest and most inexpensive methods of managing native grasses. Selective suppression or promotion of a plant community depends primarily upon the date of the fire in relation to the phenology of the species (Higgens 1989). It is important to recognize that a native grass stand may be comprised of both cool and warm season grasses.

Timing of the first upon establishment methologie. For example, if haying occurs in the first or second year of weed control, management for duff removal can be delayed until at least the fourth growing season. In a mixed grass planting (warm and cool season species combined) the first management should be a controlled burn. A properly timed late spring burn will facilitate warm season expansion, greatly increasing stand diversity. In fact, a late spring burn in the second or third year post planting is recommended to promote the warm season component.

Mowing and grazing can provide many benefits similar to burning. If mowing is used, DUC recommends waiting until after July 15 when most waterfowl nests have hatched. Cut as low as possible with a mower conditioner or flail-type mower. Remove as much of the old plant litter as possible to stimulate new growth. Duebbert et al. (1981) suggest that mowing does not provide a long-lasting treatment effect if the lower litter layer is not removed. Foster and Entz (1999) indicate that haying equipment cannot accommodate complete duff removal and can be considered as a less aggressive management treatment than a burn.

Grazing is also a management option on reclaimed or existing native grass stands. On wildlife priority areas, DUC recommends that grazing be well regulated with infrequent, high stocking rates. If grazing is chosen as the management tool, managers must maintain control of the grazing treatment and work within a set of obtainable objectives with a long-range goal (Naugle et al. 2000). Compared to other treatments that may occur within a short time frame, grazing must occur over a longer period of time to achieve the same results. Livestock can remove more above ground litter than desired through consumption and compaction and therefore must be closely monitored to ensure the proper treatment effect. Local pasture experts should be consulted to set up a system that is appropriate for the soil and climatic zone.

Recent studies have indicated that decadent stands of seeded native cover have average crude protein values of 7.2 per cent. Given this, haying or grazing a site prior to a prescribed burn can provide several benefits. For example, the biomass can be used as feed for livestock and the reduced fuel load can make for an easier burn. It is important to note, however, that a stubble height of at least six inches should be left to accommodate a prescribed burn.

Herbicide Treatments

Ground application of herbicides has been very successful in controlling invasive weed species in native plantings. The combination of clopyralid and MCPA ester (Curtail M) at the recommended rate of 0.80 L/acre controls many broadleaf annual and perennial weeds. Herbicide can be applied either as a spot spray or general application. The timing of the application is crucial in native plantings. The application must be applied before the native grasses have time to establish a canopy above the weeds. The combination of haying and herbicide maximizes the efficacy of the herbicide by removing of this dense vegetative layer. In most instances the target of herbicide applications in native stands is cool season broadleaf weeds. It is important to note that the herbicide application may result in some damage to the forb component in a native stand. Warm season forbs such as purple prairie clover will rebound after a herbicide treatment. Refer to the Provincial Crop Protection guide for further information on weed and brush control on native rangelands.

Treatment Effects

Research has indicated that the effects of management treatments in both Manitoba and Saskatchewan were evident into the second year post-management. Burning and haying were most effective in increasing plant productivity at high, medium and low duff sites. There was a dramatic increase in plant productivity as a result of the hay and harrow treatment in the high duff sites but a dramatic decrease in the number of culms was observed in the low duff sites. At the low duff site, the hay/harrow treatment may have dried the soil slightly or physically disturbed the native grass crowns that resulted in reduced total culm production (Forster and Entz. 1999). The effects of grazing were more short-lived, evident only into the first year post-management on a medium duff site.

Native grasses are well adapted to periodic burns. Fire can help some native grasses spread and maintain stand vigour.

Periodic mowing removes accumulated litter from native grass plantings, allowing the plants' growth points to receive more sunlight. Mowings should be timed to minimize the impact on ground-nesting birds and other wildlife.

Alternate grazing and rest periods were part of the evolutionary forces that shaped native grasses. Well planned rotational grazing can be used to manage revegetation plantings.

Agricultural Use Priority

Increasingly, agricultural producers, farmers and ranchers have been viewing native plant species as a long-term alternative or supplement to their forage needs. Recent literature (Iwassa 2004) serves to bolster Canadian ranchers' confidence in giving seeded native grass pastures a try. Recent work has also indicated that when managed properly native grass can provide high quality hay (Craig et al. 2004).

Managing planted or naturally occurring native stands with cattle is a science unto itself. This topic cannot be explored in its entirety in the few pages available in this revegetation manual. Rather, a few of the highlights are presented and it is strongly recommend that agricultural producers consult local range specialists to develop grazing plans for their farmers and ranchers.

Management Considerations

To maintain productive pasture:

- Do not graze during the establishment year. It is best to delay grazing until midsummer of the year after planting.
- In an average year, do not put the cattle on a pasture until that year's growth is four to six inches tall. This usually occurs approximately mid-May to early June in most mixed grassed areas.
- In a late summer pasture, wait until the warm season grass component is four to six inches tall, early July in most regions.
- In a pasture with a warm season component, ensure that the cattle can keep up with the new growth to keep it vegetative.

Literature Cited

Alderson, James and W.C. Sharp. 1994. Grass varieties in the United States. USDA-SCS. Agriculture Handbook No. 170. 296 pp.

Clark, G. and R.E. Redmann. 1994. Native grass and forb seed sources for Grasslands National Park. Rep. K3901-C92-079. Parks Canada, Winnipeg. 61 pp.

Duebbert, H.F., E.T. Jacobson, K.F. Higgins and E.B. Podoll. 1981. Establishment of Seeded Grasslands for Wildlife Habitat in the Prairie Pothole Region. U.S. Dept of Interior, Fish and Wildlife Service. Special Scientific Report – Wildlife No. 234. Washington, D.C. 21 pp.

Frankton, C. and G.A. Mulligan. 1987. Weeds of Canada. Agriculture Canada, Pub. 948. 217 pp.

Higgins, K.F., A.D. Kruse and J.L. Piehl. Circa 1990. Effects of Fire in the Northern Great Plains. Wildlife and Fisheries Science Dept., SDSU (rpt EC 761) Brookings, SD. 48 pp.

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

Iwaasa, A. and M. Schellenberg. 2004. 2003 Progress Report on re-establishment of a mixed native grassland in Southwest Saskatchewan (year 3 of a 4 year study). Semiarid Prairie Agricultural Research Center (SPARC) February 25, 2004. 63 pp.

Jacobson, E.T., D.B. Wark, R.G. Arnott, R.J. Haas and D.A. Tober. 1994. Sculptured Seeding, an ecological approach to revegetation. Restoration and Management Notes 12:1 pp 46-50 summer 1994. University of Wisconsin Press.

Kirkland, K.J. 1993. Chemical Weed Control in Direct Seeding Systems. Farm Facts, Saskatchewan Agriculture and Food. April 1993. 8 pp.

Mulligan, G.A. 1989. Common Weeds of Canada, Field Guide. Agriculture Canada. N C Press Ltd., catalogue #A43-9/1986E. 144 pp.

Newman, P.R. and L.E. Moser. 1988. Grass Seedling Emergence, Morphology, and Establishment as Affected by Planting Depth. Agronomy 80:383-387.

Proceedings. 16th Annual Manitoba-North Dakota Zero Tillage Workshop. 1994. Manitoba-North Dakota Zero Tillage Farmers Association. 223 pp.

Ries, R.E., R.S. White and R.J. Lorenz. 1987. Establishment of Range Plants in the Northern Great Plains. pp 29-34 in J.E. Mitchell. ed. Impacts of the Conservation Reserve Program in the Great Plains. USDA Forest Service tech. rept. GTR RM-158.

Sedivec, K.K., D.L. Dodds and D. Galt. 1991. Range Site Identification. NDSU and USDA Report. NDSU, Fargo, ND. 8 pp.

Thornburg, A.A. 1982. Plant Materials for Use on Surface-Mined Lands in Arid and Semiarid Regions. USDA-SCS SCS-TP-157. 88 pp.

Whalley, R.D.B., C.M. McKell and L.R. Green. 1966. Seedling vigor and the non-photosynthesis stages of seedling growth in grasses. Crop Science. 6:147-150.

Whitson, T.D. ed. 1992. Weeds of the West. Western Society of Weed Science, Western United States Land Grant Universities and University of Wyoming. 630 pp.

Wright, S. 1994. The Great Debate? Or a Necessary Balance – Tame versus Native Grass. pp 35-38 in Proceedings of 4th Grass Seed Production and Marketing Seminar. Saskatchewan Forage Council, Saskatoon.

Weeds of Alberta. 1981. Alberta Agriculture, Agdex 640-4. 209 pp.

Weed Seedling Identification Guide. 1986. Manitoba Department of Agriculture. Agdex 640. 25 pp.