Turfgrass Evaluation of Native Grasses

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by

Anthony Scott Mintenko

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

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Abstract

There is increasing public pressure on the turfgrass industry to reduce maintenance inputs. Grasses native to North America seem perfect candidates for low-maintenance turfgrass as they have evolved under the environmental extremes of North America. The objectives of this research were to identify native grass species suitable for use in drought, saline and low-maintenance conditions. Fifteen native grass species for a total of 31 entries were evaluated: alpine bluegrass (*Poa alpina* L.), alkali grass (*Puccinellia nuttaliana* [Schultes] Hitchc.), blue grama (*Bouteloua gracilis* [Willd. ex kunth] Lag. ex Griffiths), buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.), Canada bluegrass (*Poa compressa* L.), *fescue* spp., fowl bluegrass (*Poa palustris* L.), Idaho bentgrass (*Agrostis idaoensis*), inland desert saltgrass (*Distichlis stricta* [Torr.] Rydb.), marsh muhly (*Muhlenbergia racemose* [Michx.] B.S.P.), prairie junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes), rough hairgrass (*Agrostis scabra* Willd.), side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.), sweetgrass (*Hierchloe odorata* [L] Beauv.) and tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.). The entries with high quality ratings for low-maintenance turf use were: Minnesota ecotype blue grama, 'Bismarck' and 'Sharp's Imp. II' buffalograss, inland desert saltgrass, 'Bad River' blue grama, 'Barkoel' prairie junegrass and 'Golfstar' Idaho bentgrass. The last four were also moderately tolerant of saline soil conditions. The warm season grasses entries blue grama and buffalograss were extremely drought tolerant, maintaining consistent green colour. Most entries will require a breeding and selection program before being released to the public for low-maintenance turfgrass use. This research provides useful information on a number of native grass species suitable as low-maintenance turf and the relevant drought and saline tolerance of many native grass species.

Forward

The format of this thesis is prepared in manuscript style. Manuscript 1 discusses turfgrass evaluation of native grasses. Manuscript 2 discusses saline tolerance of native grasses. Manuscript 3 discusses drought tolerance of native grasses.

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General Introduction

There is increasing public pressure on the turfgrass industry to reduce maintenance inputs. Excessive use of fertilizers, pesticides and water for turfgrass areas are contributing to continued environmental degradation. Developing a low maintenance turfgrass has been the focus of many turfgrass researchers. Most research, however, has concentrated on the traditional turfgrasses such as Kentucky bluegrass (*Poa pratensis* L.) and fescue species (*Festuca* spp.). The grasses native to western Canada and the north central USA have not been well researched, but they may provide the ultimate low maintenance turfgrasses for the prairie region. Native grasses have the advantage of evolving under the environmental extremes of North America and should be perfect candidates for low maintenance turf.

The first objective of this thesis was to identify native grass species suitable for turfgrass plantings and determine the management regimes under which each species is best adapted. Field trials in Winnipeg and Carman, Manitoba evaluated 15 different native grass species in non-mowed and mowed studies at heights of 62mm, 38mm and 18mm. These heights simulated a golf-course rough, home lawn and golf-course fairway, respectively.

The second and third objectives were to determine the drought and saline tolerance of several native grass species. The saline study was conducted in an environmentally controlled growth chamber. The drought study consisted of a growth chamber experiment and field experiment. These experiments have provided useful information on the relevant drought and salinity tolerance of a number of native grass species.

Literature Review

1.0 Native Grasses- Introduction

The current interest today in native plants has resulted in a public desire for more knowledge and potential uses of native plants in the landscape. The excitement with native plants in general has also been extended to native grasses as well. Native grasses have tremendous potential for ornamental, reclamation and low-maintenance sustainable lawns. Native or indigenous grasses are those that occur naturally in a particular country or region. For example in North America, native grasses are those that were present at the time of initial European settlement. Early settlers brought with them many of the grass species with which they were most familiar (Smith and Smith, 1997). These species, mainly from Europe and Asia, are commonly referred to as introduced grasses. Many of these introduced grasses have shown good environmental adaptation in North America {e.g. tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.), crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], etc.} and are now planted on millions of acres. Several of these introduced grasses (e.g. Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermis* Leyss.), crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.)} are now found over such large areas that they are mistakenly called native species. More accurately, these introduced species should be referred to as "naturalized" in that they are now widespread and naturally reestablish without human intervention (Smith and Smith, 1997). Additionally, there are certain species where even the experts can not agree on their origins. Canada bluegrass (*Poa compressa* L.) and redtop [*Agrostis gigantea* Roth (syn. A. alba L.] both fall into this category since some taxonomy books classify them as native and others classify them as introduced.

With public demand for lower turfgrass maintenance requirements, interest in native grasses for turfgrass use has increased (Koski, 1999). Since native grasses have evolved under the environmental extremes of North America, they fit quite well into sustainable low maintenance landscapes as they can survive and thrive with only the inputs provided by nature itself (Diekelmann, 1982). Many of the introduced grass species that are traditionally planted for turf in the northern Great Plains of the USA and Canada require inputs of fertilizer and water to maintain healthy vigorous stands. Kentucky bluegrass is commonly planted, but without irrigation it often browns off (i.e. - becomes dormant) during periods of dry weather. Fertilizer requirements are also high for this species. Other species like the fescue spp. do not require as much water as Kentucky bluegrass, but also brown off in extreme dry weather and in northern regions winter survival is sometimes a concern (Dernoeden et al, 1994).

In comparison, native grasses of this region have evolved under low moisture and fertility conditions and temperature extremes. The majority of native grasses show excellent long-term survival. Warm season native grasses in this region maintain leaf colour through extended periods of high temperatures and low moisture. It is for this reason that native grasses are being investigated for low-maintenance sustainable turfgrass (Mintenko and Smith, 1998, 1999).

In North America, there is a largely untapped genetic resource for most of the native grasses which show good turfgrass potential. This is especially true for grasses native to the Great Plains region of North America since there are large rangeland areas where cultivation never occurred. Plant collectors and plant breeders have the simple choice of deciding whether their collection will cover a wide geographic range or a narrow one.

Blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths.) provides a good example in that it naturally occurs from Mexico throughout the western USA and into Canada (up to 500 km north of the USA/Canada border) (Looman, 1982). Geographic range and resulting genetic diversity may be narrow when a plant breeder desires a collection of plants with specific traits like salinity tolerance or fine leaf texture. Even in these cases, sufficient plant material is usually available. A more common limitation occurs when key limiting traits are not present within natural populations. Seed yield is often a limiting factor for native grass species, and many of these species simply do not have diversity for this important trait (Smith and Smith, 1997).

1.1 Cool-Season (C3) and Warm-Season (C4) Grasses

Native grasses include both warm and cool-season grasses. In Canada all introduced perennial turfgrasses are cool season grasses. Cool and warm-season grasses differ in the time of season they are most actively growing. Cool-season grasses prefer the cool temperatures of early summer and early fall, while warm-season grasses prefer the hot temperatures of summer. This distinction between the types is a result of their differing photosynthetic pathways (Salisbury and Ross, 1992). At lower temperatures (10-25°C), such as in the spring or fall, photosynthetic rates of warm-season grasses are equal to or lower than cool-season grasses. However, warm-season grasses, like other C4 plants have higher photosynthetic rates than C3 plants at higher temperatures (>25°C). Warm-season grasses photosynthetic processes are twice as efficient as cool-season grasses at temperatures between 25-35°C. Warm season grasses are suited to regions with periodic drought and high temperatures. Warm season grasses effectively pump carbon dioxide into the bundle sheaths which allows stomates to close when drought stress is occurring without limiting carbon dioxide needed for continued photosynthesis

(Salisbury and Ross, 1992). Studies have also determined that warm-season grasses can be more competitive than introduced cool-season grasses as a result of higher growth rates even with low soil nitrogen levels (Brown, 1984) and low soil moisture levels (Feldhake et al, 1983; Kim and Beard, 1988).

A separate group of native cool-season grasses exist, the *Stipeae* spp., that have their optimum growth at temperatures similar to warm-season gasses. This is a result of the unique way these plants fix their photosynthate, requiring warmer temperatures than other cool-season grasses (Chapman, 1996).

Warm and cool-season grasses should not be moved very far from their point of origin. Plants moved further north risk the danger of winterkill. In these grasses dormancy may be delayed in the fall, as well as delaying spring growth. This is a problem on the Canadian prairies, for most native grass seed sources are from the central region of the USA. Therefore, point of origin should be confirmed before planting any native grass. Warm-season grasses especially should not be moved more than 450km north, or 300km south of their point of origin. Also, an 150m change in elevation corresponds to 160km of latitude (Smith and Smith, 1997). If native grass seed is sold commercially in Canada without regard to adaptation, total stand losses from winterkill are possible.

2.0 Turfgrass Research with Native Grasses- Past, Present and Future

2.1 Past Research

Most research into native grasses has concentrated mainly on ecological adaptation (Rogler, 1943), physiology (Berg, 1995), range management of native grass pastures, and related aspects of livestock production (Hook and Burke, 1995). This has definitely been the case with blue grama, side-oats grama (*Bouteloua curtinpendula*

[Michx.] Torr.) and many other native grass species as well (Newman and Moser, 1988).

A recent search of the literature indicated that there has been very little research into the suitability of native grasses for turfgrass use. Many native grass species are mentioned for turfgrass use, but most publications refer to non-mown or infrequent mowing situations as opposed to managed turfgrass (Davidson and Gobin, 1998; Jacobson, 1996).

There have been many low-maintenance turfgrass trials, but most utilized commercially available introduced turfgrass species such as the *Festuca* spp. (McKeran and Ross, 1997; Dernoeden et al, 1994, 1998). When native grasses have been evaluated, only those grasses with readily available seed supplies were selected for study (e.g. Canada bluegrass [*Poa compress* L.]) (Diesburg et al, 1997). It is unfortunate that insufficient seed supplies limited past native grass turfgrass research, as many of these grasses are suitable for turfgrass use.

Although there has been very little in the scientific literature recommending native grass species for turfgrass use, information is available through a number of other sources. These include seed industry publications (Stock, 1999), government extension reports (Holzworth, 1990; Jacobson, 1996), books and popular literature concerning lawn care (Daniels, 1995; Denver 1996; Ellis, 1997; Lynch, 1996; Schultz, 1989; Williams, 1997) and native plant restoration manuals (Lyseng, 1993; Morgan et al, 1995; Wark et al, 1994). The native grass species most often recommended for managed turf stands are buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) and blue grama. These two species are characterized with a low growth habit and drought tolerance and are mentioned repeatability as options in non-mown or low maintenance lawn situations.

The native grass that has been most extensively investigated for managed turf stands is buffalograss (NTEP, 1995; Browning et al, 1994; McCarly and Colvin, 1992). This grass, native to the central and western USA, has become sought after for turf planting during the last 10 to 20 years. Buffalograss is a true low maintenance turfgrass with its low growth habit, drought tolerance and natural competitiveness (Lambert and Colvin, 1992; Feldhake et al, 1984). Although early buffalograss cultivars required establishment using vegetative plugs or sod, there are now a number of seeded cultivars (Frank et al, 1998, NTEP, 1995).

The potential use of buffalograss in Canada is uncertain because most current cultivars originated in the central west and southwestern USA and have questionable winter hardiness when planted in northern locations. The most northern sourced buffalograss is a recent USDA-NRCS ecotype release from North Dakota, known as 'Bismarck'. It has been evaluated at the University of Manitoba turfgrass research program (Winnipeg, Manitoba) and holds some promise as a winter hardy buffalograss variety for use in the northern U.S. mid-west states and western Canadian provinces.

2.1 Present Research

Current research with native grasses for turfgrass use is primarily focused on buffalograss (Bughrara et al, 1998; Huang, 1998; Johnson and Riordan, 1998; Qian et al, 1999). Researchers continue to expand their knowledge of buffalograss physiology, genetics, breeding techniques and general turfgrass management (Bowman et al, 1998; Frank et al, 1998; Gaitan-Gaitan et al, 1998; Wu et al, 1998).

The University of Manitoba turfgrass research program has studied many native grass species for turfgrass use and is presently conducting an evaluation of various native grass species (Mintenko and Smith, 1998, 1999). These species were obtained from seed companies and conservation organizations across western Canada and western USA.

When planted in 1996, this experiment included all available seed sources of native grasses with turfgrass potential in the north central USA.

All of the species being evaluated in the Manitoba study are recommended for erosion control, or reclamation (Looman, 1982, 1992; Alderson and Sharp, 1995). Several of the entries have also been suggested for low-maintenance turfgrass. These species include tufted hairgrass (*Descampsia caespitosa* [L.] Beau.) (Mitchell, 1988), Idaho bentgrass (*Agrostis idahoensis*) (Brede, 1999), Canada bluegrass, prairie junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes), blue grama, buffalograss and alpine fescue (*Festuca alpina* L.)(Alderson and Sharp, 1995).

Buffalograss has had many varieties released solely for turfgrass use and has proven to be an excellent low-maintenance turf (NTEP, 1995). A junegrass variety 'Barkoel' from Europe and 'Golfstar' Idaho bentgrass were developed and released specially for turfgrass use and have preformed well in the University of Manitoba turfgrass trials (Mintenko and Smith, 1998, 1999).

Blue grama is commonly recommended in popular lawn care publications for turfgrass use, but few management experiments have been conducted for this species. There have been several blue grama cultivars that have been released by the USDA-NRCS and universities in the USA, but none were selected under managed turf conditions. In fact, most blue grama seed available in North America is harvested directly from native stands. This species has shown excellent potential as a low-maintenance turfgrass at the University of Manitoba (Mintenko and Smith, 1998, 1999) and a turfgrass breeding and selection program has recently been initiated.

2.3 Future Research

Turfgrass research and breeding with native grasses is occurring at other locations in North America (Huff and Brilman, 1999; Koski et al, 1999; Yocum et al, 1999), but it will be several years before a range of species/cultivars developed specially for managed turf is available. With the exception of buffalograss, the greatest limitation for expanded use of most native species is limited seed supplies and seed prices that are often three to five times the cost of traditional turf species (Smith and Smith, 1997).

Some species have inherent biological limitations for seed yield, but selecting for higher seed yields and improvements in harvesting technology will lead to increased yields. Many native grasses may never reach the seed yield potential of tall fescue and perennial ryegrass and therefore seed costs will probably always be somewhat higher. None-the-less, widespread acceptance in the marketplace will require ample quantities of seed at reasonable prices, and every effort should be made to produce seed of native cultivars/species. True low-maintenance turf should have no problem competing in the marketplace even if seed costs are double or triple that of traditional turf species since maintenance costs will be dramatically reduced.

3.0 Grass Physiology

Knowledge of the principles of plant physiology is critical to the interpretation and understanding of past and present research involving native grasses. Plant physiology studies plant functions from the moment a new plant begins its life to its death. By studying the physical and chemical factors that affect how a plant responds to environmental conditions, researchers are able to understand the processes occurring inside the plant. This section will review some of the stresses of importance in native grass research.

3.1 Drought Stress

Drought stress, as defined for plants, is when the soil moisture in the root zone is at, or below the plant's wilting point. The wilting point is a result of evaporative dehydration from the plant, meaning the plant is releasing more water than it is gaining. When drought conditions occur in a plant, dehydration involves loss of cell turgor and results in cell flaccidity (absence of cell turgor) (Levitt, 1972). Grasses have several mechanisms to avoid or tolerate drought stress, which will be discussed in later sections.

3.1.1 Cell Turgor Loss

Dehydration causes a decrease in turgor pressure, which results in growth inhibition and stomatal closure. A decrease in cell growth is the first response of the plant to water stress and a direct result of cell turgor loss. For a cell to grow or even to maintain its present size represents a substantial water sink for the plant, using 50 to 60 % of total stem water input. Dehydration impacts directly on this massive water sink in the plant and therefore impacts directly on reduced cell growth. The closure of the stomates results in an almost complete cessation of photosynthesis due to the following: zero carbon dioxide diffusion into the leaf, dehydration of photosynthetic reactions, and increased mesophyll resistance to photosynthesis. Respiration is also limited by decreased oxygen diffusion into the leaf. Intracellular spaces decrease in size, squeezing intercellular air out and further inhibiting photosynthesis and respiration (Kramer, 1980).

3.1.2 Dehydration Effects During Plant Wilting

Cell flaccidity or plant wilting can trigger certain plant responses such as growth inhibition, senescence initiation, earlier anthesis, and more rapid seed maturation with fewer and smaller seeds as a consequence. Metabolic disruptions also occur at this stage which decrease photosynthesis and respiration even further. These result from the breakdown of metabolic reactions by lack of water (Day et al, 1978).

Metabolic disruptions impact directly on cell growth and therefore result in reduced leaf growth. This impacts on turfgrass quality by causing reduced green colour, lower density and increased leaf firing (leaf mortality) (Biran et al, 1981: Huang et al, 1997).

3.1.3 Drought Injury

Decreased photosynthetic activity (i.e. photosynthesis) results in the lowering of photosynthate production rate to a level equal to or lower than the respiration rate, resulting in a net photosynthate equal to or less than zero. If drought conditions continue long enough, cell injury and death can occur as a result of "plant starvation" (Kramer, 1980).

Protein also begins to breakdown faster than it can be replaced since protein synthesis decreases with decreased photosynthesis and respiration. Toxins released from the breakdown of protein begins to accumulate and cause biochemical lesions in the plant. Enzymes are also inactivated and nucleic acids (DNA, RNA) are lost due to protein breakdown and cell starvation. Growth retardant hormones increase over growth promoters. The final result of these injuries is reduced plant growth and accelerated senescence in the plant if the plant is rehydrated and if not, plant death occurs (Salisbury and Ross, 1992).

3.1.4 Drought Avoidance

One method plants use to avoid the effects of drought is to make physiological modifications. As mentioned previously, closure of stomates results in photosynthesis decline and growth inhibition. Water saving xerophytic plants only open their stomates during the daylight of early morning during periods of drought. In these plants stomates act as humidity sensors and close before appreciable dehydration of the leaf occurs. However, decreased growth still occurs (Feldhake et al, 1983; Salisbury and Ross, 1992).

When drought stressed, C4 plants like buffalograss only open their stomates at night to assimilate carbon dioxide and photosynthesis occurs during the day when the stomates are closed. Therefore, when high temperatures and drought conditions occur transpiration is reduced greatly and growth maintained (Huang et al, 1997; Salisbury and Ross, 1992; Qian et al, 1997).

A plant can also lower cuticular transpiration by increasing lipid deposition within or on the surface of the leaf. Deposition of wax above the stomates (as thick hair like structures) will also slow down transpiration loss. These processes occur during drought hardening of the plant. Decreasing the transpiration surface of the plant by rolling, folding or shedding of leaves, also aids in drought resistance (Levitt, 1972).

Roots can avoid drought stress by decreasing water loss from roots in dry soil, decreasing the permeability of roots to water. Roots can also decrease transpiration by increasing the hydraulic resistance of water to the shoots. In grasses, water uptake during drought is often maintained by increasing root-to-shoot ratio, allowing more volume of soil to be tapped for water. Roots accomplish this by increasing root density and growing deeper in the soil column. This is especially true in cool-season turfgrasses that have moderate drought tolerance (e.g. tall fescue) (Paleg and Aspinall, 1981; Qian et al, 1997).

In shallow-rooted, warm-season grasses, such as buffalograss, rooting depth is only increased moderately, but drought tolerance occurs via internal mechanisms which decrease water use rates (i.e. functioning at low cell water potentials) (Qian et al, 1996, 1997)

3.1.5 Drought Tolerance

Plants that tolerate drought, do so by either maintaining a high internal turgor pressure or continue to function at a low cell water potential. This is accomplished via osmoregulation, increasing wall plasticity or, increasing elastic extenability (Salisbury and Ross, 1992; Qian et al, 1996). Growth inhibition is avoided by opening stomates at lower cell water potentials, allowing photosynthesis to continue. By functioning at lower cell water potentials, metabolic stress is avoided which in turn allows respiration and other physiological processes to continue. Many grasses are able to lose 20 to 50% of their fresh weight in water, without drought injury to the cell. Blue grama (Bouteloua gracilis) can lose 98% of its fresh weight in water without injury and recover. However, blue grama is an extreme example and is often referred to às the most drought tolerant native grass species (Levitt, 1972; Paleg and Aspinall, 1981).

3.2 Salt Stress

Salt affected soils contain high levels of soluble salts which has a negative affect most plants' growth. Salt affected soils fall into three groups, saline soils with high soluble salts, sodic soils with high exchangeable sodium, or saline-sodic soils with high levels of soluble salts and exchangeable sodium (Carrow and Duncan, 1998). For definition purposes, plants that can grow in high NaCl salt concentrations are known as halophytes, while plants that cannot grow under high NaCl salt concentrations are called glycophtes (Salisbury and Ross, 1992). The most common occurring forms of salt stress in arid or semiarid environments are from sodium and sulfate salts. Marshes and swamps adjacent to ocean coastal areas commonly contain high sodium chloride (NaCl) levels (Carrow and Duncan, 1998).

Human activity can also cause soils to become salt-affected soils. In regions that are subjected to winters with below zero Celsius temperatures, NaCl used for roadside snow and ice removal causes soil adjacent to these salt treated roads to exhibit saline-sodic soil conditions (Hughes et al, 1975). Irrigation of agricultural land and turfgrass areas has also resulted in increased soil salinization. Irrigation in arid regions of agricultural crops or turfgrass areas has been in the past the primary cause of salt-affected soils. All fresh water contains low levels of dissolved salts which can accumulate in arid soils. This occurs as a consequence of the high evaporation rates present in arid regions which causes over time increased levels of salt deposition in the soil with continued irrigation. Many turfgrass areas use reclaimed or secondary water sources (e.g. waste water) for irrigation, which can also lead to accelerated salinity problems. These secondary water sources typically have higher salt concentrations than fresh water (Marcum, 1999).

3.2.1 Salt Injury

The primary stress due to salinity are osmotic stress. The addition of various salts to water lowers its osmotic potential. When a plant is transferred from a low to a high salt medium, osmotic dehydration occurs. Consequently, when osmotic potential is lower outside the cell than inside the cell, turgor loss occurs and ultimately growth inhibition. Even if a plant can prevent decreasing cell turgor by osmoregulation, the energy required to maintain this unbalanced osmotic gradient results in inhibited growth (Salisbury and Ross, 1992).

Salt stress also produces nutrient and ion imbalances as Na ions are absorbed over K and Mg ions and metabolic processes are disrupted. Photosynthesis, respiration, protein and nucleic acid synthesis, and enzyme activities are all affected by salt stress in a similar way to drought stress. Dehydration of cells occurs in both types of stress, with similar metabolic damage (Harivandi et al, 1992).

This ion imbalance can also lead to ion toxicity where specific ions affect root or shoot tissues. This can result in leaf desiccation (leaf burn), reduced root water/ nutrient uptake and general reduced plant vigor and growth. Turfgrasses generally have higher tolerance to ion toxicity since excess ions accumulate at the leaf tips and are removed by mowing (Carrow and Duncan, 1998; Harivandi et al, 1992).

Soils with high exchangable Na^+ (sodic or saline-sodic soils) and low levels of Ca^{+2} and Mg^{+2} suffer from soil structure degradation. The excess Na^+ soils are characterized by decreased water percolation, infiltration and drainage caused by lack of macropores and pore continuity throughout the soil structure. With this adverse soil pore structure, the water holding capacity also increases, soil O^{-2} content is lowered and soil hardness increases. Excess Na^+ in the soil essentially degrades soil structure by weakening and destroying soil aggregates which leads to pore break down and the previously mentioned soil degradations (Carrow and Duncan, 1998).

3.2.2 Salt Stress Avoidance

Plants can avoid salt stress by either passive exclusion (simple membrane diffusion) or active exclusion, using a Na^+ pump. Plants can also dilute the entering salt ions by absorbing sufficient amounts of water to prevent increased salt ion concentration (Carrow and Duncan, 1998) Inland desert saltgrass (*Distichlis stricta* [Torr.] Rydb.), when subjected to high salt stress, uses a salt gland to avoid desiccation. This salt gland consists of a large basal cell and cap cell, which actively excretes excess salts. This requires additional energy and while the plant will survive quite well in saline soils, growth will be reduced (Hansen et al, 1976; Harivandi et al, 1992).

3.3.3 Salt Stress Tolerance

Tolerance of salt stress is primarily by osmoregulation. This is accomplished by the avoidance of cell dehydration via salt secretion into vacuoles or dehydration tolerance via organic solutes accumulated in the cell. Nutrient deficiency can also be tolerated by substituting Na^+ for K^+ in the metabolic processes. The plant thus survives and maintains metabolic processes required for continued growth (Levitt, 1972).

4.0 Turfgrass Evaluation Techniques

Researchers routinely use visual rating scales to evaluate turfgrass quality, leaf texture, turfgrass colour, uniformity and percent plant ground cover. Visual ratings can be taken quickly in the field and provide important evaluation information. Although quantitative techniques may provide more precise data, time and cost constraints often limit their use (Horst et al, 1984b; Wanous et al, 1991). Research to quantify these measurements have failed because most technology developed cannot account for the parameters that exist within a measurement such as turfgrass colour. The human eye accounts for these measurement parameters in a more efficient and effective way than any technology developed to date (NTEP, 1998a).

Turfgrass evaluation of various cultivars or species are not measured with respect to yield or nutrient value, as done with most agricultural plants such as wheat. The end result in a turfgrass evaluation trial is deciding which entry has the highest aesthetic appeal and functional use. Whether a trial is to determine the most drought tolerant or most wear tolerant turfgrass cultivar, the end product must still be aesthetically pleasing for turfgrass industry and ultimately the public (NTEP, 1998a).

The common criticism of any visual rating scales are that they are too subjective, since they are based on human judgment. Although bias is possible, a trained observer can be very accurate with visual ratings. To avoid bias it is essential that the evaluator does not know the identity of treatments. This means one does not rate plots with a rating sheet in one hand, and a plot plan in the other. One must focus on the plot being evaluated, remaining consistent and uniform in all ratings across all plots. The scorer must have a clear definition of the measurements to be taken and they should be definite in their own mind as to what constitutes an "ideal" and "poor" rating. With all visual ratings, a single observer should evaluate a trial until complete and keep a photographic record of rating differences. If bias is avoided then visual observations can be subjected to statistical analysis (Lefkovitch, 1991; Little, 1985; Horst et al, 1984).

The standard practice in turfgrass visual ratings is to first observe the overall appearance of the trial. Note visual difference between treatments and entries and decide which entries represent the top, middle and bottom of the rating scale. This range of ratings will allow the evaluator to determine all entry rating values confidently and quickly. To ensure consistent visual rating data it is important to evaluate when the sun is at its highest, between mid-morning and early afternoon to avoid shadowing and reflections (NTEP, 1998a).

5.0 Integrating Native Plants into Urban Landscape Design

Society is beginning to see the damage it has inflicted on the environment and it becomes clear to many that society needs to change its attitude. Evidence of environmental degradation can be seen in decreasing air and water quality, along with overflowing landfills. In the urban landscape environmental rehabilitation will require reduced inputs of water, fertilizer and pesticides/ herbicides, and other forms of direct or indirect pollution.

The use of native plants in the urban landscape in North America began in the 1800's. This section will illustrate the environmental benefits of integrating native plants into urban landscape design. It will also highlight several individuals who were instrumental in this process. A brief biography of each and an explanation of key areas of their landscape design elements will be presented. The advantages of native plants will also be discussed, from regional, ecological and sustainable development perspectives. Additionally, a brief outline of the elements of landscape design will be presented along with an examination of several projects using native plants in the landscape in the United States and Canada.

5.1 Historical Evolution of Natives Plants in Urban Design

5.1.1. A.J Downing

Andrew Jackson Downing began what became known as the parks movement in America beginning in the mid-1800's. The rapid growth of American cities launched an interest in public spaces, to help city dwellers escape the pollution of the city and provide recreational settings. His influence and writings allowed landscape gardening to be established. His work with cemetery design and other public space projects such as the Mall and White House in Washington D.C. were the forebears of the parks movement, which started with Central Park in New York in the 1860's (Pregill and Volman, 1993).

His book, "Treatise on the Theory and practice of Landscape Gardening Adapted to North America" (1841), encouraged the public to take an interest in horticulture and the environment around them (Major, 1997). He believed that the environment influenced human behaviour and that the success of a healthy community depended on public parks. One could enjoy the benefits of country living near the culture of city life (Grese, 1992).

Downing preferred the 18th century English modern/ natural/ irregular landscape design as opposed to the ancient/ formal/ geometric style. He recognized and enjoyed the exquisite beauty of natural forms. Natural scenery had the distinct qualities of the beautiful and the picturesque. He believed in nature's ideal in plant form rather than an imitation created by the shears and saws of humans (Major, 1997).

Early in his career, Downing was indifferent to native plant use in landscape design but this changed as over time and he began to champion the use of native plants. He wrote in 1847 that the finest indigenous ornamental trees in the world were growing in America. Most Americans, however, were fixated on the newly available introduced plants from Europe and Asia. Downing wrote that the introduced species were "not half the real charms and not a tenth part adapted" to the environments of America (Major, 1997). He recommended street tree plantings be of the finest native trees growing in the soil and climate of the city where the trees would be located and best adapted. Downing promoted native trees for these advantages as well as their beauty, tolerance of summer sun and ability to hold foliage longer than introduced species (Major, 1997).

5.1.2 F.L. Olmsted

Fredrick Law Olmsted is known as the father of urban parks in America. Olmsted along with his business partner Calvert Vaux, designed and constructed Central Park in New York, the first great city park to be used and maintained by the public (Kelly et al, 1981). The completion of central park in 1860 spurred a flurry of public parks in Brooklyn, Chicago, Buffalo and Montreal, designed in part by Olmsted and Vaux (Pregill and Volkman, 1993).

The effects that Olmsted's designs have on today's landscape are significant. He created the front lawn by setting the house back from the street. He also introduced the curvilinear layout of American streets with separation of traffic using underpasses, overpasses, parkways and bicycle paths. He introduced, on a grand scale, planting trees and shrubs in an irregular and naturalized style (Kelly et al, 1981).

Olmsted's designs were influenced by the English romantic style which celebrated nature by recreating it in an artistic or picturesque manner. This style is based on the belief that modern man will find more clarity and enjoyment in a natural landscape. Characteristics of this landscape involve broadly rolling hills, gentle sloping pastures dotted with clumps of trees and contoured water bodies. Olmsted believed that a park was a work of man-made art, therefore any changes in the park must look at the entire park as a single entity (Kelly et al, 1981).

Three elements of the pastoral landscape are represented in Olmsted parks: turf, wood and water, each in balance with the other. Use of vistas and sequential experiences throughout the park provide the visitor with different experiences and emotions, a key aspect of Olmsted design. These parks, through use of earthen berms or plant screens on the park perimeter provide a barrier to the noise of the city. Olmsted did not believe in altering the topography of the site significantly and but instead used it as the underlying pattern of the landscape design (Kelly et al, 1981).

Although Olmsted tried to use native plants in his landscapes, he did not object to using introduced plants if it created the overall effect he wanted. Many of his introduced species in Central Park either could not tolerate the environmental conditions of New England or became weedy pest plants. However, he did recognize the importance of using native plants to achieve the natural style he desired (Kelly et al, 1981).

5.1.3 Jens Jensen

Jens Jensen is considered a pioneer of landscape design using native plants exclusively. He recognized the aesthetic and functional value of native plants. His belief that design forms and materials should relate directly to the surrounding region with the influence of Olmsted and Downing developed into "Prairie Style" landscape design (Ndubsi, 1997).

His work with the Chicago parks system in the late 1800's included the designing of the public parks of Humbolt, Garfield and Columbus in the expanding city. Other public works designed by Jensen outside of Chicago include the Racine, the Wisconsin park system, Lincoln Memorial Garden in Springfield, Illinois and numerous private residences (Grese, 1992). He was also a strong advocate of establishing nature preserves around the Chicago region, most notably what is known today as the Indiana Dunes National Lakeshore and State Park (Pregill and Volkman, 1993).

Jensen explored the natural areas around the Chicago region and gained an understanding of the visual and spatial characteristics and ecological niches of the regional flora. This was in a time before the field of ecology was a major study in science.

a) The Prairie Style

The basic elements of the prairie style are conservation of existing natural areas, restoration of local colour in the design and a repetition of the horizontal line of land and sky. The frequent combination of a relatively few species is what creates local colour in design, with a continual repetition of a species and colour. This style emphasized the broad horizontal lines of the mid-western prairie landscape (Grese, 1992).

b) Design Characteristics

Jensen used native plant species particular to a region, which were grouped together as they would be in nature. Introduced species were only used at a client's request. These introduced species were kept in the background of the landscape and did not dominate the property. A key theme of Jensen's designs were time and changes in the landscape. He designed the landscape to change seasonally, physically and successionally over time. Successional change was part of an evolving design, planned for and accepted in the overall landscape plan (Grese, 1992).

The best plant species for the existing site conditions were planted for a successful and long term landscape design. Plants were used in masses for harmony and unity to suggest natural patterns of texture and form. However, groupings of plants must be irregular in fashion, as would exist in nature. This technique requires great skill and practice as randomization needs planning. Jensen believed that plants should be allowed to reach their natural form without clipping, except in orchards or vegetable gardens (Grese, 1992).

Meadows in the landscape were designed by Jensen to give the impression of unending space. This was achieved using flat or gently rolling topography and leading the viewer's eye to open spaces with irregular edges. He would bend open space view points by setting vegetation in front and slightly off-centre. The viewer would never see the end points of the meadow with the constant curving of sight lines. Jensen was skilled at using light and shadow in his design. Sun openings along a forested path is characteristic of his design. He oriented long open spaces along east-west axis for sunrise and sunset to be seen at either end. He utilized plants which would be highlighted by low angle sun for different colour effects. Use of broadly curving path/ roadways fitting historical (animal trails) or geological events (ancient beach line) created an anticipation of what lies beyond the curve. This broad curving style was also used to create prairie river effects with water as well. In Jensen's designs, gathering areas for people are common, such as council rings, vegetable gardens and outdoor theaters (Grese, 1992).

c) Summary

Jensen used native plants in the landscape in part to eliminate cultivation and reduce maintenance costs (Domer, 1997). His understanding of the ecology of a region and the importance of preserving wilderness areas were ahead of his time. His principles of using ecology and sustainability in landscape design were visionary as these two topics were only in their infancy in the academic community. Jensen's design principles fit into environmentally sustainable landscape principles so well that they could be taught today and still seem visionary.

5.1.4 Alfred Caldwell

Alfred Caldwell was a great believer in the Prairie Style of landscape design. He was an assistant to Jens Jensen from 1924-1931 and completed a large number of landscape projects with him. Caldwell's own work was a continuation of Jensen's philosophy regarding naturalized design. Working mostly as a teacher of landscape students, he introduced a new generation to the Prairie Style, from the 1960's to the 1980's (Domer, 1997).

Caldwell was a promoter of nature in the cities. He proposed that city planners should return more green space to the city. Parks and gardens should be within walking distance for all citizens and the city should be decentralized into small isolated areas, separated by wilderness (Domer, 1997).

5.1.5 Landscape Designers of the 1970's

a) Ian McHarg

Increased awareness of environmental concerns in the 1960's and 1970's, produced a new wave of landscape designers who emphasized ecology in design. The most significant designer in this ecological movement was Ian McHarg, who published "Design with Nature" in 1969 (Ndubisi, 1997). McHarg viewed ecology as the scientific basis for landscape architecture and planning and invented ecological design. He defined ecological design as a process whereby a region is understood as a biophysical and social process comprehensible through the operation of laws and time (McHarg, 1997).

McHarg (1997) saw the deterioration of the global environment on such a scale that, in his view, non-ecological design and planning were irresponsible and insignificant. He saw ecological design as the only solution. He suggested that to ignore natural processes was ignorant and the profession of landscape architecture would be damaged by it. He believed landscape architects should acquire the knowledge to make a significant contribution to conserving, managing and restoring the environment. Therefore a landscape architect who understands the landscape's geology, climate, hydrology and soils will easily select the appropriate plants that should survive well on that landscape (McHarg, 1997).

McHarg (1997) felt that the cultural component is also important, such that the desires, needs, and views of the environment by the occupants of the landscape are an important part of the design process. Ecological planning and design therefore includes natural and cultural processes. Knowledge of both of these components provides a context for planning and design.

McHarg (1997) believed in Charles Darwin's view that the surviving organism is fit for the environment. If one is fit, then one is healthy, which also applies to the landscape. Plants which are fit for their environment are healthy and can recover from injury or disease more easily (McHarg, 1997). This idea has a direct link to native plant use in landscape design. A native plant has adapted over thousands of years in a local ecosystem and therefore is fit for that environment. Using that species in designing a landscape will most likely result in a successful thriving plant which will require less inputs and maintenance since it has adapted to the climate, moisture and nutrient levels of that ecosystem.

Why hasn't ecological design been practiced extensively in landscape architecture? McHarg (1997) believed that an obstruction to ecological design is the fact that architectural planning is derived by orthogonal two-dimensional drawings. Nature, however, is a multi-dimensional, a living, growing and moving form that expands and interacts with the landscape. His solution was to use three-dimensional field designs, to allow all aspects of the landscape to be accounted for in the design (McHarg, 1997).

Another obstruction to ecological design is the perception that landscape architects have of plants. Their training should include the natural sciences since ecosystems provide an example of ecological design and planning. Plant forms, materials and their processes have all evolved in nature by trial and error, and are therefore a proven success (McHarg, 1997). If landscape architects do not understand the physiology and ecology of plants, they will continue to see them as non-living components in the landscape, to be treated as such. They must see plants as living, breathing organisms, with their unique place in an ecosystem.

McHarg (1997) proposed that a national ecological inventory of biological, physical and social systems be undertaken at a regional and local scale. This would present landscape architects with hard data for choosing the appropriate plants in their designs (McHarg, 1997).

b) Darrel G. Morrison

Darrel Morrison (1975) is currently a landscape architecture professor at the University of Georgia and has been a leader on native landscape restoration from the 1970's to the present. His paper, "Restoring the Mid-Western Landscape", explains the benefits of native landscape restoration. The foremost benefit is the re-establishment of differences between regions and between micro-ecosystems within the region. The educational value of exposure to native plants and the diversity present can also increase awareness of protecting and expanding rare local species. Morrison (1975) considers the greatest value of native restoration is the increase in the positive experience people obtain from this landscape. He compares this to the "standard accepted design environment", which is the typical landscape design that exists across the U.S.A. This standard is a smooth ground layer of Kentucky bluegrass planted with scattered ornamental trees and specimen shrubs all selected and placed for arbitrary reasons. This results in a frozen landscape with decreasing diversity over time as unsuitable plantings die off. Flowering and changes in seasonal colour are restricted to the woody plants present. However, in the native landscape, an abundance of herbaceous ground layer plants provide flower and seasonal colour change. It is this very change in the landscape which enhances a viewer's experience within it (Morrison, 1975).

The University of Wisconsin landscape architecture program attempted to change this trend by stressing an understanding of native plant communities and the environmental processes that shape them. An example of Morrison's (1975) work is

Walden Park on the University of Wisconsin campus and the CUNA Mutual Insurance Society Headquarters both in Madison, Wisconsin. These designs showed that local species can tolerate urban stresses, but before native plants are fully established, intensive weeding and upkeep are initially required, decreasing over time. Intensive maintenance is required as most restoration sites are highly disturbed areas, perfect for weed colonization. A problem for both these projects was finding sources of herbaceous plants native to the region due to low supply and demand of native plants in general. Larger projects have often experienced shortages of native plant material which is still a problem today (Morrison, 1975).

Morrison's (1975) advice for restoring urban sites to native landscape is to know the local composition and characteristics of the local native plant communities, using these as models for the landscape design. The site charactèristics and micro-habitats should be known and then the planting design can be modified accordingly. Seasonal and successional changes in the landscape should be accounted for in the planting design (Morrison, 1975).

c) Robert S. Dorney

Robert Dorney was professor of ecology at the University of Waterloo, Ontario and president of an environmental planning firm. His viewpoint of landscape design in the late 1970's and early 80's was from a biological outlook combined with an extensive background in regional planning (Dorney, 1975). His writing on ecological restoration and utilization of urban rights-of-ways (ROW) address ways in which native plants and nature can be introduced into urban sites. Right-of-ways includes highway, hydro, water/sewer and gas-line buffer zones. Uses of ROWs range from natural habitats for wildlife, to recreational trails, to gardening. One must remember that all ROWs require infrequent maintenance and 24 hour access, which must be accounted for in any design (Dorney, 1990).

Today ROW areas are still largely planted to grass which is obviously cheap and relatively easy to establish. The surrounding community typically realizes little benefit from these ROWs. By using natural plantings, these areas can become diverse wildlife areas, improving the ecology and public enjoyment of the region. Dorney (1990) recommends that grass and shrub plantings be kept separate to avoid planting stress between them and to provide a more natural appearance. Extensive consultation between utility companies, government and the public is important for the implementation and success of ROW redevelopment (Dorney,1990).

d) John Diekelmann

John Diekelmann's (1982) book, "Natural Landscaping" was a culmination of his experience through the 1970's on how to combine good landscape practices with low-maintenance plantings. He promotes naturalizing the landscape where plants are allowed to grow, flower and reproduce with little interference. This book illustrates how expensive the traditional landscape is to maintain. In America 40 million mowers consume 200 million gallons of gasoline annually. Water consumption by this landscape represents 2/3 of all water use and 1/6 of all fertilizers produced is used on lawns. Forty percent of pesticides used are on lawns and gardens (Diekelmann, 1982).

Two traditional methods of naturalizing are the "no-mow" and the "replanting native species" methods. The first method will only be successful in marginal soils too wet or too dry. In nitrogen rich soils weeds will be an initial problem. Over many years native and introduced plants will colonize the area and may produce an attractive, low-maintenance landscape. However, it may take decades for land to return to a natural ecosystem (Diekelmann, 1982).

The more promising method is planting non-weedy native species in the landscape. These species have evolved to their specialized ecosystem and can out-compete other plants by exploiting their own unique environments. The combination of these plants form a diverse and interesting landscape, as discussed in previous sections. Changes in native plant communities is ongoing. For example, a typical native grassland has two new species bloom every day from May to October.

Natural landscapes are self-perpetuating without maintenance. The amount of water and nutrients already present in the soil is all that is required for regeneration over the years. Water is supplied by nature and nutrients are gained from decaying plant material from previous years. Protection from insects and disease is provided by the plants own defenses, pest/disease resistance and beneficial insects, acquired over the centuries (Diekelmann, 1982).

Diekelmann's approach to natural landscaping combines plant selection to the concept of plant communities.

i) Plant Selection

Plants must first be chosen for their fitness to the region, then for their colour, shape and texture. Plants which co-exist together in communities should also be used together in the landscape design. Plants from different environments placed together to form a woodland will be short lived. These plants do not occur in combination in nature and will be competing with each other for similar resources until only one species dominates over the others. Picking the correct combination of hundreds of native plants in one region is difficult, therefore studying plant communities is the solution. Plants in the wild will organize themselves into groups which are adapted to the light, moisture, soils, warmth and nutrients of that habitat. Similar plants will grow in certain environments and similar environments will give rise to similar plant groupings. These plants represent the unique environment of the region and therefore represent that region (Diekelmann, 1982).

ii) Using Communities as a Model for Landscaping

In design, it would be impossible to duplicate a native plant community, since it is too vast. However, it is possible to identify the dominant species in the community (in size or numbers). In grasslands for example, the dominant grass species can be planted together.

Local communities with similar environments should be included in the design model, keeping in mind that a city creates many micro-climates that may be different than the region's climate. A plant community design must be in harmony with its surroundings (Diekelmann, 1982).

Diekelmann (1982) presents a three step approach to naturalized planting, which involves analyzing the site, planning for site use and designing the planting. Analyzing the site includes structures on the site, climate data, topography, and moisture gradients throughout the site. Site use should be divided among the recreation, utility and plantings appropriate to the site's micro-habitats (Diekelmann, 1982).

When planting a naturalized landscape, neighbours should be informed of the native plant design plans and be able to relate the plantings to the neighbourhood flora. A clear distinction should be maintained between lawn and shrubs by using herbaceous plants to soften the transition. An important consideration to fit pathways into this landscape is to design them to meander and curve to the destination for a more natural feel. Pathways should be edged with vegetation to give justification to the curves. Native plant material can be obtained from local native nurseries or removed from areas under threat from construction. Plants obtained within 80 km of the site will survive and thrive better (Diekelmann, 1982).

5.2 Native Plant Ecological Advantages

In most cities around North America, a landscape consisting of arching boulevard trees with green lawns and scattered ornamental trees is the only view of nature to the urban population. The composition and arrangement of these plants is based not on natural processes, but on landscape design and land use. These plants survive with careful maintenance, but decline rapidly with neglect. On average in U.S.A. cities, a street tree only survives 10 years. Trees are chosen from a list of 8-10 species that survive a given lifespan with little care and are not a maintenance problem. Problems arise as a tree variety becomes popular, since it is then planted in mass by the city and private citizens (Spirn, 1984).

Dutch elm disease is a tragic example of the serious problems that can occur when a disease spreads easily through an urban monoculture forest. Simply planting a diversity of tree species can localize disease outbreaks and prevent disease epidemics. Ironically, cities like Winnipeg are planting a monoculture of green ash trees to replace diseased elms. It is easy to predict that future problems may arise.

Lawn and trees both compete for water and nutrients, requiring inputs of each to keep a healthy balance. Maintenance is expensive, as is the amount of energy required to produce inorganic fertilizers, gas for mowers, clippers and tillers. This results in a massive energy flow into the landscape. Water supplies in many cities are shrinking and cannot keep up with the excessive watering that many high maintenance urban landscapes need to survive, where fifty percent of an average household's water is applied to the lawn (Williams, 1997).

Cities must be designed to work with nature, not against nature. The city is part of nature and can be designed to be healthy and diverse. Greater use of native plants is a step towards that goal. Anne Spirn (1984) writes in her book "Granite Garden" that the city should be viewed as an entire functioning system. Each building, street and park is a subsystem of the city. To understand how to be sustainable/ecological in design, a study of each system with its inputs and outputs is needed (Spirn, 1984).

Traditional parks must be examined as an open system, requiring major inputs of energy to operate. These inputs are replacement trees, seed/sod, fuels, pesticides, fertilizers and irrigation. The outputs are grass clippings, dead trees, pollutants and water runoff. Inputs and outputs would be reduced by designing and maintaining parks as semi-closed systems with plants growing in self-generating, self-sustaining units. In a closed ecosystem, input and outputs are zero. No fertilizer, maintenance, new plantings or additional water is needed for the system to operate. The more a park resembles a natural closed ecosystem, the more sustainable the park. Fewer resources are used, less pollutants and wastes are released and nutrients are recycled. Home lawns, industrial sites, golf courses and utility right-of-ways can all be redesigned to fit this model (Spirn, 1984). Native plants fill this role easily, since they can be used as plant communities that exist in a closed system. Another advantage with native plants is that they also re-establish a regional identity to a city, a topic discussed in the following section.

Lawns still exist in a reduced form and with the use of hardy native grasses developed for turfgrass use, a more closed system could be achieved. These grasses would require less fertilizer, pesticides, water and mowing but still meet the requirements of a "good" lawn. People cherish the open ground of a lawn, but they must critically evaluate how much lawn is really needed. Excessive labour and inputs maintaining excessive areas of lawn are wasteful and unproductive (Williams, 1997).

Anne Spirn (1984) dispels the idea that the more hostile the environment, the greater the cost of maintaining plants. Evidence of this is seen on abandoned urban lots where "weedy" shrubs, flowers, and trees thrive. Native and non-native plants flourish in low water, nutrient deficient, compacted soil urban lots are considered "weedy", while cultivated ornamental plants suffer in even less stressful environments (Spirn, 1984).

"Neo-native" or "naturalized" introduced plants thrive as urban plant communities. Instead of disdaining these plants, they can be used in the landscape (Kenfield, 1975). It must be remembered that the urban landscape is a very stressful one, and the microhabitats of urban areas may not even exist in that region. Nature is an ever adaptive force that will find a way for plant communities to re-establish.

For natural areas to succeed, landscape design should be on a scale that is a manageable. Natural plantings only require a simple maintenance plan, but the design should allow for plant succession. All the people affected by the natural planting should be involved, both for input and for education (Spirn, 1984).

5.3 Native Plants and Their Role in Regional Identity

Native plants can restore a regional identity to urban and rural areas. Parks, gardens and formal open spaces in many cities have been subjected to a universal design, as Michael Hough (1990) explains, that "denies a sense of place" to that region. Newly developed suburbs in cities around the world are much the same. These areas often have no connections with their surroundings and natural environments. There is little recognition of the different climates between cities. The ecological diversity of the local native plant species has been replaced by horticulture of introduced plant species.

Landscape design contributes to this problem since it is more motivated by design theory rather than an understanding of the ecology of a region. Local native flora and fauna communities existed due to the unique topography, climate, soils and geological formations of that region. Those elements connect a place to its region, giving it identity. Instead, urban residents are often subjected to an "unchanging cultivated landscape of turf, ornamental trees and herbaceous borders" (Hough, 1990).

One may ask why is it important for landscape design to be identified within its region? Ecologically, a landscape that is connected to its regional plant communities is able to survive, thrive and reproduce in that region with little or no external inputs. Plants that evolved in a region are usually best suited for that region. Landscape designs which contribute to regional identity express the natural diversity of the area and also the unique species of the region. The enjoyment people gain from such a landscape is tremendous. The plants that are representative of a region may not exist anywhere else in the world and should be cherished and preserved within the landscape (Hough, 1990).

As Anne Spirn (1984) writes in her book on city and the landscape, "cultivating an urban landscape that is native to a city's region will yield an image based on that city's own natural legacy, not that of another time and place" (Spirn, 1984). The more the public is intrigued by the landscape, the more they will wish to know of the natural processes behind that landscape. An environmental understanding will educate people to be more ecologically sensitive and therefore more sustainable in all aspects of their lives. This uniqueness of a region fosters tourism, which may be the most convincing reason for business and government to protect and maintain the landscapes' regional identity (Hough, 1990).

Hough (1990), in outlining the principles for regional design, states that one must know the essential character of a place and how people use different places in everyday living. This means learning what the people living there have invested in the region and adapted to the environment over time. Hough (1990) believes in using remnants of natural and cultural properties to form an identity. Public space should also reflect the cultural and natural identity of each place. This ties into maintaining a sense of history, linking the old with the new for a continuous connection with the past.

A regional design can provide environmental learning from direct experience. This can be accomplished by encouraging enjoyment and understanding of the landscape that comes from scientific knowledge and emotional experience. If natural diversity is allowed to evolve on a site, that evolution will result in maximum landscape sustainability and diversity in the long term. Sustainability in regional design can contribute to the environmental health of that region, which should only strengthen its identity. If the landscape allows, changes to a landscape should be minimized. However, many landscape design sites can be too disturbed or damaged and require massive site restoration for that design to be successful. With minimum utilization of resources and energy, the result can be maximum environmental and social benefits (Hough, 1990).

Design cannot predict or control human behavior since the site can only reveal the opportunities present there. Ignoring this can result in unused playgrounds and parks in inappropriate locations. Meaning, if designers use a universal design for all areas, this will result in similar landscaping in these areas, again. Regional design should be started where it is easiest, on a small scale where people live (e.g.- home yard). For an individual, projects should be achievable and sustainable. Combinations of small changes can ultimately connect together to form significant regional and global change (Hough, 1990).

Manuscript 1:

Turfgrass Evaluation of Native Grasses

Abstract

The high environmental costs of maintaining golf courses, home lawns and public areas has created a tremendous interest in developing low-maintenance turfgrasses. There has been very little research into the suitability of North American native grasses for use as a low-maintenance turfgrass across western Canada and north central USA, even though they have evolved under the environmental extremes of these regions. The objective of this research was to identify native grasses suitable for low-maintenance turf. Fifteen native grass species (total of 31 entries) were evaluated under different mowing regimes. The species evaluated included alpine bluegrass (*Poa alpina* L.), alkali grass (*Puccinellia nuttaliana* [Schultes] Hitchc.), blue grama (*Bouteloua gracilis* [Willd. ex kunth] Lag. ex Griffiths), buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.), Canada bluegrass (*Poa compressa* L.), Fescue spp., fowl bluegrass (*Poa palustris* L.), Idaho bentgrass (*Agrostis idaoensis*), inland desert saltgrass (*Distichlis stricta* [Torr.] Rydb.), marsh muhly (*Muhlenbergia racemose* [Michx.] B.S.P.), prairie junegrass (*Koeleria macrantha* [Ledeb.] J.A. Schultes), rough hairgrass (*Agrostis scabra* Willd.), side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.), sweetgrass (*Hierchloe odorata* [L] Beauv.) and tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.). The entries with high quality ratings over all experiments were 'Bad River' blue grama, Minnesota ecotype blue grama, 'Bismarck' and 'Sharp's Imp. II' buffalograss, inland desert saltgrass, 'Barkoel' prairie junegrass and 'Golfstar' Idaho bentgrass. The warm season grasses, inland desert saltgrass, blue grama and buffalograss were drought tolerant and maintained consistent green colour. Most entries will require a breeding and selection program before being released to the public for low-maintenance turfgrass plantings.

Manuscript 1- Turfgrass Evaluation of Native Grasses

Introduction

There is increasing public pressure for the turfgrass industry to reduce maintenance inputs (Koski, 1999). Traditional grasses like Kentucky bluegrass, perennial ryegrass and tall fescue require significant amounts of water and fertilizer for a lush green, dense stand (Bormann and Balmori, 1993). Although there have been numerous research projects to identify low maintenance turfgrass species, most have focused on these traditional introduced turfgrass species (i.e. species not native to North America) (Aronson et al, 1987; Dernoeden et al, 1994; Fry and Butler, 1989; McKernan and Ross, 1997). Turfgrass breeders have been trying to develop cultivars of these traditional turfgrass species that require less inputs over the last 15 years. During the last 5 years a number of new cultivars of perennial ryegrass, tall fescue and Kentucky bluegrass have been released that will stay green with less nitrogen and watering (NTEP, 1998bcd).

The native grasses of western Canada and the north central USA have not been well researched, but they may provide the ultimate low maintenance or xeriscape turf (Holzworth, 1990; Koski et al, 1999). Native grasses have the advantages of evolving under the environmental extremes of North America and should be perfect candidates for low maintenance turf. There has been very little research into the suitability of North American native or indigenous grasses for turfgrass use. Many native grass species are mentioned for turfgrass use, but most publications refer to non-mown or infrequent mowing situations as opposed to managed turfgrass (Davidson and Gobin, 1998; Jacobson, 1996). There have been many low-maintenance turfgrass trials, but most utilized commercially available introduced turfgrass species such as the *Festuca* spp. (McKeran and Ross, 1997; Dernoeder et al, 1994, 1998). When native grasses have been evaluated, only those grasses with readily available seed supplies were selected for study (e.g. Canada bluegrass [*Poa compress* L.]) (Diesburg et al, 1997; McKeran and Ross, 1997). Many native grasses have never been examined for turf use under intensive mowing heights (Mintenko and Smith, 1998, 1999).

The native grass that has been most extensively investigated for managed turf stands is buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) (NTEP, 1995; Browning et al, 1994; McCarly and Colvin, 1992; Qian et al, 1997). This grass, native to the central and western USA, has been growing in popularity as turf during the last 10 to 20 years. Buffalograss is a true low maintenance turfgrass with its low growth habit, drought tolerance and natural competitiveness (Bowman et al, 1998; Feldhake et al, 1984; Lambert and Colvin, 1992; Wu et al, 1998). Although early buffalograss cultivars required establishment using vegetative plugs or sod, there are now a number of seeded cultivars (NTEP, 1995).

This project further explores the potential of North American native grasses for low maintenance turfgrass conditions that will have acceptable quality and adaptation to the Canadian prairies. It is hoped the success of buffalograss can be duplicated with other native grass species. The goal of this project is to explore native grass species suitable for turfgrass plantings and determine the management regimes under which each species is best adapted.

Materials and Methods

Experiment I (Mowed Evaluation)

This experiment was established in 1996 at the University of Manitoba Plant Science research stations in Winnipeg and Carman, Manitoba, Canada. The Winnipeg trial was planted on a Riverdale clay-loam soil classified as Cumulic Regosol (13% sand, 45% silt and 42% clay) with a pH of 7.6. The Carman trial was planted on an Eigenhof sandy-loam soil classified as Orthic Black (50% sand, 21% silt and 30% clay) with a pH of 7.2. Both locations can be characterised by an extreme range in environmental conditions typical of the Great Plains region of North America (USDA Zone 3)(Table 1). Winter lows of -35 to -40°C are not uncommon and summer highs of 40°C have been recorded. Average annual precipitation is 550mm at Winnipeg and 500mm at Carman, with approximately one third falling as snow. Growing season precipitation is shown in table 1 for 1997, 1998 and the long term average.

The first year (1996) was considered an establishment year, with mowing treatments and data collection starting in 1997. Seed was broadcast at 10g m^{-2} (adjusted for percent live seed) with the following exception, 'Golfstar' Idaho bentgrass (*Agrostis idaoensis*) was seeded at 5g m^{-2} due to its smaller seed size. Trials were established 21 June 1996 in Winnipeg and 3 July 1996 in Carman. Following seeding both trials were covered with Famcomat (fiberglass mat cover manufactured by AAF International, Lousiville, KY, USA) to facilitate germination and to reduce the chance of seed movement between plots during the initial establishment phase. The cover was removed 10 days after seeding. Both trials were irrigated as required to ensure a moist seedbed during the germination and emergence period. Irrigation was applied on a weekly to biweekly basis all summer to alleviate moisture stress and encourage root growth during the establishment year. Irrigation in 1997 was limited, with 25mm of water being applied to the plots if rainfall over a three-week period was less than 25mm. Irrigation was only required two times in 1997, once in late July and once in early August. However, to more closely simulate low-maintenance conditions, no irrigation was applied in 1998.

Native grass species were sourced from across western Canada and the western USA, primarily through contacts in the seed trade and conservation organisations (Table 2). Species such as buffalograss, where adapted northern material is limited, were obtained from the south-central USA. The strategy was to evaluate a wide range of species and geographic origins to determine the best adapted plant material. Thirteen different native grass species were included in the experiment. Several species were represented more than once resulting in a total of 28 entries. The experimental design was a randomised complete block in a split-block arrangement with four replications. Native grass entries were the main plots, 1 by 3m, with mowing treatments splitting each entry into three $1m^2$ subplots.

Native grass entries were subjected to different heights of mowing: 18mm (3/4 inch), 38mm (1 ½ inches) and 62mm (2 ½ inches). These management practices were designed to approximate the heights of cut synonymous with a golf course fairway, a home lawn and a golf course rough, respectively. 'Sharp's' blue grama (*Bouteloua gracilis* [Willd. ex Kunth) Lag. ex Griffiths) was only planted in Winnipeg due to insufficient seed supply. This entry was replaced by hard fescue in Carman after the original planting date, but not included in the results due to poor establishment. Mowing frequency for each treatment was weekly with clippings removed using a rotary mower (John Deere 14 PZ 21-inch walk behind rotary mower). The 18mm mowing height was achieved by the rotary mower at 38mm and a second pass with a wheel driven reel type mower at 18mm (Scotts Silent Hand Push-Reel Mower).

Soil fertility was monitored monthly throughout both growing seasons, with fertiliser application occurring in June, July and August 1997 and 1998. In the establishment year of 1996, one fertiliser application of a water soluble fertiliser (17-17-17) occurred in early August, with total nutrients of 500g N, 500g P, 500g K $100m^{-2}$ $year^{-1}$ applied. In 1997 a water soluble fertiliser (17-17-17) was applied at 250g N, 250g P, 250g K $100m^{-2}$ $year^{-1}$, while in 1998 a slow release fertiliser (32-4-8) was applied for a total of 900g N, 112g P, 225g K $100m^{-2}$ $year^{-1}$. To keep plots separate, glyphosate (isopropylamine salt of N-(phosphono-methyl) glycine) herbicide was dripped between plots in July 1997. Weed control in 1996 consisted of hand weeding only, while in 1997-98 a herbicide mixture of 62% 2,4-D ((2,4-diclorophenoxy) acetic acid), 32% mecoprop (2-(4-chloro-2-methyl phenoxy) propionic acid) and 6% diacamba (3,6-dichloro-0-amisic acid) at 2.5% concentration was applied in early July. Invading grasses, such as bentgrass from nearby seed production fields were hand wicked using glyphosate to eliminate within plot competition.

Monthly visual measurements of turf quality, colour and percent ground cover were recorded on 30 May,1 July, 2 August, 4 September, 2 October 1997; 2 June, 30 June, 4 August, 30 August, 28 September 1998. Quality and colour were measured using the NTEP (National Turfgrass Evaluation Program) visual assessment rating system from 1 to 9. Turf quality ratings were 1=poor turfgrass, and 9=ideal turfgrass; turf colour ratings were 1=brown/ yellow, 5=light green, 7=blue-green, and 9=dark green. Percent visual ground cover range from 0-100 percent. Weekly regrowth after mowing was measured every two weeks along with spring green-up and fall dormancy ratings measured weekly starting 9 May until 5 June 1997 and 4 September until 15 October 1997; 8 April until 26 May 1998, 7 September until 23 October 1998, respectively. Ratings of weed density (4 August 1998), percent winterkill (22 June 1998) and turfgrass texture (7 September 1998) were also measured on an one-time basis.

Data were analysed using a split-spit plot design to determine whether significant differences existed between years, locations, months and mowing heights for each entry. This was examined to determine if pooling of data could be achieved. With as many different species being examined along with differences between locations and differences between each year's climate, pooling of data was occasionally valid but not consistent for every entry. Since there was a significant interaction between years, locations, months and mowing heights consistently for most entries, pooling of data within each source of variation was not possible (Little and Hills, 1978). With these significant interactions an analysis of variance (ANOVA) was conducted on entry means using the statistical analysis system (SAS, 1991) where entries were considered fixed effects and replications considered random effects. Entry means within each mowing height for each month, year and location were compared using Fisher's protected least significant difference procedure.

Experiment II (Non-mowed Evaluation)

This experiment was planted 10 July 1997 and included the same native grass entries as experiment I, except that sheeps fescue (*Festuca ovina* L.) was planted in the place of 'Canon' Canada bluegrass (*Poa compressa* L.) due to seed availability (Table 2). The experimental design was randomised complete block design with 1 by 2m plots and four replicates. Seed was broadcast at 10g m^{-2} (adjusted for percent live seed) with the following exception, 'Golfstar' Idaho bentgrass was seeded at 5g m^{-2} due to its smaller seed size. Following seeding the experiment was covered with Famcomat (a fibreglass turf cover) to facilitate germination and to reduce the chance of seed movement between plots during the initial establishment phase. The cover was removed 10 days after seeding. The experiment was irrigated as required to ensure a moist seedbed during the germination and emergence period. Irrigation was applied on a biweekly basis all summer to alleviate moisture stress and encourage root growth during the establishment year. Soil tests in the establishment year indicated adequate soil nutrient levels required for a lawn.

In the establishment year (1997) measurements included emergence vigour, stand uniformity, turfgrass texture, colour and percent cover using the NTEP visual rating scale described for experiment I. The entire experiment was mowed in early October 1997 and 1998 at 90mm (3 ½ inches) with clippings removed, to achieve uniform height across the experiment to allow uniform snow distribution across the experiment. Past research at this location showed that differential stand height caused snow drifting on certain plots and biased winter survival ratings the following spring.

In 1998, monthly measurements of colour, percent cover and plant height were recorded on 15 April, 7 May, 1 July, 30 June, 4 August. Stand uniformity and turfgrass texture measurements were recorded 1 July 1998. Additional measurements included seedhead presence, disease ratings and lodging problems. Spring green-up was measured weekly from 8 April until 26 May1998 and fall dormancy was measured weekly from 7 September until 23 October 1998. No irrigation or fertiliser was applied during 1998 to simulate low maintenance areas (e.g. roadside, golf rough, utility and pipeline right of ways, etc). On 8 July 1998 when most seed heads had formed and before seed matured, the experiment was mowed down to 90mm (3 ½ inches) with all plant material removed due to the large quantity of plant dry matter present. The experiment was mowed to prevent seed contamination between plots. Additionally, extensive lodging that had occurred within and between plots that would have biased late summer measurements. Weed control in 1997 was limited to hand weeding, while in 1998 a herbicide mixture of 62% 2,4-D, 32% mecoprop and 6% diacamba at 2.5% concentration was spot-sprayed on weeds using a backpack sprayer in late June. Invading bentgrass plants from nearby seed production fields along with plants from adjoining plots were hand wicked with glyphosate in late June of 1997 and 1998 to eliminate within plot competition.

Data were analysed as a randomised complete block keeping months separate for colour and percent ground cover ratings since there was an interaction between months (Little and Hills, 1978). An analysis of variance (ANOVA) was conducted on entry means using the statistical analysis system (SAS, 1991) where entries were considered fixed effects and replications considered random effects. Entry means within each month was compared using Fisher's protected least significant difference procedure.

Experiment III (Vegetatively Propagated Native Grass Evaluation)

During the first week in August 1996 several vegetatively propagated native grasses were planted for turfgrass evaluation. The entries included the warm season species, inland desert saltgrass (*Distichlis stricta* [Torr.] Rydb.) and 'Bismarck' buffalograss and the cool-season species sweetgrass (*Hierchloe odorata* [L] Beauv.). Buffalograss consists of separate male and female plants. The Bismarck buffalograss originated from a composite of two accessions of buffalograss male plants collected by the USDA-NRCS (Bismarck, North Dakota) from central North Dakota (Englert and

White, 1997). The original collection site is one of the northernmost naturally occurring buffalograss stands in the USA. Unfortunately only male buffalograss plants were obtained to form this cultivar, so no seed is available. The sweetgrass entry was from Manitoba and was collected by John Morgan of Prairie Habitats (Argyle, Manitoba, Canada) and the inland desert saltgrass was a collection of plants from across Manitoba and Saskatchewan, collected by the University of Manitoba turf program in the 1980's. Both the inland desert saltgrass and sweetgrass are difficult to establish by seed as very complex conditions are required to break seed dormancy (Cluff, et al, 1983, 1987).

Vegetative propagules were increased in the greenhouse prior to transplanting in the field. Rhizomes (sweetgrass, inland desert saltgrass) or stolons (buffalograss) were transplanted into 10 parallel trenches 30cm apart per plot and covered with 2-4 cm soil. The experiment was irrigated as required to ensure a moist seedbed during the transplant root formation period. Irrigation was applied on a weekly to biweekly basis the remainder of the summer and fall to alleviate moisture stress and encourage continuous root growth during the establishment year.

Experiment III was planted as two trials both in a randomised complete block design with 4 replications and 1 by 3m plots. Trial 1 (Experiment IIIa) was mowed weekly at 62mm (2 ½ inches) (with clippings returned) using a rotary mower. Trial 2 (Experiment IIIb) was not mowed, except in late September of 1997 and 1998 to provide uniform snow cover across all plots as described for experiment II. These plots were mowed down to 90mm (3 ½ inches) with clippings removed. Both trials were rated for turfgrass quality, colour, percent ground cover (as described in Experiment I) and recorded on 1 July, 24 July, 4 September, 30 September 1997; 5 June, 2 July, 4 August, 30 August, 28 September 1998. Spring green-up was measured weekly from 9 May until

5 June 1997; 1 May until 27 May 1998 and fall dormancy measured weekly from 4 September until 5 October 1997; 7 September until 23 October 1998. Maximum height was also measured in trial 2 during 1997 and 1998.

Soil fertility was monitored monthly throughout the growing season, with fertiliser application occurring in June, July and August 1997 and 1998. In 1997 a water soluble fertiliser (17-17-17) of 500g N, 500g P, 500g K $100m^{-2}$ $year^{-1}$ was applied, while in 1998 a slow release fertiliser (32-4-8) was applied with a total of 900g N, 250g P, 500g K $100m^{-2}$ $year^{-1}$. Weed control in 1997 consisted of hand weeding only, while in 1998 a herbicide mixture of 62% 2,4-D, 32% mecoprop and 6% diacamba at 2.5% concentration was spot sprayed in early July on weeds using a backpack sprayer. Since all three species in this trial spread aggressively, plot integrity was maintained with a combination of removal by hand or hand wicking with glyphosate. Invading grasses from adjoining plots were removed once a month from June to August in 1997 and 1998. A spraying of glyphosate in early April 1997 to remove sweetgrass from the semi-dormant buffalograss and inland desert saltgrass plots resulted in limited damage to several plots. The buffalograss plots recovered quickly over the summer, while the inland desert saltgrass did not fully recover until early fall.

Data for each trial (mowed, non-mowed) were analysed as a randomised complete block keeping months and years separate for turfgrass quality, colour and percent ground cover ratings since there was an interaction between and within months and years (little and Hills, 1978). An analysis of variance (ANOVA) was conducted on entry means using the statistical analysis system (SAS, 1991) where entries were considered fixed effects and replications considered random effects. Entry means within each month and year were compared using Fisher's protected least significant difference procedure.

Visual Rating Scales for Quality and Colour in Experiments I, II and III

As mentioned in experiment I material and methods, quality and colour were measured using the NTEP (National Turfgrass Evaluation Program) visual assessment rating system from 1 to 9. The quality rating scale and colour rating scales in order to be accurate and efficient must be well defined. Turf quality ratings start from 1=poor turfgrass (e.g. worn down sports field), 5-6= adequate turfgrass (e.g. boulevard turfgrass) and 9=ideal turfgrass (e.g. perfect Kentucky bluegrass lawn). Visual turfgrass quality ratings involve the factors of turfgrass colour, texture, density and overall environmental stress (plant mortality and disease) of the grass.

The wide range of native grass species being evaluated in these experiments contained every different shade of green, from light to dark green, yellow-green to blue-green. The turf colour ratings in detail consisted of 1=brown / yellow, 2-4 increasing degrees of green colour over brown / yellow, 5=light green, 6= light blue-green, 7=blue-green, 8=dark blue-green and 9= dark green. The colour ratings 8-9 would be typical of a Kentucky bluegrass cultivar or the bentgrass cultivar '18th Green'. While the colour rating of 7 would be typical of buffalograss, blue grama and Canada bluegrass. The colour scale used in these experiments is different from a genetic colour scale that measures the inherent colour of the entry not under stress (NTEP, 1998a). Since all entries were evaluated under stress conditions, the colour scale used for these experiments recorded the actually colour of each entry under the various stresses typical of a low-maintenance turf (e.g. mowing, drought, heat and disease stresses).

Table 1.1. Summary of monthly precipitation at Winnipeg and Carman, Manitoba, Canada locations for 1997, 1998 and average monthly precipitation from 1961-1990.

Location	Year	Monthly Precip.				
		May	June	July	August	Sept
		mm				
Winnipeg†	1961-90	59.8	83.8	72.0	75.3	51.3
Winnipeg‡	1997	36.3	53.1	93.2	73.4	50.5
Winnipeg	1998	118.6	71.2	67.8	15.0	14.2
Carman§	1961-90	52.7	72.8	69.1	65.5	49.0
Carman	1997	24.0	59.0	117.0	67.6	32.6
Carman	1998	38.2	93.8	32.6	45.4	12.0

† Environment Canada data Winnipeg International Airport weather station 1961 to1990, Winnipeg, Manitoba.
‡ Monthly precipitation was calculated from University of Manitoba Plant Science weather stations, Winnipeg, Manitoba.
§ Environment Canada data Carman, Manitoba weather station 1961-1990.

Table 1.2. Long term average monthly temperatures from 1961 to 1990 at Winnipeg, Manitoba international airport weather station.

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
	Temperature											
	Month											
	C°											
High	-13.2	-9.7	-1.8	9.8	18.6	23.4	26.1	24.9	18.6	11.3	-0.0	-9.9
Low	-23.6	-20.6	-12.4	-2.3	4.5	10.4	13.4	11.7	6.1	0.1	-9.2	- 19.4
Mean	-18.3	-15.1	-7.0	3.8	11.6	16.9	19.8	18.3	12.4	5.7	-4.7	-14.6

Table 1.3. Average monthly temperature during the growing season at the Carman and Winnipeg, Manitoba locations for 1997 and 1998.

Location	Year	Monthly Temperature				
		May	June	July	August	Sept
		C°				
Winnipeg†	1997	9.8	20.3	20.8	19.4	15.1
Winnipeg	1998	11.0	16.7	21.0	21.6	15.6
Carman	1997	9.0	18.6	18.9	18.1	14.1
Carman	1998	12.9	15.1	18.6	20.1	14.3

† Monthly temperature was calculated from University of Manitoba Plant Science weather stations at Winnipeg and Carman, Manitoba.

Table 2.0. Native grasses seeded in the turfgrass evaluation experiments in Winnipeg and Carman, Manitoba in 1996-1998.

Entries	Scientific Name	Seed Source	Entry Origin
Cool Season Grasses			
Alpine bluegrass	*Poa alpina*	Prairie Seeds	Southern Alberta
Alkali grass	*Puccinellia nuttaliana*	USDA-NRCS Bridger, MT	Montana
Alpine fescue	*Festuca ovina* var.*brachyphylla*	Prairie Seeds	Central Alberta
'Ruebens' Canada bluegrass	*Poa compressa*	Jacklin Seed	Cultivar- Idaho
Canada bluegrass	*Poa compressa*	Seaborne Seeds	Alberta
'Canon' Canada bluegrass	*Poa compressa*	Seaborne Seeds	Cultivar- Alberta
Canada bluegrass	*Poa compressa*	Prairie Seeds	Central Alberta
Fowl bluegrass	*Poa palustris*	Seaborne Seeds	Alberta
Fowl bluegrass	*Poa palustris*	Prairie Seeds	Central Alberta
'Golfstar' Idaho bentgrass	*Agrostis idahoensis*	Jacklin Seed	Cultivar- Idaho
'Barkoel' prairie junegrass	*Koeleria macrantha*	Barenbrug	Cultivar- N.Europe
Prairie junegrass	*Koeleria macrantha*	Prairie Seeds	Central Alberta
Prairie junegrass	*Koeleria macrantha*	Ducks Unlimited	Minnesota
Prairie junegrass	*Koeleria macrantha*	USDA-NRCS Bridger, MT	Iran
Marsh muhly	*Muhlenbergia racemosa*	USDA-NRCS Bridger, MT	Montana
Rough hairgrass	*Agrostis scabra*	Seaborne Seeds	Alberta
Rough hairgrass	*Agrostis scabra*	Prairie Seeds	Central Alberta
'Nortran' tufted hairgrass	*Deschampsia caespitosa*	Prairie Seeds	Cultivar-Alaska/Iceland
Tufted hairgrass	*Deschampsia caespitosa*	International Seeds	Oregon
Tufted hairgrass	*Deschampsia caespitosa*	Seaborne Seeds	Alberta
'Peace River' rough hairgrass	*Agrostis scabra*	Seaborne Seed	Alberta
Warm Season Grasses			
Entries	**Scientific Name**	**Seed Source**	**Entry Origin**
'Bad River' blue grama	*Bouteloua gracilis*	USDA-NRCS Bismark, N.D.	South Dakota
Blue grama	*Bouteloua gracilis*	Ducks Unlimited	Minnesota
Blue grama	*Bouteloua gracilis*	Sharp Bros. Seed	Kansas
'Sharp□s Imp.II' buffalograss	*Buchloe dactyloide*	Sharp Bros. Seed	Cultivar-Kansas
'Killdeer' side-oats grama	*Bouteloua curtipendula*	USDA-NRCS Bismark,N.D.	Cultivar-North Dakota
'Pierre' side-oats grama	*Bouteloua curtipendula*	USDA-NRCS Bismark,N.D.	Cultivar-South Dakota
'El Reno' side-oats grama	*Bouteloua curtipendula*	Sharp Bros. Seed	Cultivar-Kansa

Results and Discussion

Experiment I (Mowed Evaluation)

There was a significant interaction between years, locations, months and mowing heights for most entries, which prevented pooling of data within each source of variation (Little and Hills, 1978) (Tables 3.0 and 3.1). Comparisons between entry means were within each mowing height for each month, year and location.

The objectives of this experiment were to identify native grass entries are suitable for turfgrass use and to also identify native species that had potential for turfgrass use, but where further selection and breeding would be required (Table 2.0). The native grass entries with "potential" were determined as those that showed moderate to high turfgrass quality (ratings greater than or equal to five) over both years, at all mowing heights and both locations (Table 4.0). From this group of promising entries, five entries had consistently high turfgrass quality ratings over both years (1997 and 1998), mowing heights (62mm, 38mm, 18mm) and both locations (Carman and Winnipeg) (Table 4.1). Entries with high turfgrass quality included: 'Bad River' blue grama (USDA-NRCS) (Figure 2.0), blue grama from Minnesota (Ducks Unlimited), 'Sharp's Imp.II' buffalograss (*Buchloe dactyloide*) (Figure 3.0), 'Golfstar' Idaho bentgrass and 'Barkoel' prairie junegrass (*Koeleria gracilis*). Entries with high turfgrass quality ratings showed high percentage ground cover (Table 4.8 and 4.9), limited disease or pest problems, high adaptability to mowing stress, consistent green colour (Tables 4.4, 4.5 and 4.6) and fine leaf texture (Table 4.9.1).

The high quality ratings of Barkoel prairie junegrass, Golfstar Idaho bentgrass and Sharp's Imp.II Buffalograss should be expected as each have undergone turfgrass breeding and selection programs and have been released for use as turfgrass cultivars (Brede, 1999; NTEP, 1995). The blue grama entries however have not undergone such programs but their high quality ratings indicate the tremendous potential this species has as a turfgrass. The blue grama entries are essentially ecotypes and have only been selected for seed yield or plant vigour.

Although quality ratings across each mowing height were similar, entries were analyzed separately at each mowing height and since there was an entry x mowing height interaction. The highest quality rating for blue grama and buffalograss entries on a relative scale was at the 62mm mowing height, nevertheless, these entries had high quality at all mowing heights. Early fall dormancy reduced quality of these warm season grasses over all mowing heights in September of both years (Figure 4.0). The highest relative quality ratings for Idaho bentgrass occurred at the 62mm mowing height in June and July 1997 and 1998. However, in the drought periods of August and September 1998 quality over all mowing heights decreased. The prairie junegrass turfgrass cultivar Barkoel consistently had high quality ratings all season and over all heights in 1997 and most months in 1998. In the drought period of August 1998 quality over all mowing heights decreased slightly but recovered by the September 1998 measurement date.

Other promising entries with consistently moderate turfgrass quality ratings included: fowl bluegrass (*Poa palustris* L.) from Alberta (Seaborne Seeds), prairie junegrass from Iran (USDA-NRCS), rough hairgrass (*Agrostis scabra* Willd.) from Alberta (Seaborne Seeds), 'Nortran' tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.) and tufted hairgrass from Alberta (Seaborne Seeds). All these cool-season grass entries had relatively higher quality ratings at the 62mm mowing height (Table 4.2). In the cooler and higher moisture conditions of June these entries performed quite well. Quality decreased throughout July and August as temperatures increased and precipitation decreased. Both tufted hairgrass entries in this grouping experienced substantial rust infestations beginning in July for both years reducing quality and colour. The tufted hairgrass entries showed excellent density, texture and adaptation to mowing stress and would have received much higher quality ratings in the absence of rust.

The last group of entries were those that received low turfgrass quality ratings (ratings less than five) over both years (1997 and 1998), mowing heights and both locations. Table 6.3 presents the results for these low quality entries at the 62mm mowing height only since most of these entries showed relatively higher quality ratings at this height. Low quality ratings generally resulted from one of the following or a combination of: low plot density, brown turfgrass colour, disease problems, or poor recovery from mowing stress. The Kansas blue grama entry had very high quality ratings in 1997, comparable to the other blue grama entries, but high levels of winterkill over the winter of 1997/1998 resulted in much lower quality ratings in 1998. The side-oats grama entries had excellent drought tolerance and colour (Table 4.4, 4.5 and 4.6), typical of warm-season grasses, but the low percent ground cover scores for these entries negatively impacted on quality (Table 4.7 and 4.8).

The Carman location generally had higher quality ratings for all entries compared to Winnipeg, however the top, moderate and low quality entry groupings remained unchanged. The Carman soil conditions are more representative of short grass and mixed grass prairie soils where most of these native grasses originated. The heavy clay soils of the Winnipeg location are more representative of river bottom/ flood plain conditions originally dominated by tall grass species (i.e. tall grass prairie).

Tables 4.4, 4.5 and 4.6, illustrates the great variation in colour among all the entries. The higher quality entries displayed good colour at all heights (Figure 5.0). Entries which did not tolerate mowing stress exhibited a more brown colour as a result of very slow regrowth of grass blades or most leaf material having been removed under the intensive mowing heights (e.g. Canada bluegrass entries). Another indication of poor tolerance to mowing stress was the decreasing percent ground cover for many entries as the season progressed (Table 4.7 and 4.8). Marsh muhly provides very good example with relatively high ground cover scores at all mowing heights in June 1997 and very low values by August 1998. Entries that sustained winterkill also had lower ground cover scores in 1998 compared to 1997. Rust infestations also impacts on colour, as seen with the lower colour ratings for the tufted hairgrasses with their increasingly brown appearance from July onward.

Many of the entries that showed substantial winterkill (Table 4.9.2) originated more than 500km south of our planting locations. These included the blue grama and buffalograss entries from Kansas where winterkill exceeded forty percent. Other entries suffered winterkill from a combination of disease or poor tolerance to mowing stress. Either condition likely reduced the total amount of root and crown reserves necessary to prevent winter damage.

Measurements of regrowth after mowing allowed us to compare the influence of precipitation and soil moisture on cool and warm-season grasses. Both groups showed decreasing regrowth with decreasing precipitation amounts, especially at the Carman, MB location in 1998. There was a highly negative correlation between decreasing precipitation and regrowth in cool-season grasses but less so with the warm-season grasses (Figures 1.1, 1.2, 1.3). Decreasing daylength and the onset of fall dormancy were other factors that played a role in reducing the regrowth of the warm-season grasses. The top entries showed little correlation between precipitation and regrowth, while low quality entries were affected more by decreasing precipitation, which resulted in slower regrowth and recovery from mowing stress. The many factors that affect the regrowth of each native grass entry deserve future study.

Disease/Pest Problems Limited

Most entries had no disease or insect pest problems. This may be expected with native grasses that have evolved under the stresses of the Great Plains region. Snow mold, a common disease problem in Manitoba, was generally absent with the exception of Golfstar Idaho bentgrass. Minor rust infestations occurred on the junegrasses, along with a major rust infection of the tufted hairgrass entries. This reduced the turfgrass quality of the tufted hairgrass entries from excellent under cool spring temperatures, to poor during the warm, humid summer conditions typical of a Manitoba summer.

Summary

The results of this experiment indicted that several native grass species are suitable for low-maintenance turfgrass use. Three of the five high quality entries were cultivars released for turfgrass use (Sharp's Imp.II buffalograss, Golfstar Idaho bentgrass and Barkoel prairie junegrass), shows that intensive turfgrass selection programs can be very successful. However, it is recommended that only winter hardy northern varieties of buffalograss are used for turf in this region (e.g. Bismarck buffalograss from North Dakota, see experiment II). The blue gramas and most of the moderate quality entries from this experiment are collections from remnant native stands with very little or no selection for turfgrass use. These entries are possible candidates for future turfgrass breeding and selection programs. The high turfgrass quality ratings of many of the blue grama entries suggest that native harvested seed may be suitable for some turfgrass plantings (i.e. golf course roughs). Before widespread public use of native grasses becomes a reality, more turfgrass research needs to be conducted. As a result of this experiment, the University of Manitoba Plant Science department turfgrass program, under the direction of Dr. S.R. Smith, has initiated a turfgrass breeding and selection program for blue grama.

Choosing the proper native grass for a successful low-maintenance lawn ultimately depends on whether a particular native grass species actually exists within the region. Using a grass species that is native to the region and therefore naturally adapted to the existing climatic and soil conditions will result in a competitive turf stand. Ignoring a region's particular climatic and soil conditions will increase the requirement for external inputs to maintain turfgrass quality (Bormann and Balmori, 1993). This negates the reason for selecting native grasses in the first place, which was to reduce lawn inputs.

Summary of Top Entries

Bad River blue grama and Minnesota blue grama

These entries showed excellent drought tolerance, good winter hardiness, colour, density and adapted very well to mowing stress. Limitations included late spring green-up and early fall dormancy typical of all warm season grasses. Most of the warm season grasses in 1997 and 1998 had complete green-up by mid-May to early June and fall dormancy began mid-September with complete dormancy by early October. These two entries showed high turfgrass quality without previous turfgrass selection or breeding research, indicating the great potential of this species as a low-maintenance turfgrass.

Sharp's Imp.II buffalograss

Well known as a successful turfgrass cultivar in the central USA, this aggressive stoloniferous grass showed excellent drought tolerance, colour, density and adapted very well to mowing stress as would be expected of a turfgrass cultivar. Similar spring and fall dormancy was observed for this entry as for blue grama. This entry originated from Kansas and poor winter hardiness was a major limitation. This was expected since most native grasses, especially warm season grasses are less winter hardy when moved more than 450 km north of their origin. However, as a result of the aggressive spreading nature of buffalograss, surviving plants had recolonized most winterkilled spots within plots over the summer. For comparison, a blue grama entry also from Kansas suffered similar winterkill problems, but showed little recovery in 1998.

Golfstar Idaho bentgrass

Golfstar Idaho bentgrass had excellent colour, density and responded well to low mowing heights, but showed low drought tolerance. This entry was damaged by snow mold, especially at the Winnipeg location, where snow mold inoculum likely spread from adjacent turfgrass research areas and invading bentgrass plants. There was less snow mold at the Carman location since the experimental station and surrounding area had been planted to agricultural crops for many years.

Barkoel prairie junegrass

Barkoel prairie junegrass originated from plants collected in northern Europe. The success of Barkoel indicates the potential of the North American junegrasses for turfgrass use. It showed excellent colour and density with moderate drought tolerance. Spring green-up was not as early as the North American junegrasses and the leaves were subject to shredding after mowing. Disease problems were low, except for a mild rust infestation during hot and humid periods in 1997 and 1998.

Table 3.0. Analysis of variance of turfgrass quality over all heights and months for native grasses evaluated in Winnipeg and Carman, Manitoba in 1997 and 1998.

Source of Variation	df	Mean square
REP	3	3.11 NS
ENTRY	26	223.92 ****
REP X ENTRY (error a)	78	3.07 ****
YEAR	1	14.06 ****
ENTRY X YEAR	26	12.78 ****
REP X YEAR(ENTRY) (error b)	81	1.12 NS
LOCATION	1	113.77 ****
ENTRY X LOCATION	26	14.46 ****
YEAR X LOCATION	1	26.69 ****
ENTRY X YEAR X LOCATION (error c)	6	5.73 ****

**** Significant at the 0.0001 probability level.

Table 3.1. Analysis of variance for native grass turfgrass quality over three mowing heights (62mm, 38mm, 18mm) and four months (June, July, August, September) at the Winnipeg location in 1998†.

Source of Variation	df	Mean square
REP	3	7.94 *
ENTRY	27	67.33 ****
REP X ENTRY (error a)	81	2.45 ****
HEIGHT	2	14.08 ****
ENTRY X HEIGHT	54	0.97 ****
REP X HEIGHT(ENTRY) (error b)	168	0.15 NS
MONTH	3	13.46 ****
ENTRY X MONTH	81	6.04 ****
HEIGHT X MONTH	6	0.26 NS
ENTRY X HEIGHT X MONTH (error c)	162	0.13 NS

*, **, ***, **** Significant at the 0.05, 0.01, 0.001and 0.0001 probability levels.

† Analysis of variance for Carman, Manitoba location follows same pattern as the Winnipeg, Manitoba location.

Table 4.0. Turfgrass quality ratings for the native grass evaluation study at the 62mm mowing regime at Winnipeg and Carman, MB in 1997 and 1998.

Entry	1997Mean	1998 Mean	Overall Mean	Rank
	------ 1-9 scale† ------			
Barkoel Junegrass	6.84‡	6.84	6.84	1
Bad River Blue grama	6.22	6.22	6.22	2
Blue grama, MN	6.19	6.19	6.19	3
Sharp's Imp.II Buffalograss	5.59	5.59	5.59	4
Golfstar Idaho bentgrass	5.44	5.44	5.44	5
Tufted hairgrass, AB	5.59	4.59	5.09	6
Nortran Tufted hairgrass	5.47	4.41	4.94	7
Prairie Junegrass, Iran	4.75	4.94	4.85	8
Fowl bluegrass, AB	4.53	4.81	4.67	9
Rough hairgrass, AB	4.56	4.47	4.52	10
Alpine bluegrass	4.53	4.31	4.42	11
Killdeer Side-oats grama	4.28	4.41	4.35	12
El Reno Side-oats grama	4.34	4.16	4.25	13
Tufted hairgrass, OR	4.72	3.63	4.18	14
Pierre Side-oats grama	4.13	4.09	4.11	15
Blue grama, KS§	5.06	2.94	4.00	16
Prairie Junegrass, C.AB	3.88	3.81	3.85	17
Marsh muhly	4.06	3.41	3.74	18
Peace River Rough hairgrass	3.72	3.66	3.69	19
Prairie Junegrass, MN	3.88	3.50	3.69	19
Rough hairgrass, C.AB	3.84	3.06	3.45	21
Canada bluegrass, S.AB	3.25	3.31	3.28	22
Ruebens Canada bluegrass	3.25	3.28	3.27	23
Canada bluegrass, AB	3.03	3.38	3.21	24
Alpine fescue	3.00	3.38	3.19	25
Canon Canada bluegrass	3.09	3.28	3.19	25
Fowl bluegrass, C.AB	2.91	2.97	2.94	27
Alkali grass	2.94	2.69	2.82	28

† Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass).
‡ Abbreviations :MN=Minnesota KS=Kansas C.AB=Central Alberta AB=Alberta OR=Oregon
§ Kansas blue grama not planted at Carman, Manitoba location, only Winnipeg location mean presented.

Table 4.1. Native grass entries with top turfgrass quality ratings at three mowing regimes for 1997 and 1998 at Winnipeg and Carman, Manitoba.

Entry and Mowing Height	June		July		August		September		Overall
	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR	Mean
	1-9 Scale†								
62 mm					**1997**				
Bad River blue grama‡	8.00	7.00	5.00	7.00	5.50	5.50	4.00	4.00	5.75
Blue grama, MN	6.50	7.00	4.75	6.75	5.25	5.50	3.50	3.75	5.38
Sharp's Imp.II buffalograss	6.25	6.00	4.75	6.25	6.50	5.00	4.50	4.00	5.41
Golfstar Idaho bentgrass	6.50	8.00	6.00	8.00	7.50	7.50	6.75	7.00	7.16
Barkoel prairie junegrass	7.25	7.00	7.75	6.00	7.50	7.50	6.25	7.25	7.06
LSD§	1.15	0.85	0.76	0.87	0.92	1.22	0.75	0.97	
					1998				
Bad River blue grama	6.50	6.25	6.25	8.00	6.75	7.00	4.75	4.25	6.22
Blue grama, MN	6.75	6.75	6.75	8.00	6.75	7.75	3.00	3.75	6.19
Sharp's Imp.II buffalograss	4.75	5.75	5.50	7.50	6.50	6.50	4.25	4.00	5.59
Golfstar Idaho bentgrass	6.50	7.25	5.25	8.00	4.00	4.50	4.00	4.00	5.44
Barkoel prairie junegrass	7.00	7.00	7.00	7.75	7.50	5.25	7.00	6.25	6.84
LSD	1.09	0.88	0.96	0.81	0.79	0.86	0.86	0.58	
38 mm					**1997**				
Bad River blue grama	7.00	6.25	4.75	6.00	5.75	5.50	4.00	3.75	5.38
Blue grama, MN	6.25	5.00	4.50	5.25	5.75	4.25	3.50	3.50	4.75
Sharp's Imp.II buffalograss	6.00	6.00	4.50	6.25	5.00	4.75	4.50	4.00	5.13
Golfstar Idaho bentgrass	5.25	5.00	4.75	8.00	7.50	7.50	7.75	7.50	6.66
Barkoel prairie junegrass	6.75	5.00	7.75	5.50	7.50	7.25	7.00	6.75	6.69
LSD	1.22	1.22	0.77	0.98	0.72	1.04	0.75	0.86	
					1998				
Bad River blue grama	5.50	5.50	6.25	7.00	6.75	7.00	4.75	4.00	5.84
Blue grama, MN	6.50	5.50	6.75	7.25	6.75	6.25	3.00	3.00	5.63
Sharp's Imp.II buffalograss	4.50	4.75	5.25	7.00	5.75	7.00	4.25	3.00	5.19
Golfstar Idaho bentgrass	5.50	6.25	5.50	7.00	3.75	4.00	4.00	4.00	5.00
Barkoel prairie junegrass	6.75	6.25	7.50	7.50	7.50	5.25	7.00	6.50	6.78
LSD	1.09	0.88	0.96	0.81	0.79	0.86	0.86	0.58	
18 mm					**1997**				
Bad River blue grama	7.25	6.50	4.75	4.25	5.75	5.75	4.00	3.75	5.25
Blue grama, MN	6.25	5.75	4.50	5.75	5.25	4.75	3.50	3.75	4.94
Sharp's Imp.II buffalograss	5.75	4.50	4.50	5.00	5.00	4.75	4.50	4.25	4.78
Golfstar Idaho bentgrass	4.75	4.50	4.25	8.00	7.00	8.25	8.00	8.00	6.59
Barkoel prairie junegrass	6.25	4.25	7.50	5.50	7.25	7.50	7.00	7.25	6.56
LSD	0.85	1.15	0.77	1.55	0.86	1.05	0.65	0.79	
					1998				
Bad River blue grama	5.50	5.75	6.25	7.25	6.75	7.00	4.75	4.00	5.91
Blue grama, MN	6.25	6.25	6.75	7.25	6.25	6.25	3.00	3.00	5.63
Sharp's Imp.II buffalograss	4.25	4.75	5.00	7.00	5.75	6.50	4.25	3.75	5.16
Golfstar Idaho bentgrass	5.75	7.25	5.25	7.50	3.75	4.00	4.00	4.25	5.22
Barkoel prairie junegrass	6.75	6.75	7.75	6.50	7.25	5.00	7.00	6.75	6.72
LSD	0.97	0.95	0.98	1.02	0.78	0.88	0.84	0.69	

† Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass).
‡ Abbreviations :MN=Minnesota KS=Kansas C.AB=Central Alberta AB=Alberta OR=Oregon
§ Means within a column may be compared within each year, month and mowing height and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.2. Native grass entries with moderate turfgrass quality ratings three mowing regimes in 1997 and 1998 at Winnipeg and Carman, Manitoba.

Entry and Mowing Height	Month and Location								
	June		July		August		September		Overall
	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR	Mean
	1-9 Scale†								
62 mm					**1997**				
Fowl bluegrass, AB‡	5.00	5.00	4.00	4.25	4.25	4.75	4.75	4.25	4.53
Prairie junegrass, Iran	4.75	5.75	4.25	3.25	5.00	5.00	5.00	5.00	4.75
Rough hairgrass, AB	5.00	6.25	3.50	4.25	4.75	4.00	4.75	4.00	4.56
Nortran tufted hairgrass	7.75	8.00	5.00	5.00	4.75	4.75	4.5	4.00	5.47
Tufted hairgrass, AB	7.00	7.25	5.00	5.25	5.75	5.25	5.00	4.25	5.59
LSD§	1.02	1.15	0.76	0.87	0.92	1.22	0.75	0.97	
					1998				
Fowl bluegrass, AB	5.00	5.25	5.00	4.75	4.00	5.00	4.75	4.75	4.81
Prairie junegrass, Iran	5.50	7.00	5.25	3.50	3.75	5.25	4.25	5.00	4.94
Rough hairgrass, AB	5.50	5.25	5.00	4.25	3.75	4.25	4.00	3.75	4.47
Nortran tufted hairgrass	5.50	4.25	4.75	4.00	4.00	4.25	4.50	4.00	4.41
Tufted hairgrass, AB	5.25	5.00	5.00	4.00	4.00	4.25	5.00	4.25	4.59
LSD	0.96	0.88	0.85	0.73	0.73	0.78	0.64	0.68	
38mm					**1997**				
Fowl bluegrass, AB	3.75	4.25	4.00	3.75	4.25	4.50	4.75	4.25	4.19
Prairie junegrass, Iran	4.00	4.00	4.00	3.50	4.5	4.00	5.00	4.25	4.16
Rough hairgrass, AB	3.50	6.00	3.50	5.25	5.00	4.50	4.75	4.25	4.59
Nortran tufted hairgrass	5.50	5.25	4.50	4.50	4.75	4.25	4.75	4.00	4.69
Tufted hairgrass, AB	4.25	4.50	4.50	4.25	5.00	5.00	5.00	4.25	4.59
LSD	1.14	1.22	0.77	0.98	0.72	1.04	0.75	0.86	0.94
					1998				
Fowl bluegrass, AB	4.50	4.75	4.50	4.50	4.00	4.25	4.75	4.75	4.50
Prairie junegrass, Iran	5.25	6.25	5.25	3.25	3.75	4.50	4.00	4.25	4.56
Rough hairgrass, AB	5.25	5	5.00	4.25	3.75	4.25	4.00	3.75	4.41
Nortran tufted hairgrass	5.25	4.5	4.75	4.00	4.00	4.25	4.50	4.00	4.41
Tufted hairgrass, AB	4.75	5.25	4.75	4.00	4.00	4.25	5.00	4.25	4.53
LSD	1.09	0.88	0.96	0.81	0.79	0.86	0.86	0.58	
18mm					**1997**				
Fowl bluegrass, AB	3.25	4.25	3.75	3.75	4.00	4.75	4.50	4.25	4.06
Prairie junegrass, Iran	3.75	4.00	4.00	2.50	4.25	4.25	5.00	4.75	4.06
Rough hairgrass, AB	3.5	4.50	3.25	5.00	4.50	4.75	4.75	4.00	4.28
Nortran tufted hairgrass	4.75	4.25	4.50	5.25	4.75	5.25	4.75	4.50	4.75
Tufted hairgrass, AB	4.00	4.00	4.75	3.50	5.00	5.00	5.00	4.25	4.44
LSD	1.02	0.85	0.77	1.55	0.86	1.05	0.65	0.79	
				1998					
Fowl bluegrass, AB	4.75	5.00	4.50	4.75	4.00	4.50	4.75	5.00	4.66
Prairie junegrass, Iran	4.75	6.75	5.25	3.00	3.75	4.75	3.75	4.75	4.59
Rough hairgrass, AB	5.25	5.00	5.00	4.25	3.75	4.00	4.00	3.75	4.38
Nortran tufted hairgrass	5.00	5.00	4.75	4.00	4.00	4.25	5.00	4.25	4.53
Tufted hairgrass, AB	5.00	5.00	4.75	4.00	4.00	4.25	5.00	4.25	4.53
LSD	0.97	0.95	0.98	1.02	0.78	0.88	0.84	0.69	

†Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass). ‡Abbreviations :MN=Minnesota ; KS=Kansas; C.AB=Central Alberta; AB=Alberta; OR=Oregon. §Means within a column may be compared within each year, month and mowing height and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.3. Native grass entries with low turfgrass quality ratings at the 62mm mowing regime in 1997 and 1998 at Winnipeg and Carman, Manitoba.

	Month and Location								
	June		July		August		September		Overall
Entry	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR	Mean
	1-9 Scale								
					1997				
Alpine bluegrass‡	4.25	5.75	3.50	4.00	4.25	5.00	4.75	4.75	4.53
Alpine fescue	1.75	4.50	1.50	3.25	2.25	3.75	3.00	4.00	3.00
Alkali grass	3.00	3.00	2.50	2.25	3.25	2.75	2.75	4.00	2.94
Blue grama, KS§	5.50	.	4.25	.	5.50	.	5.00	.	5.06
Canon Canada bluegrass	1.00	3.50	1.00	2.75	4.00	3.75	4.00	4.75	3.09
Canada bluegrass, S.AB	1.00	4.25	1.00	3.00	3.50	4.50	3.50	5.25	3.25
Ruebens Canada bluegrass	1.00	4.75	1.00	3.00	3.00	4.25	4.00	5.00	3.25
Canada bluegrass, AB	1.00	4.00	1.00	2.50	3.00	4.50	3.75	4.50	3.03
Fowl bluegrass, C.AB	1.00	5.00	1.00	2.75	2.50	3.75	3.50	3.75	2.91
Marsh muhly	4.75	5.75	3.50	4.25	4.00	4.00	3.00	3.25	4.06
Prairie junegrass, MN	4.50	4.50	3.00	3.50	4.00	4.00	4.00	3.50	3.88
Prairie junegrass, C.AB	4.75	4.00	3.75	2.75	4.25	4.00	4.25	3.25	3.88
Peace River rough hairgrass	1.75	4.00	3.50	4.50	4.00	5.00	3.00	4.00	3.72
Rough hairgrass, C.AB	2.25	3.75	3.25	4.25	4.50	4.50	4.00	4.25	3.84
El Reno side-oats grama	4.00	4.75	4.25	4.75	4.50	4.50	4.00	4.00	4.34
Killdeer side-oats grama	4.75	5.00	4.50	5.25	4.25	4.50	2.75	3.25	4.28
Pierre side-oats grama	4.50	4.75	4.00	4.75	4.25	4.25	3.00	3.50	4.13
Tufted hairgrass, OR	3.50	4.75	4.00	4.25	5.00	5.50	5.25	5.50	4.72
LSD¶	1.02	1.15	0.76	0.87	0.92	1.22	0.75	0.97	
					1998				
Alpine bluegrass	4.75	5.00	4.00	4.00	3.75	4.75	4.00	4.25	4.31
Alpine fescue	3.25	4.00	3.00	4.00	3.00	3.50	3.25	3.00	3.38
Alkali grass	3.00	3.25	2.25	3.00	2.50	2.75	1.75	3.00	2.69
Blue grama, KS	1.75	-	2.50	-	4.00	-	3.50	-	2.94
Canon Canada bluegrass	4.25	3.50	2.00	3.00	3.00	3.00	3.50	4.00	3.28
Canada bluegrass, S.AB	4.00	3.75	2.00	3.00	3.00	3.00	3.75	4.00	3.31
Ruebens Canada bluegrass	3.50	3.75	2.25	3.00	3.00	3.00	3.75	4.00	3.28
Canada bluegrass, AB	3.75	4.00	2.00	3.00	3.25	3.00	4.00	4.00	3.38
Fowl bluegrass, C.AB	3.00	3.75	2.25	3.25	2.50	3.25	3.00	2.75	2.97
Marsh muhly	3.50	3.25	4.00	4.00	3.50	3.25	2.75	3.00	3.41
Prairie junegrass, MN	4.00	3.75	4.00	3.00	3.00	3.75	3.50	3.00	3.50
Prairie junegrass, C.AB	4.50	4.50	4.25	3.25	3.25	3.50	3.75	3.50	3.81
Peace River rough hairgrass	3.75	3.75	4.25	4.00	3.00	3.50	3.75	3.25	3.66
Rough hairgrass, C.AB	3.25	3.00	4.00	3.00	2.75	2.50	3.25	2.75	3.06
El Reno side-oats grama	3.75	3.75	4.25	5.25	4.50	4.75	3.25	3.75	4.16
Killdeer side-oats grama	5.00	4.50	5.00	5.75	4.75	4.75	2.50	3.00	4.41
Pierre side-oats grama	4.00	4.00	4.50	4.75	4.75	4.25	3.50	3.00	4.09
Tufted hairgrass, OR	2.25	3.75	3.50	4.00	3.75	3.75	4.00	4.00	3.63
LSD	0.96	0.88	0.85	0.73	0.73	0.78	0.64	0.68	

† Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass).

‡ Abbreviations :MN=Minnesota KS=Kansas C.AB=Central Alberta AB=Alberta OR=Oregon § Kansas blue grama not planted at Carman, Manitoba location.

¶ Means within a column may be compared within each year and month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column L

Table 4.4. Visual colour ratings for the native grass evaluation study at the 62mm mowing regime in 1998 at Winnipeg and Carman, Manitoba.

		Month and Location							
	Seed	June		July		August		September	
Entry	Source	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR
		1-9 Scale†							
Alpine bluegrass	C.AB‡	5.00	6.50	7.00	4.00	4.00	7.00	5.00	5.00
Alpine fescue	C.AB	4.00	4.00	6.00	4.00	3.75	4.00	4.00	3.50
Alkali grass	MT	5.50	7.00	3.75	4.00	4.00	4.75	4.00	4.00
Bad River blue grama	SD	6.75	7.50	7.00	7.00	7.00	7.00	3.75	4.00
Blue grama	MN	6.00	7.25	7.00	7.00	6.75	7.00	2.00	2.50
Blue grama§	KS	3.25	-	6.75	-	7.00	-	5.00	-
Sharp's Imp.II buffalograss	KS	6.75	7.00	7.00	7.00	6.25	7.00	4.25	4.25
Canon Canada bluegrass	Cv-AB	4.00	4.00	2.00	2.50	3.00	3.00	4.75	4.00
Canada bluegrass	C.AB	4.00	4.75	2.00	2.75	3.00	3.00	4.00	4.00
Ruebens Canada bluegrass	Cv-AB	4.75	5.50	2.00	3.00	3.00	3.25	4.00	4.00
Canada bluegrass	AB	4.00	4.00	2.50	3.00	3.00	3.00	4.75	4.00
Fowl bluegrass	C.AB	4.00	4.50	2.50	3.00	3.00	3.25	4.00	3.50
Fowl bluegrass	AB	7.00	6.50	4.00	5.25	4.00	5.25	7.00	5.00
Golfstar Idaho bentgrass	Cv-ID	9.00	9.00	9.00	9.00	4.00	5.25	4.00	3.75
Marsh muhly	MN	6.25	6.25	6.75	6.50	6.00	6.50	3.75	4.75
Barkoel prairie junegrass	Cv-N.E	8.00	8.00	8.00	8.00	6.50	4.00	8.00	8.00
Prairie junegrass	MN	7.00	7.00	6.25	4.50	4.00	6.25	6.25	4.00
Prairie junegrass	Iran	7.00	7.00	6.25	3.00	4.75	7.00	6.00	6.25
Prairie junegrass	C.AB	7.00	7.00	7.00	3.75	3.75	6.25	6.50	4.75
Peace River rough hairgrass	Cv-AB	6.25	7.50	6.50	5.00	3.75	4.75	6.00	3.50
Rough hairgrass	C.AB	5.50	5.50	7.00	4.00	4.00	4.25	4.75	3.50
Rough hairgrass	AB	5.50	6.25	7.00	5.50	4.50	5.00	3.75	4.00
El Reno side-oats grama	Cv-KS	6.75	6.75	7.00	6.50	6.75	7.00	3.25	4.00
Killdeer side-oats grama	Cv-ND	6.75	6.50	7.00	6.75	7.00	7.00	2.00	2.50
Pierre side-oats grama	Cv-ND	6.75	6.75	7.00	6.50	7.00	7.00	2.75	3.25
Tufted hairgrass	OR	3.50	4.50	5.00	4.00	4.00	4.25	4.00	3.50
Nortran Tufted hairgrass	Cv-A Ic	8.00	6.00	3.75	3.75	4.00	4.00	4.00	3.75
Tufted hairgrass	AB	7.50	4.75	4.00	4.00	4.00	5.00	4.25	4.00
	LSD¶	1.47	1.15	1.10	0.99	0.84	1.52	1.16	0.93

†Colour Rating Scale: 1-9 (9=dark green, 7=blue green, 5=light green, 1=brown). ‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. § Kansas blue grama not planted at Carman, Manitoba location.¶Means within a column may be compared within each year and month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.5. Visual colour ratings for the native grass evaluation study at the 38mm mowing regime in 1998 at Winnipeg and Carman, Manitoba.

		Month and Location							
	Seed	June		July		August		September	
Entry	Source	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR
		1-9 Scale†							
Alpine bluegrass	C.AB‡	5.00	6.50	7.00	4.00	4.00	7.00	5.00	5.00
Alpine fescue	C.AB	3.00	4.00	4.00	4.00	3.75	4.00	4.00	3.50
Alkali grass	MT	4.00	5.50	3.75	3.75	3.75	4.00	4.75	4.00
Bad River blue grama	SD	6.75	7.50	7.00	7.00	7.00	7.00	3.75	4.00
Blue grama	MN	6.00	7.25	7.00	7.00	6.75	7.00	2.00	2.25
Blue grama§	KS	2.50	-	6.75	-	7.00	-	5.00	-
Sharp's Imp.II buffalograss	KS	6.00	7.00	7.00	7.00	6.25	7.00	4.25	4.25
Canon Canada bluegrass	Cv-AB	4.00	5.50	2.00	2.50	3.00	3.00	5.50	4.00
Canada bluegrass	S.AB	4.00	5.50	2.00	2.75	3.00	3.00	4.00	4.00
Ruebens Canada bluegrass	Cv-AB	4.00	6.25	2.00	3.75	3.00	3.25	4.00	4.00
Canada bluegrass	AB	4.00	4.00	2.00	3.00	3.00	3.00	4.75	4.00
Fowl bluegrass	C.AB	4.00	5.50	2.75	3.00	3.00	3.25	4.00	3.50
Fowl bluegrass	AB	4.50	6.50	4.00	5.50	4.00	5.25	7.00	5.00
Golfstar Idaho bentgrass	Cv-ID	7.75	9.00	9.00	7.00	4.00	4.00	4.00	3.75
Marsh muhly	MN	3.25	4.50	5.50	6.25	4.00	4.75	3.25	3.50
Barkoel prairie junegrass	Cv-N.E	6.50	8.00	8.00	8.00	6.25	4.00	8.00	8.00
Prairie junegrass	MN	7.00	7.00	5.50	4.50	4.00	6.25	6.25	4.00
Prairie junegrass	Iran	7.00	7.00	6.25	3.00	4.75	7.00	6.00	6.25
Prairie junegrass	S.AB	7.00	7.00	7.00	3.75	3.75	5.50	6.50	4.75
Peace River rough hairgrass	Cv-AB	6.75	7.50	6.50	5.00	3.75	5.50	6.00	3.50
Rough hairgrass	C.AB	4.00	5.50	7.00	4.00	3.75	4.25	4.75	3.50
Rough hairgrass	AB	5.50	6.25	7.00	5.50	4.50	5.00	4.50	4.00
El Reno side-oats grama	Cv-KS	4.75	6.25	7.00	6.50	7.00	7.00	3.50	4.00
Killdeer side-oats grama	Cv-ND	6.75	6.75	7.00	6.75	7.00	7.00	2.00	2.50
Pierre side-oats grama	Cv-ND	5.50	5.50	7.00	6.50	7.00	7.00	2.75	3.25
Tufted hairgrass	OR	3.00	4.75	5.00	4.00	4.00	4.25	4.00	3.50
Nortran Tufted hairgrass	Cv-A Ic	7.00	6.00	3.75	3.75	4.00	4.00	4.00	3.75
Tufted hairgrass	AB	5.00	4.50	4.00	4.00	4.00	5.00	4.25	4.00
	LSD¶	1.52	1.51	1.11	1.22	0.88	1.35	1.32	0.93

†Colour Rating Scale: 1-9 (9=dark green, 7=blue green, 5=light green, 1=brown). ‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. § Kansas blue grama not planted at Carman, Manitoba location.¶Means within a column may be compared within each year and month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.6. Visual colour ratings for the native grass evaluation study at the 18mm mowing regime in 1998 at Winnipeg and Carman, Manitoba.

		Month and Location							
	Seed	June		July		August		September	
Entry	Source	WPG	CAR	WPG	CAR	WPG	CAR	WPG	CAR
		1-9 Scale†							
Alpine bluegrass	C.AB‡	5.00	6.50	7.00	4.00	4.00	7.00	5.00	5.00
Alpine fescue	C.AB	3.00	4.00	4.00	4.00	3.25	4.00	4.00	3.50
Alkali grass	MT	4.75	5.50	3.75	3.75	3.50	4.00	4.75	4.00
Bad River blue grama	SD	6.75	7.50	7.00	7.00	7.00	7.00	3.75	4.00
Blue grama	MN	6.25	7.25	7.00	7.00	6.75	7.00	2.00	2.25
Blue grama§	KS	2.50	-	6.75	-	7.00	-	5.00	-
Sharp's Imp.II buffalograss	KS	6.00	7.00	7.00	7.00	6.25	7.00	4.25	4.25
Canon Canada bluegrass	Cv-AB	4.00	5.50	2.00	2.50	3.00	3.00	5.50	4.00
Canada bluegrass	C.AB	4.00	5.50	2.00	3.00	3.00	3.00	4.00	4.00
Ruebens Canada bluegrass	Cv-AB	4.00	5.50	2.00	2.75	3.00	3.25	4.00	4.00
Canada bluegrass	AB	4.00	4.00	2.25	3.00	3.00	3.25	4.75	4.00
Fowl bluegrass	C.AB	4.00	5.50	2.75	3.00	3.00	3.25	4.00	3.50
Fowl bluegrass	AB	4.50	7.25	4.00	6.25	4.00	6.50	7.00	6.00
Golfstar Idaho bentgrass	Cv-ID	7.75	9.00	9.00	8.25	4.00	5.00	4.00	5.00
Marsh muhly	MN	2.75	4.00	5.50	6.25	4.00	4.75	3.25	3.50
Barkoel prairie junegrass	Cv-N.E	6.50	8.00	8.00	8.00	6.25	4.00	8.00	8.00
Prairie junegrass	MN	7.00	7.00	5.50	4.50	4.00	6.25	6.25	4.00
Prairie junegrass	Iran	7.00	7.00	6.25	3.00	4.75	7.00	6.00	6.25
Prairie junegrass	C.AB	7.00	7.00	7.00	3.75	3.75	5.50	6.50	4.75
Peace River rough hairgrass	Cv-AB	6.75	7.50	6.50	5.00	3.75	5.50	6.00	3.50
Rough hairgrass	S.AB	5.00	5.50	7.00	4.00	3.75	4.25	4.75	3.50
Rough hairgrass	AB	5.50	6.25	7.00	5.50	4.00	5.00	4.50	4.00
El Reno side-oats grama	Cv-KS	4.75	4.75	7.00	6.50	7.00	7.00	3.50	4.00
Killdeer side-oats grama	Cv-ND	6.25	5.25	7.00	6.75	7.00	7.00	2.00	2.50
Pierre side-oats grama	Cv-ND	5.50	4.75	6.25	6.50	7.00	7.00	2.75	3.25
Tufted hairgrass	OR	3.00	4.75	5.00	4.00	4.00	4.25	4.00	3.50
Nortran Tufted hairgrass	Cv-A Ic	7.00	7.00	4.00	5.00	4.00	5.25	4.00	4.75
Tufted hairgrass	AB	5.00	4.75	4.00	4.00	4.00	5.00	4.25	5.00
	LSD¶	1.73	1.57	1.2	1.19	0.94	1.65	1.32	1.45

†Colour Rating Scale: 1-9 (9=dark green, 7=blue green, 5=light green, 1=brown). ‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. § Kansas blue grama not planted at Carman, Manitoba location.¶Means within a column may be compared within each year and month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.7. Visual rating of percent ground cover over all mowing regimes for the native grass evaluation study in June 1997 and August 1998 at Winnipeg, Manitoba.

		Mowing Height								
	Seed	18mm			38mm			62mm		
Entry	Source	Jun-97	Aug-98	Change†	Jun-97	Aug-98	Change	Jun-97	Aug-98	Change
		%								
Alpine bluegrass	C.AB‡	78.75	62.50 ns§		75.00	65.00 **	-10.00	76.25	61.25 ns	
Alpine fescue	C.AB	33.75	30.00 ns		32.50	32.50 ns		32.50	43.75 ns	
Alkali grass	MT	56.25	16.50 **	-39.75	62.50	23.75 **	-38.75	63.75	40.00 ns	
Bad River blue grama	SD	81.25	78.75 ns		83.75	77.50 ns		90.75	77.50 **	-13.25
Blue grama	MN	81.25	71.25 ns		85.00	72.50 **	-12.50	85.00	70.00 **	-15.00
Blue grama	KS	81.25	42.50 **	-38.75	82.50	46.25 **	-36.25	83.75	50.00 **	-33.75
Sharp's Imp.II buffalograss	KS	77.50	67.50 **	-10.00	80.00	65.00 **	-15.00	82.50	68.75 **	-13.75
Canon Canada bluegrass	Cv-AB	88.75	67.50 **	-21.25	94.25	72.50 **	-21.75	94.50	75.00 **	-19.50
Canada bluegrass	C.AB	88.75	65.00 **	-23.75	91.75	68.75 **	-23.00	94.50	68.75 **	-25.75
Ruebens Canada bluegrass	Cv-AB	85.00	66.25 **	-18.75	90.00	70.00 **	-20.00	92.50	70.00 **	-22.50
Canada bluegrass	AB	83.75	67.50 **	-16.25	91.00	67.50 **	-23.50	95.25	70.00 **	-25.25
Fowl bluegrass	C.AB	75.00	51.25 **	-23.75	85.00	56.25 **	-28.75	83.75	55.00 **	-28.75
Fowl bluegrass	AB	80.00	81.25 ns		86.25	83.75 ns		87.50	85.00 ns	
Golfstar Idaho bentgrass	Cv-ID	87.50	73.75 ns		92.50	75.00 **	-17.50	87.50	77.50 ns	
Marsh muhly	MN	61.25	22.50 **	-38.75	70.00	35.00 **	-35.00	75.00	42.50 **	-32.50
Barkoel prairie junegrass	Cv-N.E	90.00	86.25 ns		90.00	87.50 ns		91.25	87.50 ns	
Prairie junegrass	MN	57.50	63.75 ns		58.75	62.50 ns		61.25	65.00 ns	
Prairie junegrass	Iran	60.00	62.50 ns		65.00	65.00 ns		65.00	67.50 ns	
Prairie junegrass	C.AB	65.00	63.75 ns		66.25	66.25 ns		65.00	65.00 ns	
Peace River rough hairgrass	Cv-AB	78.75	63.75 ns		82.50	65.00 **	-17.50	80.00	68.75 ns	
Rough hairgrass	C.AB	75.00	61.25 ns		76.25	57.50 **	-18.75	77.50	61.25 **	-16.25
Rough hairgrass	AB	90.00	71.25 ns		94.25	77.50 **	-16.75	92.50	75.00 **	-17.50
El Reno side-oats grama	Cv-KS	61.25	47.50 ns		61.25	40.00 **	-21.25	65.00	53.75 ns	
Killdeer side-oats grama	Cv-ND	71.25	60.00 **	-11.25	78.75	61.25 **	-17.50	78.75	66.25 **	-12.50
Pierre side-oats grama	Cv-ND	63.75	47.50 ns		70.00	55.00 **	-15.00	71.25	60.00 **	-11.25
Tufted hairgrass	OR	78.75	51.25 **	-27.50	90.00	53.75 **	-36.25	92.00	60.00 **	-32.00
Nortran Tufted hairgrass	Cv-A Ic	90.00	91.25 ns		92.00	92.50 ns		96.00	95.00 ns	
Tufted hairgrass	AB	92.75	91.25 ns		97.25	95.00 ns		97.25	93.75 ns	

† Subtracts percent ground cover from August 1998 from June 1997 for each mowing height when differences between the two are significant at P=0.05‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. § *=Means significant at P=0.05 level within each entry over dates and ns=not significant at P=0.05 level within each entry over dates

Table 6.8. Visual rating of percent ground cover over all mowing regimes for the native grass evaluation study on June 1997 and August 1998 at Carman, Manitoba.

		Mowing Height								
	Seed	18mm			38mm			[illegible]mm		
Entry	Source	Jun-97	Aug-98	Change†	Jun-97	Aug-98	Change	Jun-97	Au[illegible]98	Change
		%								
Alpine bluegrass	C.AB‡	78.75	65.00 **§	-13.75	76.25	65.00		87.50	70.00 **	-17.50
Alpine fescue	C.AB	62.50	53.75 ns		77.50	61.25		62.50	58.75 ns	
Alkali grass	MT	57.50	35.00 ns		66.25	37.50 **	-28.75	68.75	55.00 ns	
Bad River blue grama	SD	80.00	68.75 ns		73.75	68.75		78.75	74.50 ns	
Blue grama	MN	70.00	67.50 ns		61.25	65.00		75.00	77.50 ns	
Blue grama¶	KS	-	-	-	-	-	-	-	-	-
Sharp's Imp.II buffalograss	KS	81.25	67.50 **	-13.75	81.25	66.25 **	-15.00	80.00	67.50 **	-12.50
Canon Canada bluegrass	Cv-AB	78.75	70.00 ns		86.25	70.00 **	-16.25	88.75	70.00 **	-18.75
Canada bluegrass	C.AB	76.25	70.00 ns		83.75	70.00 **	-13.75	82.50	70.00 **	-12.50
Ruebens Canada bluegrass	Cv-AB	73.75	67.50 ns		78.75	67.50 **	-11.25	85.00	70.00 **	-15.00
Canada bluegrass	AB	77.50	70.00 ns		82.50	70.00 **	-12.50	85.00	67.50 ns	
Fowl bluegrass	C.AB	75.00	58.75 ns		75.00	57.50		77.50	63.75 **	-13.75
7Fowl bluegrass	AB	78.75	71.25 ns		77.50	70.00 **	-7.50	82.50	79.75 ns	
Golfstar Idaho bentgrass	Cv-ID	82.50	91.25 **	8.75	83.75	88.75		92.00	88.75 ns	
Marsh muhly	MN	78.75	25.00 **	-53.75	78.75	27.50 **	-51.25	83.75	50.00 **	-33.75
Barkoel prairie junegrass	Cv-N.E	83.75	87.50 ns		86.25	88.75		91.25	93.75 ns	
Prairie junegrass	MN	68.75	60.00 ns		68.75	56.25		72.50	57.50 **	-15.00
Prairie junegrass	MT	67.50	66.25 ns		65.00	66.25		78.75	76.25 ns	
Prairie junegrass	C.AB	71.25	56.25 ns		70.00	52.50		76.25	66.25 ns	
Peace River rough hairgrass	Cv-AB	63.75	61.25 ns		70.00	63.75		71.25	63.75 ns	
Rough hairgrass	C.AB	58.75	48.75 ns		62.50	52.50		62.50	53.75 ns	
Rough hairgrass	AB	85.00	75.00 ns		85.00	75.00		85.00	72.50 **	-12.50
El Reno side-oats grama	Cv-KS	62.50	50.00 ns		60.00	56.25		68.75	60.00 ns	
Killdeer side-oats grama	Cv-ND	75.25	61.25 ns		71.25	58.75 **	-12.50	77.50	65.00 **	-12.50
Pierre side-oats grama	Cv-ND	71.25	55.00 ns		75.00	60.00 **	-15.00	76.25	61.25 **	-15.00
Tufted hairgrass	OR	75.00	71.25 ns		75.00	70.00		80.00	71.25 ns	
Nortran Tufted hairgrass	Cv-A Ic	83.75	87.50 ns		87.50	80.00		94.00	80.00 ns	
Tufted hairgrass	AB	85.00	96.25 **	11.25	85.00	95.75		98.50	97.25 ns	

† Subtracts percent ground cover from August 1998 from June 1997 for each mowing height when differences between the two are significant at P=0.05.‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. § Kansas blue grama not planted at Carman, Manitoba location. § *=Means significant at P=0.05 level within each entry over dates and ns=not significant at P=0.05 level within each entry over dates

¶ Kansas blue grama not planted at Carman, Manitoba location.

Table 4.9.1. Visual turfgrass texture ratings for the native grass evaluation over all mowing heights on 7 September 1997 at Winnipeg, Manitoba.

Entry	Seed Source	Texture
		1-9 Scale†
Alpine bluegrass	C.AB‡	9.00§
Alpine fescue	C.AB	9.00
Alkali grass	MT	8.00
Bad River blue grama	SD	8.00
Blue grama	MN	7.00
Blue grama	KS	7.00
Sharp's Imp.II buffalograss	KS	6.75
Canon Canada bluegrass	Cv-AB	6.50
Canada bluegrass	C.AB	6.50
Ruebens Canada bluegrass	Cv-AB	6.25
Canada bluegrass	AB	6.00
Fowl bluegrass	C.AB	6.00
Fowl bluegrass	AB	6.00
Golfstar Idaho bentgrass	Cv-ID	6.00
Marsh muhly	MN	6.00
Barkoel prairie junegrass	Cv-N.E	5.75
Prairie junegrass	MN	5.75
Prairie junegrass	MT	5.75
Prairie junegrass	C.AB	5.75
Peace River rough hairgrass	Cv-AB	4.75
Rough hairgrass	C.AB	4.75
Rough hairgrass	AB	4.75
El Reno side-oats grama	Cv-KS	4.25
Killdeer side-oats grama	Cv-ND	4.00
Pierre side-oats grama	Cv-ND	3.00
Tufted hairgrass	OR	3.00
Nortran Tufted hairgrass	Cv-A Ic	3.00
Tufted hairgrass	AB	2.00
	LSD*	1.04

† Visual turfgrass texture rating scale: 1-9, 1=very course, 9=very fine.

‡ Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland

§ Means are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 4.9.2. Visual rating of winterkill for the native grass evaluation study over all mowing regimes on 22 June 1998 at Winnipeg and Carman, Manitoba.

Entry	Seed Source	Mowing Height: Winnipeg Location 18mm	38mm	62mm	Carman Location 18mm	38mm	62mm
		%					
Alpine bluegrass	C.AB†	0.00‡	0.00	0.00	0.00	0.00	0.00
Alpine fescue	C.AB	0.00	0.00	0.00	0.00	0.00	0.00
Alkali grass	MT	0.00	0.00	0.00	0.00	0.00	2.50
Bad River blue grama	SD	0.00	0.00	0.00	0.00	0.00	0.00
Blue grama	MN	0.00	0.00	0.00	0.00	0.00	0.00
Blue grama§	KS	89.50	83.25	83.25	-	-	-
Sharp's Imp.II buffalograss	KS	45.00	42.50	30.00	21.25	16.25	17.50
Canon Canada bluegrass	Cv-AB	0.00	0.00	0.00	0.00	0.00	0.00
Canada bluegrass	C.AB	0.00	0.00	0.00	0.00	0.00	0.00
Ruebens Canada bluegrass	Cv-AB	0.00	0.00	0.00	0.00	0.00	0.00
Canada bluegrass	AB	0.00	0.00	0.00	0.00	0.00	0.00
Fowl bluegrass	C.AB	7.50	1.25	1.25	10.00	12.50	17.50
Fowl bluegrass	AB	5.00	6.25	3.75	12.50	13.00	15.00
Golfstar Idaho bentgrass	Cv-ID	8.75	8.75	8.75	0.00	0.50	0.00
Marsh muhly	MN	40.00	40.00	22.50	70.00	62.50	42.50
Barkoel prairie junegrass	Cv-N.E	0.00	0.00	0.00	1.25	0.00	0.00
Prairie junegrass	MN	0.00	0.00	0.00	0.00	0.00	0.00
Prairie junegrass	MT	0.00	0.00	0.00	0.00	0.00	0.00
Prairie junegrass	C.AB	0.00	0.00	0.00	0.00	0.00	0.00
Peace River rough hairgrass	Cv-AB	47.50	50.00	53.75	32.50	30.00	30.00
Rough hairgrass	C.AB	52.50	53.75	62.50	52.50	52.50	50.00
Rough hairgrass	AB	15.00	12.50	12.50	2.50	2.50	2.50
El Reno side-oats grama	Cv-KS	27.50	27.50	13.75	32.50	28.75	15.00
Killdeer side-oats grama	Cv-ND	8.75	6.25	1.25	27.50	25.00	17.50
Pierre side-oats grama	Cv-ND	31.25	25.00	7.50	47.50	35.00	22.50
Tufted hairgrass	OR	72.50	68.75	67.50	22.50	23.75	32.50
Nortran Tufted hairgrass	Cv-A Ic	3.75	5.00	2.50	8.75	14.25	14.25
Tufted hairgrass	AB	10.00	10.00	7.50	8.75	6.25	13.75
	LSD	15.75	13.77	12.77	13.45	10.62	11.73

† Abbreviation :Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; C.AB= Central Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A Ic=Alaska/Iceland. ‡ Means within each entry, mowing height and location are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD. § Kansas blue grama not planted at Carman, Manitoba location.

Figure 1.1. Regrowth total one week after mowing at 18mm mowing regime and precipitation amounts over that period for the native grass evaluation study in 1998 at Carman, Manitoba.

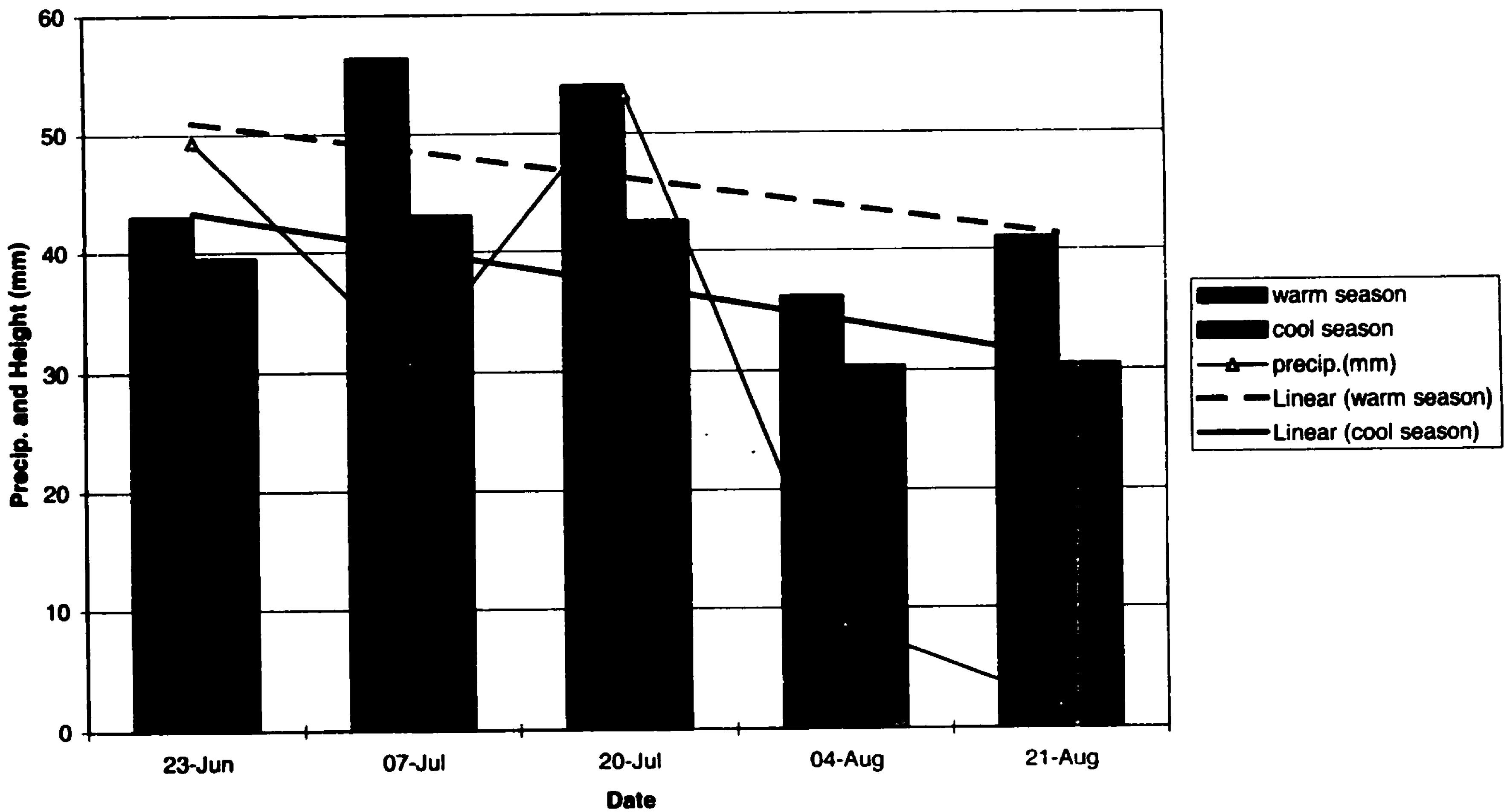


Figure 1.2. Regrowth total one week after mowing at the 38mm mowing regimes and precipitation amounts over that period for the native grass evaluation study in 1998 at Carman, Manitoba.

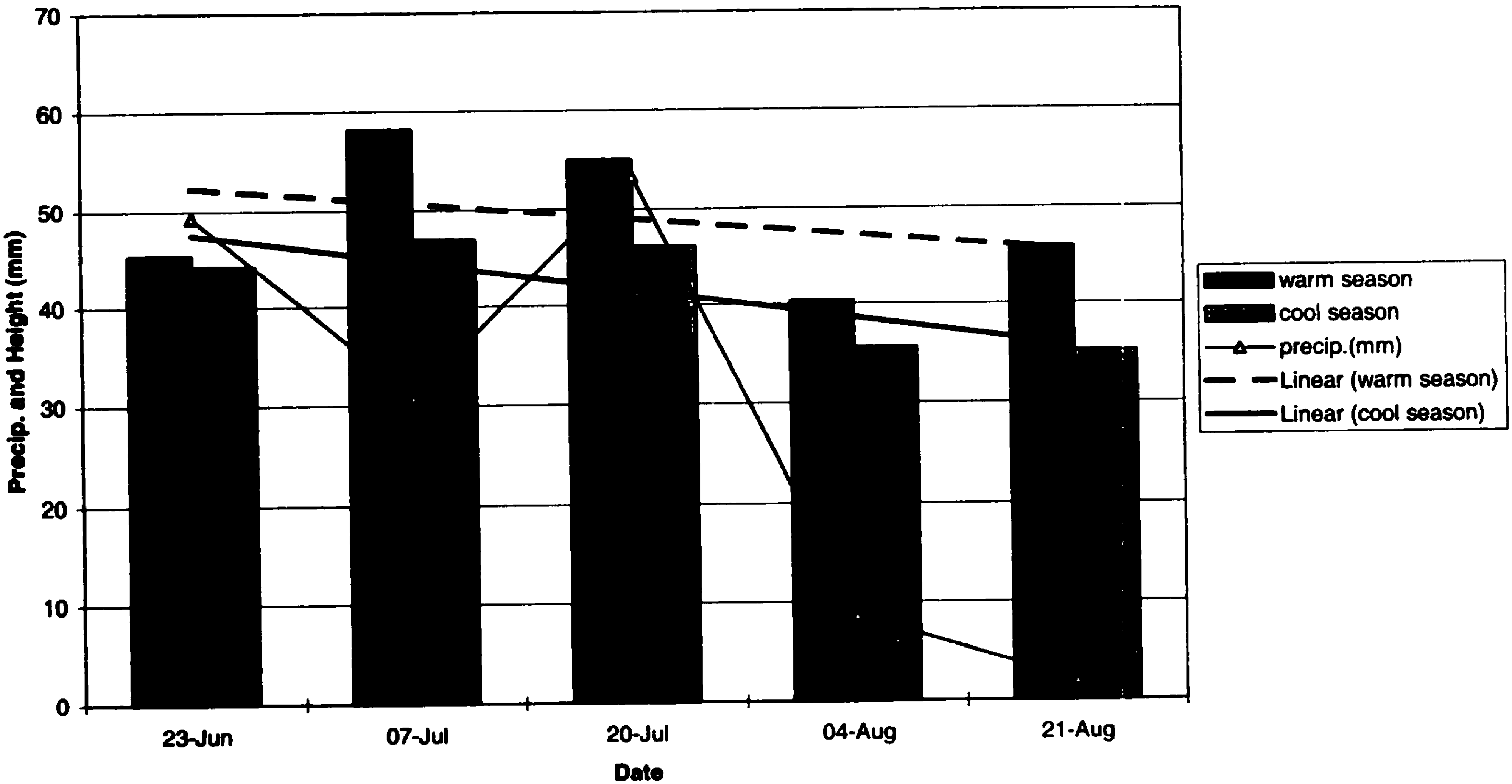
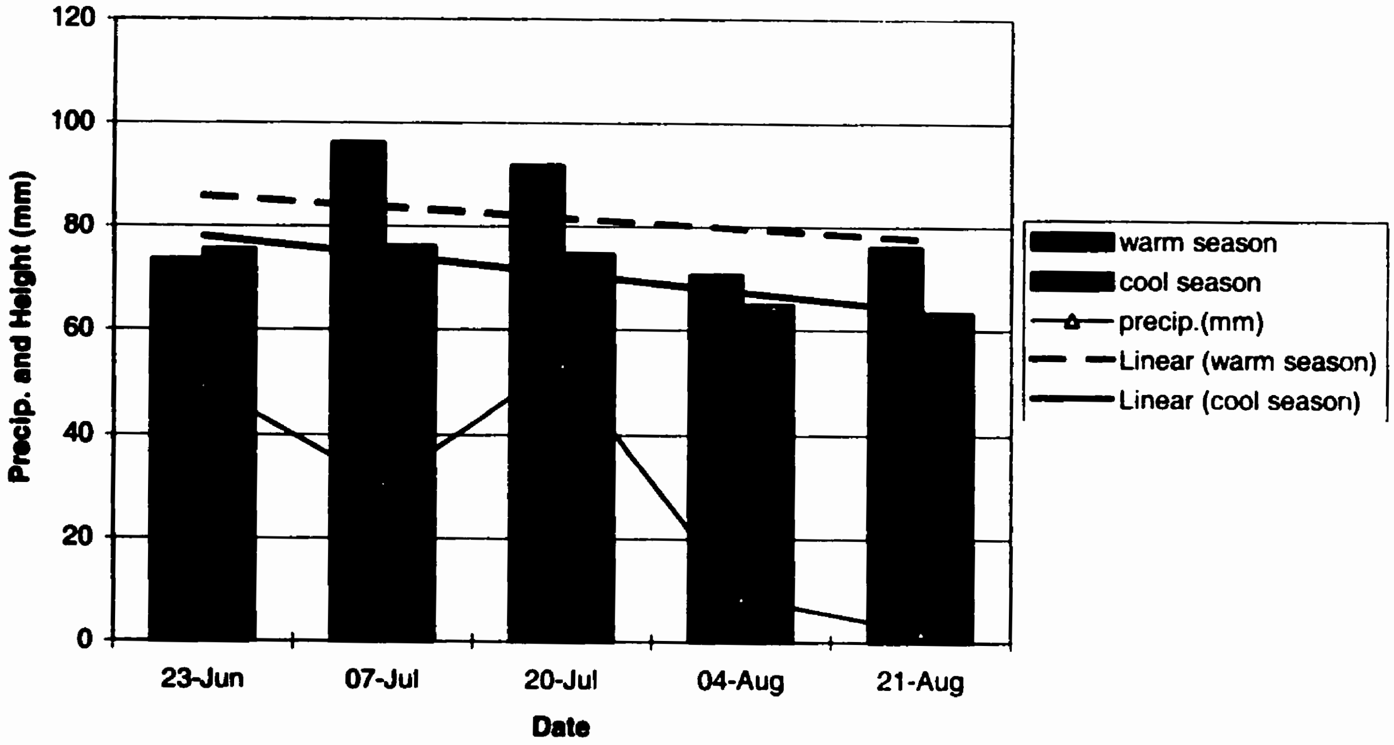


Figure 1.3.Regrowth total one week after mowing at the 62mm mowing regime and precipiatation amounts over that period for the native grass evaluation study in 1998 at Carman, Manitoba.



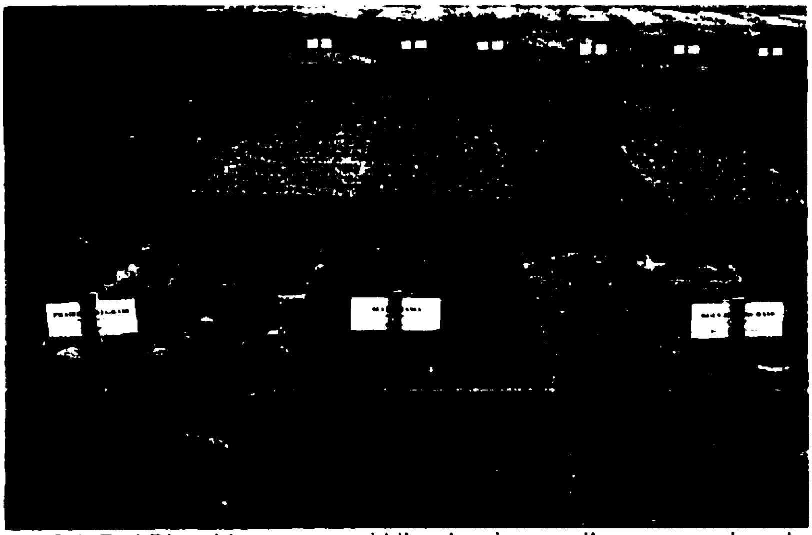


Figure 2.0. Bad River blue grama (middle) showing excellent green colour during drought, while the cool season grasses on either side have browned off. August 1998 at the turfgrass evaluation of native grasses mowed experiment (I) in Carman, MB.

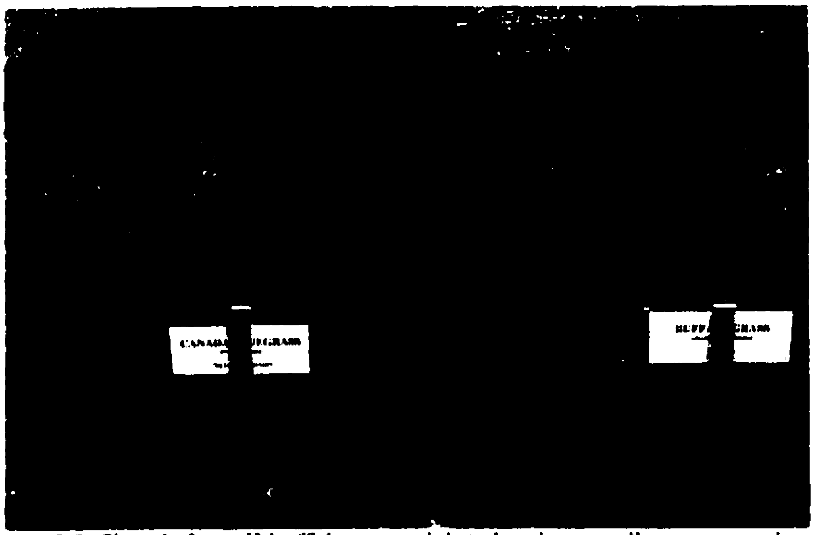


Figure 3.0. Sharp's Imp. II buffalograss (right) showing excellent green colour during drought, while Canada bluegrass has browned off. August 1998 at the turfgrass evaluation of native grasses mowed experiment (I) in Carman, MB.

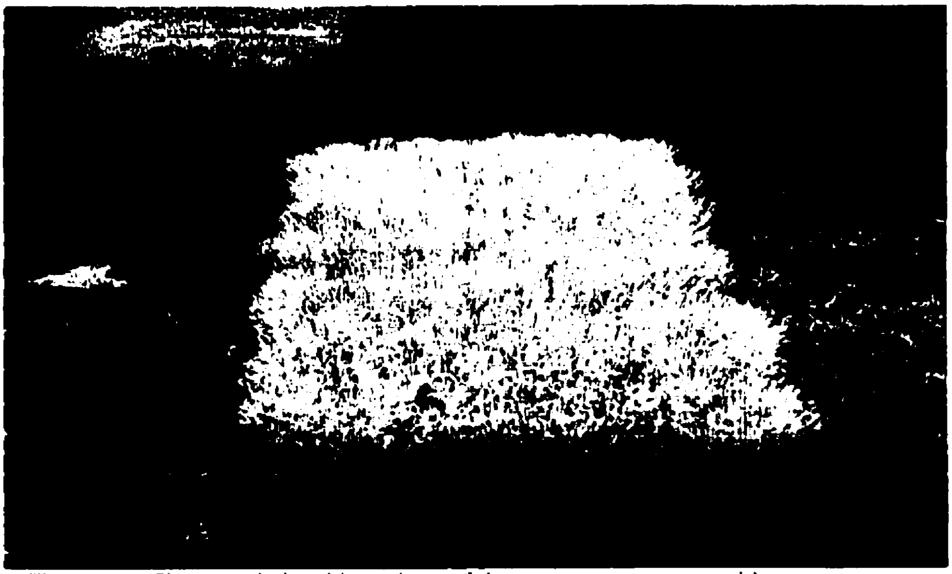


Figure 4.0. Characteristic white colour of the warm season grass side-oats grama (middle) after fall dormancy and green colour of the cool season grasses on either side. Native grass non-mown experiment (II) on 1 October 1997 at Winnipeg, MB.

Figure 5.0. Typical blue-green turfgrass colour of blue grama at the native grass mowed experiment (I) at the 62mm mowing height. August 1998 at Carman, MB.

Experiment II (Non-Mowed Evaluation)

There was a significant interaction between months consistently for most entries, preventing pooling of data (Little and Hills, 1978) (Table 5.0). Comparisons between entry means were within each month. Species suitable for non-mowed situations show the following desirable traits: low height, fine texture, stand uniformity, high plot density and low disease or lodging ratings (Tables 6.0, 6.1 and 6.2). The blue grama entries, Golfstar Idaho bentgrass and Sharp's Imp.II buffalograss all qualified as good, low-maintenance turfgrasses.

The blue grama and buffalograss entries showed consistent uniformity, excellent plot densities, a blue-green colour and heights between 20 and 22cm (Tables 6.0, and 6.1) (Figures 6.0 and 7.0). The three blue grama entries had not developed seedheads at the 8 July 1998 mowing and exhibited bleached leaf tips as a result of a yet unidentified leaf spot disease (Table 6.2). This disease problem in the blue grama entries may have resulted from higher than normal seeding rates and resulting high plant densities for a non-mowed situation. The Sharp's Imp.II buffalograss had not formed seedheads before the July mowing date. It showed no disease problems and showed an aggressive stoloniferous growth habit. No winterkill problems were detected over the first winter for this entry, however ratings in the spring of 1999 indicate substantial winterkill damage (40% range).

The junegrass entries also showed desirable height. texture and colour ratings but suffered from leaf rust and lower plot densities, which resulted in lower stand uniformity ratings (Tables 6.0, 6.1 and 6.2). Rust infestations were present on all tufted hairgrass entries. Many of the cool-season entries showed lower than expected plot densities, which were likely a consequence of a late seeding date (10 July 1997), with germination and emergence occurring during the increasing temperatures and low moisture conditions of July (Table 6.2).

Golfstar Idaho bentgrass showed excellent dark green colour and high plot densities. Vegetative plant heights averaged 20cm with no lodging or disease problems. Since all grasses were mowed off in early July, turf quality of Golfstar Idaho bentgrass during the seedset period was not determined (Tables 6.0, 6.1 and 6.2).

All warm season grass species showed complete spring green-up by 20 May 1998, which was similar to their response under mowing in experiment I. Most of the cool seasons grass species showed complete spring green-up by early April 1998, as snow cover disappeared and soil temperatures increased. The warm season grasses showed consistent fall dormancy ratings in comparison to these same species in the mowed experiment (I). Dormancy occurred between 12 October and 23 October 1998 in both experiments. Surprisingly, one of the cool season grasses, marsh muhly exhibited dormancy by 4 October 1998. The early onset of dormancy of this species was likely a result of mowing stress and frost in early September, which impacted on regrowth.

Turf quality of the fowl bluegrass entry from Alberta was reduced due to contamination by timothy seed. When using native grass seed for a lawn or ground cover it is essential that the seed is free of other seed contaminants. With the absence of seed regulation in the native seed industry it is important for buyers and sellers of native seed to have seed lots tested. However, a new certification system is now beginning to be implemented in Canada.

This non-mowed experiment (II) acted as a control for the mowed experiment (I), since most entries were repeated in both experiments. The information gained from evaluating these entries under limited mowing helped to explain why some species were unsuitable under mowing. For example, the Canada bluegrass entries did poorly in the mowed experiment since most of its leaf growth occurred above the highest mowing height (62mm). This could have not been confirmed without this non-mowed experiment II, which showed leaf growth was well established above 62mm. Also, forage grass contaminants were readily identified under an infrequent mowing regime. When evaluating grass species not used previously as a turf, it is important to evaluate under mown and non-mown situations.

Soil tests indicate that nutrient levels were more than adequate for a lawn situation. These higher than normal nutrient levels may have biased plant height and colour ratings, since they were not representative of most low-maintenance situations. Continued measurements in 1999 under lower soil nutrient levels may provide a better indication of entry performance under true low-maintenance conditions.

Summary

The importance of this non-mowed study was primarily to determine growth habit and overall plant appearance under low-maintenance conditions. Equally important was the function this experiment performed as a "control" for the mowed experiment (I) and the insight gained in understanding why entries reacted to mowing stress the way they did. The Sharp's Imp.II buffalograss and blue grama entries, with their excellent drought tolerance and low growth habit, seem ideally suited for highway embankments or other steep terrain where a grass species is desired. The reduced right-of-way maintenance inputs (mowing particularly) and improved erosion control of these species would result in economic savings for municipalities and highway departments. For northern regions of North America, such as Manitoba, a more northern adapted buffalograss collection or cultivar needs to be available avoid the winterkill problems that occur with southern plant material (e.g. Sharp's Imp.II buffalograss from Kansas).

Table 5.0. Analysis of variance for turfgrass colour for native grasses evaluated (experiment II) in Winnipeg, Manitoba in 1998.

Source of Variation	df	Mean square
REP	3	0.31 NS
ENTRY	27	17.50 ****
REP X ENTRY	81	0.49 NS
MONTH	3	62.62 ****
ENTRY X MONTH	81	8.66 ****

**** Significant at the 0.0001 probability level.

Table 6.0. 1998 Native grass non-mowed experiment (II) monthly turfgrass colour ratings at Carman, MB (planted 1997).

Entry	Seed Source	Month April	May	June	July
		---------- 1-9 Scale†			----------
Alpine bluegrass	S.AB‡	7.00§	7.00	7.25	7.00
Alpine fescue	S.AB	8.25	8.00	8.00	3.00
Alkali grass	MT	6.50	7.00	7.00	1.50
Bad River blue grama	SD	1.75	6.00	7.00	7.00
Blue grama	MN	1.75	6.25	7.00	6.75
Blue grama	KS	1.00	6.75	7.00	7.00
Sharp's Imp.II buffalograss	KS	1.25	7.00	7.00	6.50
Canada bluegrass	S.AB	7.00	7.00	7.50	7.00
Ruebens Canada bluegrass	Cv-AB	7.00	7.25	7.00	7.00
Canada bluegrass	AB	7.00	7.25	7.75	7.00
Fowl bluegrass	S.AB	6.00	6.75	7.00	6.25
Fowl bluegrass	AB	6.00	7.25	7.50	5.75
Golfstar Idaho bentgrass	Cv-ID	6.75	8.00	8.00	8.00
Marsh muhly	MN	7.00	4.00	6.00	5.00
Barkoel prairie junegrass	Cv-N.E.	8.50	9.00	9.00	4.00
Prairie junegrass	MN	7.00	7.00	7.25	4.00
Prairie junegrass	Iran	7.00	7.00	7.00	4.50
Prairie junegrass	S.AB	7.00	7.00	7.00	5.50
Peace River rough hairgrass	Cv-AB	6.50	6.50	5.50	6.00
Rough hairgrass	S.AB	5.75	5.25	5.25	5.50
Rough hairgrass	AB	7.00	6.75	7.00	7.25
Sheeps fescue	AB	7.75	7.75	7.00	8.00
El Reno Side-oats grama	Cv-KS	2.00	5.50	5.50	5.00
Killdeer Side-oats grama	Cv-ND	2.00	6.00	6.00	5.50
Pierre Side-oats grama	Cv-ND	2.25	6.00	6.50	5.25
Tufted hairgrass	OR	6.50	9.00	9.00	5.25
Nortran tufted hairgrass	Cv-A/Ic	9.00	9.00	8.75	6.50
Tufted hairgrass	AB	9.00	9.00	8.75	6.00
	LSD§	0.65	0.69	0.87	1.44

† Colour rating scale:1-9 (9=dark green,7=blue-green,5=light green turfgrass,1=brown).
‡ Abbreviations: Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; S.AB=Southern Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A/Ic=Alaska/Iceland.
§ Means within a column may be compared within each month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 6.1. 1998 Native grass non-mowed experiment (II) monthly percent ground cover ratings at Carman, MB (planted 1997).

Entry	Seed Source	Month			
		15 April	7 May	2 June	30 Aug.
		%			
Alpine bluegrass	S.AB†	67.50‡	60.00	75.00§	52.50
Alpine fescue	S.AB	40.00	42.50	46.25	45.00
Alkali grass	MT	81.25	58.75	71.25	51.25
Bad River blue grama	SD	88.75	75.00	82.50	81.25
Blue grama	MN	80.00	67.50	75.00	76.25
Blue grama	KS	85.00	68.75	76.25	77.50
Sharp's Imp.II buffalograss	KS	94.50	65.00	75.00	82.50
Canada bluegrass	S.AB	96.00	72.50	93.75	70.00
Ruebens Canada bluegrass	Cv-AB	97.25	88.75	96.25	70.00
Canada bluegrass	AB	96.50	90.00	97.50	70.00
Fowl bluegrass	S.AB	95.25	86.25	92.50	62.50
Fowl bluegrass	AB	97.25	88.75	95.00	62.50
Golfstar Idaho bentgrass	Cv-ID	85.50	70.00	91.25	73.75
Marsh muhly	MN	63.75	62.50	83.75	86.25
Barkoel prairie junegrass	Cv-N.E.	75.00	63.75	82.50	80.00
Prairie junegrass	MN	52.50	53.75	63.75	33.75
Prairie junegrass	Iran	41.25	45.00	51.25	47.50
Prairie junegrass	S.AB	55.00	51.25	58.75	43.75
Peace River rough hairgrass	Cv-AB	78.75	63.75	75.00	47.50
Rough hairgrass	S.AB	94.00	81.25	62.50	52.50
Rough hairgrass	AB	94.50	80.00	100.00	87.50
Sheeps fescue	AB	55.00	55.00	86.25	62.50
El Reno Side-oats grama	Cv-KS	67.50	48.75	55.00	71.25
Killdeer Side-oats grama	Cv-ND	81.25	60.00	73.75	77.50
Pierre Side-oats grama	Cv-ND	76.25	57.50	70.00	80.00
Tufted hairgrass	OR	86.25	76.25	90.00	50.00
Nortran tufted hairgrass	Cv-A/Ic	60.00	60.00	95.00	37.50
Tufted hairgrass	AB	83.75	78.75	97.50	65.00
	LSD‡	13.33	10.46	11.83	14.68

† Abbreviations: Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; S.AB=Southern Alberta; AB=Alberta; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A/Ic=Alaska/Iceland.

‡ Means within a column may be compared within each month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD. § Plots mowed 8 July 1998, slow regrowth for many plots from this point on.

Table 6.2. Visual assessments and height measurements of the native grasses in the non-mown experiment (II) in 1998 at Carman, MB (planted 1997).

Entry	Seed Source	Max. Leaf Ht.	Inflorescence Present†	Texture ‡	Uniformity §	Emergence Rate	Negatives
		cm		------- 1-9 Scale ----			
Alpine bluegrass	S.AB¶	15.75	Yes	2.00	5.00	Poor#	-
Alpine fescue	S.AB	73.75	Yes	8.00	5.00	Poor	-
Alkali grass	MT	39.50	Yes	5.75	8.75	Good	-
Bad River blue grama	SD	22.50	No	6.75	6.50	Excellent	-
Blue grama	MN	21.75	No	7.00	6.00	Excellent	-
Blue grama	KS	22.00	No	6.50	4.75	Good	-
Sharp's Imp.II buffalograss	KS	22.00	No	6.50	5.75	Good	-
Canada bluegrass	S.AB	32.25	Yes	6.00	7.00	Poor	Lodging
Ruebens Canada	Cv-AB	32.75	Yes	5.75	7.25	Good	Lodging
Canada bluegrass	AB	32.00	Yes	5.75	6.25	Good	Lodging
Fowl bluegrass	S.AB	35.00	Yes	8.00	5.75	Good	Lodging
Fowl bluegrass	AB	38.00	Yes	4.25	5.25	Good	Lodging
Golfstar Idaho bentgrass	Cv-ID	20.25	Yes	5.75	5.75	Poor	-
Marsh muhly	MN	27.50	No	4.00	5.25	Excellent	-
Barkoel prairie junegrass	Cv-N.E.	12.25	Yes	7.00	5.50	Poor	Rust
Prairie junegrass	MN	17.25	Yes	6.25	5.75	Poor	Rust
Prairie junegrass	MT	15.75	Yes	6.00	5.50	Poor	Rust
Prairie junegrass	S.AB	15.50	Yes	6.00	5.50	Poor	Rust
Peace River rough	Cv-AB	31.25	Yes	9.00	5.75	Good	-
Rough hairgrass	S.AB	26.00	No	9.00	5.00	Poor	Lodging
Rough hairgrass	AB	37.00	No	6.00	6.75	Good	Lodging
Sheeps fescue	AB	25.00	Yes	5.00	7.00	Poor	Lodging
El Reno Side-oats grama	Cv-KS	24.25	Yes	3.00	5.00	Excellent	-
Killdeer Side-oats grama	Cv-ND	24.75	Yes	3.00	5.50	Good	-
Pierre Side-oats grama	Cv-ND	23.00	Yes	3.00	5.75	Good	-
Tufted hairgrass	OR	26.00	No	4.75	6.25	Good	Rust
Nortran tufted hairgrass	Cv-A/Ic	29.75	No	4.75	6.00	Good	Rust
Tufted hairgrass	AB	38.50	Yes	4.75	8.00	Good	Rust
	LSD††	-	-	1.04	1.20	-	-

† Presence of inflorenence before 4 August 1998.

‡ Texture scale: 1-9 (1=very course, 9= very fine).

§ Uniformity scale: 1-9 (1=non-uniform, 9=very uniform).

¶ Abbreviations: Cv= Cultivar; MN=Minnesota; ND=North Dakota; SD=South Dakota; KS=Kansas; S.AB=Southern Alberta; AB=Alberta ; OR=Oregon; N.E.=Northern Europe; ID=Idaho; A/Ic=Alaska/Iceland.

†† Means within a column may be compared within each month and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD. # Emergence rate 22 days after seeding on 10 July 1998.

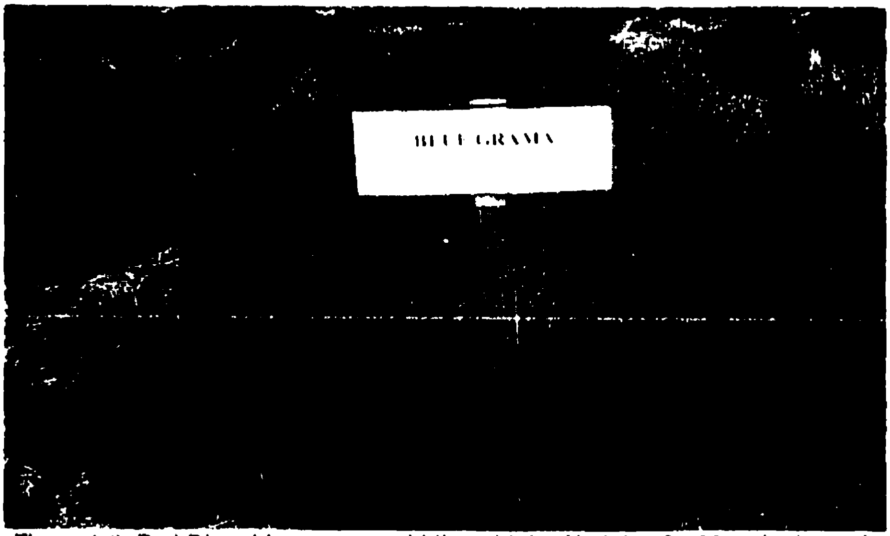


Figure 6.0. Bad River blue grama (middle) with leaf heights 20-22cm in the native grass evaluation non-mown experiment (II). August 1998 at Carman, MB.

Figure 7.0. Sharp's Imp. II buffalograss (middle) with leaf heights 20-22cm in the native grasses evaluation non-mown experiment (II). August 1998 at Carman, MB.

Experiment III (Vegetatively Propagated Native Grass Evaluation)

There was a significant interaction between years and months for all entries, preventing pooling of data within each source of variation (Little and Hills, 1978) (Tables 7.0 and 7.1). Comparisons between entry means were within each month and year. This experiment evaluated sweetgrass, buffalograss and inland desert saltgrass for their suitability as a low-maintenance turfgrasses, in mown and non-mown situations. Over the two years of this study Bismarck buffalograss had significantly higher quality for all rating periods in the mown and non-mown trials over both years (Tables 8.0 and 8.1). Bismarck is a vegetatively propagated cultivar comprised of two genotypes collected in North Dakota and showed excellent winter hardiness, texture, complete plot cover, blue-green colour and drought tolerance (Englert and White, 1997). Stolon activity was very aggressive, reaching high levels of plot cover (greater than 80%) within one complete growing season after transplanting (Tables 8.2 and 8.3). The maximum height of Bismarck in the non-mown trial ranged between 10 cm and 15.0cm. The appearance of numerous brown coloured male spikelets extending several centimetres above the leaves from June onward reduced turfgrass quality in the non-mown buffalograss plots (Table 8.1) (Figure 8.0). If planted for ornamental use these spikelets may seem appropriate. Consequently, unmowed Bismarck never received ideal turf quality ratings (9= ideal turfgrass). The turf quality for buffalograss was consistently higher in the mown trial (Table 8.0).

As a result of herbicide damage, many of the inland desert saltgrass plots received lower turfgrass ratings in 1997 (i.e. extremely sensitive to glyphosate herbicide). Following complete recovery in 1998, the turfgrass quality ratings for both trials improved to moderate levels (Table 8.0 and 8.1). This warm season grass entry showed excellent blue-green colour, texture, drought tolerance, and winter hardiness. Turfgrass quality was reduced because of inadequate plot densities (percent ground cover) (Tables 8.2 and 8.3). In the non-mown trial maximum height for inland desert saltgrass ranged between 15 cm and 18 cm. Although rhizome activity was high, most rhizomes were not concentrated within their original plot but spread to adjacent plots and border areas (Figure 9.0).

The sweetgrass entry showed poor quality ratings due primarily to its very low percent ground cover, coarse texture and taller stature (30 cm to 40 cm), making it less suitable for low-maintenance or non-mown areas (Tables 8.0, 8.1, 8.2 and 8.3). This cool season grass had very aggressive rhizominous activity but did not form a dense sod. This species actually created problems with plot maintenance because it spread into other plots and border areas.

As expected with the warm season grass species, they showed late green-up in the spring and an early onset of fall dormancy. However, the inland desert saltgrass containing Manitoba and Saskatchewan populations had a more accelerated spring green-up (near complete green-up by 1 May 1998) and delayed fall dormancy (15 October 1998, both trials) compared to Bismarck buffalograss (near complete green-up 13 May 1998; fall dormancy 1 October 1998 mown trial, 6 October 1998 non-mown trial). There was no disease or insect problems observed over the two years of the study for any of the entries.

Summary

Problems with winterkill in 'Sharp's Imp.II' buffalograss from Kansas in experiment I were absent in Bismarck buffalograss from North Dakota in this experiment. This superior winter hardiness should make this northern buffalograss an excellent grass species for low-maintenance lawns in Manitoba. For non-mown situations the use of female plants over male plants would be desirable. In the USA many vegetatively propagated buffalograss cultivars are comprised of female plants since the pistillate structures located close to the soil surface make them more aesthetic as a mown turf. For ornamental use, the male plants may be more appropriate. Continued turfgrass management research of Bismarck buffalograss will be continued by the turfgrass research program at the University of Manitoba. Future research will be focused on establishment, sod potential, mowing frequency, mowing height, thatch control and weed management. With seed unavailable for this cultivar, all research will occur with vegetatively propagated plots only.

Inland desert saltgrass has great potential for use in mown or non-mown areas if genotypes can be identified that express less aggressive rhizome spreading so as to increase grass stand density. Due to its high tolerance of salt and drought stress this species would be an ideal low-maintenance grass for urban highway medians. It can be found occurring naturally along high salt roadways at several sites within the city of Winnipeg. Future turfgrass selection programs for inland desert saltgrass should select plant material from these sites. Although seed is available, past research has indicated that achieving acceptable germination rates can be a difficult and complex process (Cluff, et al, 1983, 1987). It is therefore recommended that all plantings should use rhizomes for successful establishment (Pavlicek et al, 1977). It is hoped that research will continue with this species for this unique urban niche.

Table 7.0. Analysis of variance for turfgrass quality for native grasses evaluated (experiment IIIa) at Winnipeg, Manitoba in 1997 and 1998.

Source of Variation	df	Mean square
REP	3	0.73 NS
ENTRY	2	84.26 ****
REP X ENTRY	6	3.52 ****
MONTH	3	5.12 ****
ENTRY X MONTH	6	7.62 ****
REP X MONTH(ENTRY)	27	0.25 NS
YEAR	1	19.26 ****
ENTRY X YEAR	2	1.38 *
MONTH X YEAR	3	4.84 ****
ENTRY X MONTH X YEAR	6	1.13 *

*, **, ***, **** Significant at the 0.05, 0.01, 0.001and 0.0001 probability levels.

Table 7.1. Analysis of variance for of turfgrass quality of native grasses evaluated (experiment IIIb) at Winnipeg, Manitoba in 1997 and 1998.

Source of Variation	df	Mean square
REP	3	0.28 NS
ENTRY	2	22.01 ****
REP X ENTRY	6	0.16 NS
MONTH	3	9.78 ****
ENTRY X MONTH	6	1.49 ****
REP X MONTH(ENTRY)	27	0.12 NS
YEAR	1	0.09 ****
ENTRY X YEAR	2	1.90 ****
MONTH X YEAR	3	19.26 ****
ENTRY X MONTH X YEAR	6	2.94 ****

*, **, ***, **** Significant at the 0.05, 0.01, 0.001and 0.0001 probability levels.

Table 8.0. Monthly turfgrass quality ratings of Experiment IIIa mowed trial in 1997 and 1998 at Winnipeg, MB.

Entry	Month			
	June	July	Aug.	Sept.
	1-9 Scale†			
	1997			
Buffalograss	5.25a‡	6.00a	7.50a	4.00a
Inland desert saltgrass	3.50b	3.00b	3.50b	3.50ab
Sweetgrass	2.00c	2.00b	3.00b	3.00b
	1998			
Buffalograss	8.00a	7.00a	7.00a	4.25a
Inland desert saltgrass	5.00b	5.25b	4.50b	3.50b
Sweetgrass	3.00c	3.50c	2.50c	3.50b

†Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass).
‡ Means within each column for each year and month followed by the same letter are not significantly different at the P=0.05 level using Fisher's LSD test.

Table 8.1. Monthly turfgrass quality ratings of Experiment IIIb non-mowed trial in 1997 and 1998 at Winnipeg, MB.

Entry	Month			
	June	July	Aug.	Sept.
	1-9 Scale†			
	1997			
Buffalograss	4.75a‡	5.50a	7.00a	5.00a
Inland desert saltgrass	4.00b	4.00b	5.00b	4.50a
Sweetgrass	3.25c	3.25c	4.00c	3.50b
	1998			
Buffalograss	8.25a	5.25a	4.00a	3.00a
Inland desert saltgrass	6.75b	5.00a	4.00a	3.00a
Sweetgrass	4.25c	4.00b	4.00a	3.00a

†Turfgrass quality rating scale: 1-9 (9=ideal turfgrass, 1=poor turfgrass).
‡ Means within each column for each year and month followed by the same letter are not significantly different at the P=0.05 level using Fisher's LSD test.

Table 8.2. Monthly visual percent ground cover ratings of Experiment IIIa mowed trial in 1997 and 1998 at Winnipeg, MB.

Entry	Month			
	June	July	Aug.	Sept.
	%			
	1997			
Buffalograss	62.50a†	82.50a	92.50a	90.00a
Inland desert saltgrass	37.50b	43.75b	52.50b	51.25b
Sweetgrass	35.00b	35.00b	41.25c	42.50c
	1998			
Buffalograss	92.50a	100.00a	97.50a	97.50a
Inland desert saltgrass	53.50b	57.50b	65.00b	63.75b
Sweetgrass	35.00c	35.00c	38.75c	50.00b

† Means within each column for each year and month followed by the same letter are not significantly different at the P=0.05 level using Fisher's LSD test.

Table 8.3. Monthly visual percent ground cover ratings of Experiment IIIb non-mowed trial in 1997 and 1998 at Winnipeg, MB.

Entry	Month			
	June	July	Aug.	Sept.
	%			
	1997			
Buffalograss	65.00a	76.25a	87.50a	83.75a
Inland desert saltgrass	37.50b	55.00b	62.50b	57.50b
Sweetgrass	35.00b	47.50c	52.50c	50.00c
	1998			
Buffalograss	90.00a	100.00a	100.00a	93.75a
Inland desert saltgrass	66.25b	70.00b	78.75b	71.25b
Sweetgrass	47.50c	50.00c	60.00c	51.87c

† Means within each column for each year and month followed by the same letter are not significantly different at the P=0.05 level using Fisher's LSD test.

Figure 8.0. Bismarck buffalograss (middle) in the non-mowed trial with brown male spikelets evident in the native grass evaluation experiment (III). August 1998 at Winnipeg, MB.

Figure 9.0. Inland desert saltgrass (middle) in the non-mowed trial spreading by rhizomes into the pathway in the native grass evaluation experiment (III). August 1998 at Winnipeg, MB.

Manuscript 2:

Salinity Tolerance of Selected Native Grasses

Abstract

Saline soil conditions exist on many turfgrass areas across North America, and are becoming more abundant with the use of secondary water sources for turf irrigation. The objectives of this research were to evaluate the salinity tolerance of several native grass species. The following native grasses were included: 'Bad River' blue grama (*Boutoua gracilis* [Willd. ex Kunth] Lag. ex Griffiths.), 'Barkoel' prairie junegrass (*Koelaria macrantha* [Ledeb.] J.A. Schultes), 'Golfstar' Idaho bentgrass (*Agrostis idahoensis*) and Alberta ecotype alkali grass (*Puccinellia nuttaliana* [Schultes] Hitchc.). Two development stages (advanced seedlings and mature plants) were evaluated in wooden flats which were surrounded by a plastic jacket and subirrigated with a 1% saline (NaCl) water every 3 weeks. This closed system provided increasing soil salinity levels over time. Alkali grass showed high levels of saline tolerance at both stages of development, with no plant mortality occurring over the course of the experiment. Bad River blue grama, Golfstar Idaho bentgrass and Barkoel prairie junegrass were tolerant of moderately saline soil (soil conductivity 8-12 mC cm^{-1}) as mature plants and moderately tolerant of slightly saline soil (soil conductivity 4-8 mC cm^{-1}) as advanced seedlings.

Manuscript 2 - Saline Tolerance of Selected Native Grasses

Introduction

There is a need for salinity tolerant turfgrass species for saline affected soils. Saline soils exist across North America in regions with saline subsoils and high water tables. The increased use of secondary water for irrigation for golf courses and continued use of salt to de-ice roadways in Canada has also increased the amount of saline affected soil. The common occurring forms of saline soils are sodium salts and sulfate salts. Many of the traditional turfgrass species used for golf course, roadside/median turfgrass cover (e.g.-Kentucky bluegrass, creeping red fescue) are sensitive to soil salinity and show reduced vigour or increased plant mortality as soil salinity increases (Lunt et al, 1961). Although many native grass species are adapted under saline conditions, there is very little information available on their potential use as turfgrass in saline soils (Carrow and Duncan, 1998; Marcum, 1994; Throsell, 1996).

Recent native grass evaluation and management research indicated that several species show potential for managed turf (Miluch, 1997; Mintenko and Smith, 1998, 1999). These species include blue grama (*Boutoua gracilis* [Willd. ex Kunth] Lag. ex Griffiths.), prairie junegrass (*Koelaria macrantha* [Ledeb.] J.A. Schultes), Idaho bentgrass (*Agrostis idahoensis*) and alkali grass (*Puccinellia nuttaliana* [Schultes] Hitchc.). Among these four, past research has suggested that alkali grass has the best tolerance to saline soils (Hughes et al, 1975; Lunt et al, 1961) and occurs naturally along roadsides where NaCl has been used extensively (Ahti et al, 1980; Harivandi et al, 1992, Madison, 1971). Past research results with blue grama show a wide range of salinity tolerance from moderately sensitive to tolerant (Carrow and Duncan, 1998; Harvandi et al, 1992). Data on the salinity tolerance of Idaho bentgrass and prairie junegrass have not been documented in any scientific literature to date. The objective of this research was to determine the relative salinity tolerance of these four species.

Material and Methods

This research was initiated in January 1998 (experiment 1) to evaluate the salt tolerance of four native grasses. The entries were 'Barkoel' prairie junegrass, 'Bad River' blue grama, 'Golfstar' Idaho bentgrass and alkali grass planted in a randomised complete block design with four replicates. The first three entries were selected as a result of their exceptional turfgrass quality as shown in previous research at the University of Manitoba (Mintenko and Smith, 1998, 1999). Barkoel prairie junegrass was selected from northern Europe and has undergone an intensive turfgrass selection and breeding program. Golfstar Idaho bentgrass was selected from across the North American Rocky mountain region and was also subjected to an intensive turfgrass selection and breeding program. Bad River blue grama was an ecotype collected from a native stand in South Dakota. The alkali grass used in this study was an ecotype from North Dakota. Treatments consisted of a normal water control and saline (NaCl) water both applied using subirrigation.

A double-walled container was used for this study, consisting of an outer water jacket and an inner wooden plant container (100 cm x 30 cm x 20 cm) with a mesh bottom (Figure 10.0). The outer water jacket was filled every three weeks with water or a saline solution to a level even with the soil surface of the plant container (Figure 11.0). With this technique the inner plant container absorbed the moisture through capillary action through the bottom. Therefore, the entire watering process occurred without disturbing the soil within the inner plant container (Ahti et al, 1980). The soil medium was a mixture of clay and sandy loam soil (20% clay, 40% sand, and 40% silt).

Each entry was seeded at 6mm depth in 11 rows with a 4cm row spacing. There were two entries per container with a 14 cm spacing between entries. The experiment was conducted in a controlled environmental chamber with a 15 hour photoperiod and 20°C day/ 15°C night temperature. After emergence, seedlings were then thinned to 100 plants per entry per replicate and allowed to grow for 40 days before the saline solution treatment was initiated. Watering during this initial period followed the process described below for the saline solution treatment.

Following the Ahti et al (1980) salinization procedure, initial salinization used a 1.00% NaCl solution along with a soluble fertiliser applied at the rate of 25kg N, 25kg P, 25kg K ha^{-1}. The saline solution was poured into the outer jacket level to the soil surface of the inner container, after 30-40 minutes, the excess saline solution was drained from the outer water jacket. The salinity content of the soil increased in this closed system with repeated applications of the saline solution. Both the control and saline solution treatment were subirrigated in this manner on 22 February, 9 March, 23 March 20 April, 11 May and 25 May 1998. Salinity levels were monitored throughout the study by determining the electrical conductivity of the soil and removing soil samples before each repeated treatment (Table 1)(Ahti et al, 1980). Plants were clipped weekly at 38mm with clippings removed. Flats were maintained in the growth chamber for 79 days. The primary salinity tolerance measurements were based on weekly regrowth, plant mortality and visual turfgrass quality ratings (where 1= poor and 9 = ideal turfgrass). Visual turfgrass quality ratings involve the factors of turfgrass colour, texture and overall environmental stress (plant mortality, disease) of the grass. A rating of 5-6 indicates an adequate turfgrass quality, while a rating of 9 indicates the ideal turfgrass quality. Measurements were recorded weekly from 2 March until 25 May, 1998.

This experiment was repeated (experiment 2) using more mature grasses (approximately 5 months old). The saline solution treatments, and measurements followed the procedures outlined in experiment 1. However no control treatment was used in experiment 2. Treatments were started on 10 June and repeated on 29 June, 20 July, 5 August, and August 27, 1998. Measurements were recorded again weekly starting 15 June until 15 September, 1998.

Analysis of variance (ANOVA) was conducted on entry means using the statistical analysis system (SAS, 1991) where entries were considered fixed effects and replications considered random effects (Little and Hills, 1978). Entry means within each measurement date were compared using Fisher's protected least significant difference procedure.

Results and Discussion

As expected, the alkali grass entry showed high levels of salinity tolerance as an advanced seedling (experiment 1) and at the mature plant stage (experiment 2) at severe soil salinity levels (soil conductivity greater than 12 mC cm^{-1}). Although alkali grass regrowth after clipping was reduced with increasing salinity, no plant mortality occurred for the duration either experiment (Tables 10, 11 and 13) (Figure 12.0). Turfgrass quality of this entry remained high at the advanced seedling stage (experiment 1) with ratings ranging from 7 to 8 (9 being ideal turf, 1 equaling poor turf quality) (Table 9). At the mature plant stage (experiment 2) this entry showed reduced tolerance to clipping stress with turfgrass quality decreasing from 7 to 5, but this was still considered adequate (Table 12).

Bad River blue grama, Golfstar Idaho bentgrass and Barkoel junegrass exhibited 50% plant mortality at the advanced seedling stage (experiment 1) (Table 10), inadequate turfgrass quality (quality rating less than 5)(Table 9) and reduction in regrowth (Table 11, Figure 12.0) at soil salinity levels ranging from slightly to moderately saline (soil conductivity 4-12 mC cm^{-1}). Although references are limited, these species are generally considered moderately tolerant of saline soil levels (Carrow and Duncan, 1998).

At the mature plant stage the blue grama, Idaho bentgrass and prairie junegrass entries exhibited 50% plant mortality (Table 13) and inadequate turfgrass quality (quality rating less than 5) (Table 12) at moderate saline soil levels. The lower initial mortality levels for the Barkoel prairie junegrass is due to its slow reaction to any stress, as observed in the drought and mowing studies of this research project. Compared to the advanced seedling stage, these entries were more tolerant of moderately saline soil levels (soil conductivity 8-12 mC cm^{-1}) at the mature grass stage. It is not uncommon for the effects of soil salinity on grasses to be different at various stages of maturity. Past studies have shown that two traditional turfgrasses, Kentucky bluegrass and creeping bentgrass may be more sensitive to soil salinity during germination and early seedling growth (Lund et al, 1961). This statement appears to hold true for these experiments as well.

Since no control treatment was available for the mature growth stage (experiment 2), regrowth comparisons between control and salinity treatments were not possible within entries. Plant mortality and turfgrass quality were still valid indicators of saline tolerance between entries. Actually, for a turfgrass to be considered tolerant or sensitive to saline soil, the turfgrass quality rating (which takes into account plant mortality) is more important than plant regrowth. In other words, high levels of regrowth (total yield) are not as important as the aesthetics. In some cases reduced growth is even an advantage by reducing mowing frequency. Therefore, regrowth rate does not need to be at optimum levels, but only at levels adequate for good wear tolerance (Carrow and Duncan, 1998).

Summary

In conclusion, these results show that alkali grass is very tolerant of severe saline soil levels at both the advanced seedling and mature plant stage. Bad River blue grama, Golfstar Idaho bentgrass and Barkoel prairie junegrass are moderately tolerant of slightly saline soil levels as seedlings and tolerant of moderately saline soil levels as mature plants. Although the alkali grass entry tested in these experiments was saline tolerant, other alkali grass cultivars or ecotypes more tolerant of mowing stress would be more desirable.

All of these entries in these experiments are suitable for planting under moderate saline soil conditions. Different varieties or selections of these species may respond differently to variations in soil salinity levels, shown by Horst and Taylor (1983) with Kentucky blue grass and by Horst and Beadle (1984) with tall fescue. These conclusions were based on a short term salinity study under controlled environmental conditions. Further research should be conducted with these entries/ species under various environmental conditions and soil types to determine the robustness of these findings (Harivandi et al, 1992).

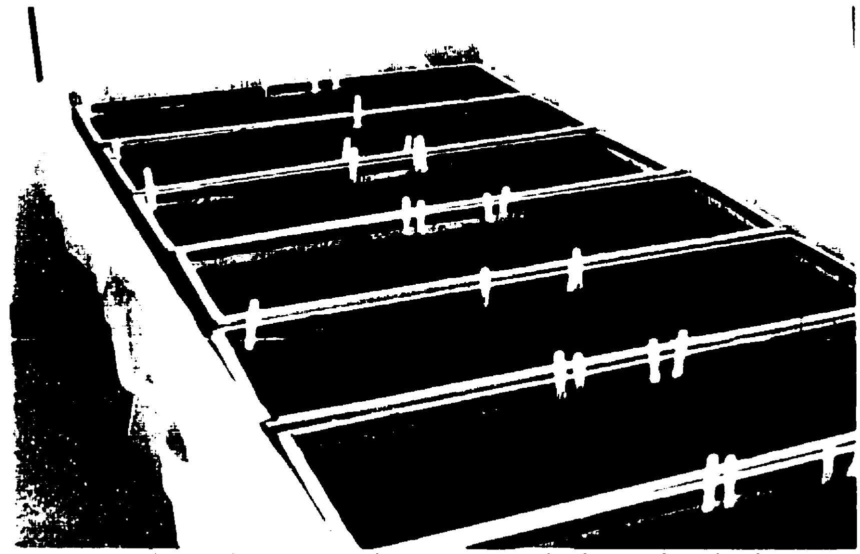


Figure 10.0. Salinity tolerance experiment grass entries in wooden planting trays placed inside a plastic lined container which allows for sub-irrigation of the soil column.

Figure 11.0. Salinity tolerance experiment showing subirrigation of native grasses in wooden planting trays placed inside a plastic lined container.

Table 9. Turfgrass quality of four native grass entries evaluated as seedlings at increasing levels of soil salinity (Experiment 1).

Entry	Measurement Date											
	9 March	16 March	23 March	30 March	6 April	13 April	20 April	27 April	5 May	May-11	19 May	25 May
	1-9 Scale†											
Alkali grass	9.00	8.00	8.00	7.50	8.75	7.25	8.50	8.25	7.50	7.00	7.00	7.00
Bad River blue grama	8.50	6.25	4.75	3.25	2.00	1.50	1.25	1.00	1.00	1.00	1.00	1.00
Golfstar Idaho bentgrass	8.00	6.00	4.75	3.00	2.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00
Barkoel prairie junegrass	8.00	6.50	5.25	3.75	3.25	2.25	2.00	1.25	1.00	1.00	1.00	1.00
LSD‡	0.88	1.99	1.54	1.33	1.43	0.96	0.54	0.59	0.46	0.00	0.00	0.00
Soil Salinity Level (mC cm^{-1})	3.00	3.00	5.60	5.60	5.60	7.60	7.60	13.30	13.30	13.30	17.80	17.80
Soil Classification	Salinity Warning		Slightly Saline			Moderately Saline				Severely Saline		
Salinity Tolerance	Moderately Sensitive		Moderately Tolerant			Tolerant				Very Tolerant		

†Turfgrass quality rating scale: 1-9, 1=poor, 9=ideal turf.

‡ Means within a column may be compared with each entry and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 10. Plant mortality of four native grass entries at the seedling stage grown under increasing levels of soil salinity (Experiment 1).

Entry	Measurement Date											
	9 March	16 March	23 March	30 March	6 April	13 April	20 April	27 April	5 May	May-11	19 May	25 May
	% mortality											
Alkali grass	0.00†	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bad River blue grama	2.00	1.75	18.75	38.75	69.00	76.75	92.50	92.00	93.25	95.00	96.00	98.00
Golfstar Idaho bentgrass	3.25	9.25	10.75	39.50	64.50	81.50	94.50	93.25	97.00	96.75	97.25	98.75
Barkoel prairie junegrass	4.00	4.50	3.25	21.75	40.25	56.50	84.50	79.00	85.00	87.75	91.25	96.75
LSD‡	6.45	10.87	11.10	23.12	31.84	22.11	7.11	9.52	8.81	7.66	64.17	3.64
Soil Salinity Level (mC cm^{-1})	3.00	5.60	5.60	5.60	5.60	7.60	7.60	13.30	13.30	17.80	17.80	17.80
Soil Classification	Salinity Warning		Slightly Saline			Moderately Saline				Severely Saline		
Salinity Tolerance	Moderately Sensitive		Moderately Tolerant			Tolerant				Very Tolerant		

† Out of a total of 100 plants per plot.

‡ Means within a column may be compared with each entry and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 11. Regrowth from four native grass entries at the seedling stage one week after clipping at 32 mm and subirrigated with saline water (1% concentration) or normal water treatments (Experiment 2).

Entry	Measurement Dates								
Salt Treatments	16 March	23 March	30 March	6 April	13 April	20 April	27 April	5 May	11 May
	mm								
Alkali grass	88.75	100.00	81.25	65.00	77.50	67.50	65.00	68.75	62.5
Bad River blue grama	95.00	81.25	66.25	56.25	56.25	46.25	41.25	40.00	40.00
Golfstar Idaho bentgrass	72.50	70.00	63.75	50.00	58.75	46.25	41.25	40.00	40.00
Barkoel prairie junegrass	61.25	63.75	62.50	51.25	56.25	47.50	42.50	40.00	40.00
LSD†	13.33	13.21	10.41	12.08	12.29	7.54	3.26	5.99	2.30
Control									
Alkali grass	127.5	100	120	82.5	61.25	92.5	103.75	95	117.5
Bad River blue grama	131.25	128.75	126.25	102.5	80	91.25	98.75	97.5	103.75
Golfstar Idaho bentgrass	98.75	72.5	107.5	67.5	58.75	81.25	87.5	76.25	87.5
Barkoel prairie junegrass	63.75	65	76.25	66.25	68.75	78.75	81.25	76.25	88.75
LSD†	16.54	9.06	18.19	8.86	16.66	11.77	20.69	25.23	17.32
Salt vs. Control Growth									
	%								
Alkali grass	69.61‡	100.00	67.71	78.79	100.00	72.97	62.65	72.37	53.19
Bad River blue grama	72.38	63.11	52.48	54.88	70.31	50.68	41.77	41.03	38.55
Golfstar Idaho bentgrass	73.42	96.55	59.30	74.07	100.00	56.92	47.14	52.46	45.71
Barkoel prairie junegrass	96.08	98.08	81.97	77.36	81.82	60.32	52.31	52.46	45.07
Soil Salinity Level	3.00	5.60	5.60	5.60	7.60	7.60	13.30	13.30	17.80
Soil Classification	Salinity Warning	Slightly Saline			Moderately Saline		Severely Saline		
Salinity Tolerance	Moderately Sensitive	Moderately Tolerant			Tolerant		Very Tolerant		

† Means within a column may be compared with each entry and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD. ‡ This represents the total regrowth for each entry measured one week after clipping after comparing salinity treatments to control treatments using the equation (salt treatment/ control treatment X 100).

Table 12. Turfgrass quality of four native grass entries evaluated as mature plants growing in increasing soil salinity (Experiment 2).

Entry	Measurement date											
	15 June	25 June	29 June	6 July	13 July	20 July	27 July	5 Aug.	10 Aug.	17 Aug.	24 Aug.	31 Aug.
	1-9 Scale†											
Alkali grass	7.75	7.75	7.00	5.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Bad River blue grama	7.75	7.75	7.75	5.50	4.00	3.75	2.25	1.75	7.75	1.50	1.25	1.00
Golfstar Idaho bentgrass	8.00	8.00	7.25	4.50	2.75	1.75	1.25	1.00	1.00	1.00	1.00	1.00
Barkoel prairie junegrass	8.75	8.75	9.00	7.50	4.75	4.75	4.00	2.75	1.00	1.00	1.00	1.00
LSD‡	0.85	0.85	0.54	0.65	0.88	0.96	1.07	0.76	0.76	0.46	0.39	0.00
Soil Salinity Level (mC cm^{-1})	2.80	2.80	2.80	8.70	8.70	8.70	10.1	10.1	10.1	10.3	10.3	10.3
Soil Classification		Salinity Warning			Moderately Saline				Moderately Saline			
Grass Salinity Tolerance		Moderately Sensitive			Tolerant				Very Tolerant			

† Turfgrass quality rating scale: 1-9, 1=poor, 9=ideal turf.

‡ Means within a column may be compared with each entry and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

Table 13. Plant mortality of four native grass entries evaluated as mature plants growing in increasing soil salinity (Experiment 2).

Entry	Measurement Date											
	15 June	25 June	29 June	6 July	13 July	20 July	27 July	5 August	10 Aug.	17 Aug.	24 Aug.	31 Aug.
	% mortality											
Alkali grass	0.00†	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bad River blue grama	0.00	0.00	0.00	0.25	0.00	48.75	86.75	84.50	89.50	92.00	94.50	95.70
Golfstar Idaho bentgrass	0.00	0.00	0.00	0.00	0.00	87.00	70.00	99.00	99.25	99.50	99.00	99.00
Barkoel prairie junegrass	0.00	0.00	0.00	0.00	0.00	9.75	15.00	94.00	94.25	97.75	99.00	99.00
LSD‡	0.00	0.00	0.00	0.39	0.00	28.79	15.54	14.80	12.07	9.47	5.28	3.41
Soil Salinity Level (mC cm^{-1})	2.80	2.80	2.80	8.70	8.70	8.70	10.1	10.1	10.1	10.3	10.3	10.3
Soil Classification	Salinity Warning			Moderately Saline			Moderately Saline					
Grass Salinity Tolerance	Moderately Sensitive			Tolerant			Very Tolerant					

† Out of a total of 100 plants per plot.

‡ Means within a column may be compared with each entry and are significantly different at the P=0.05 level whenever the difference between two means is equal or greater than the column LSD.

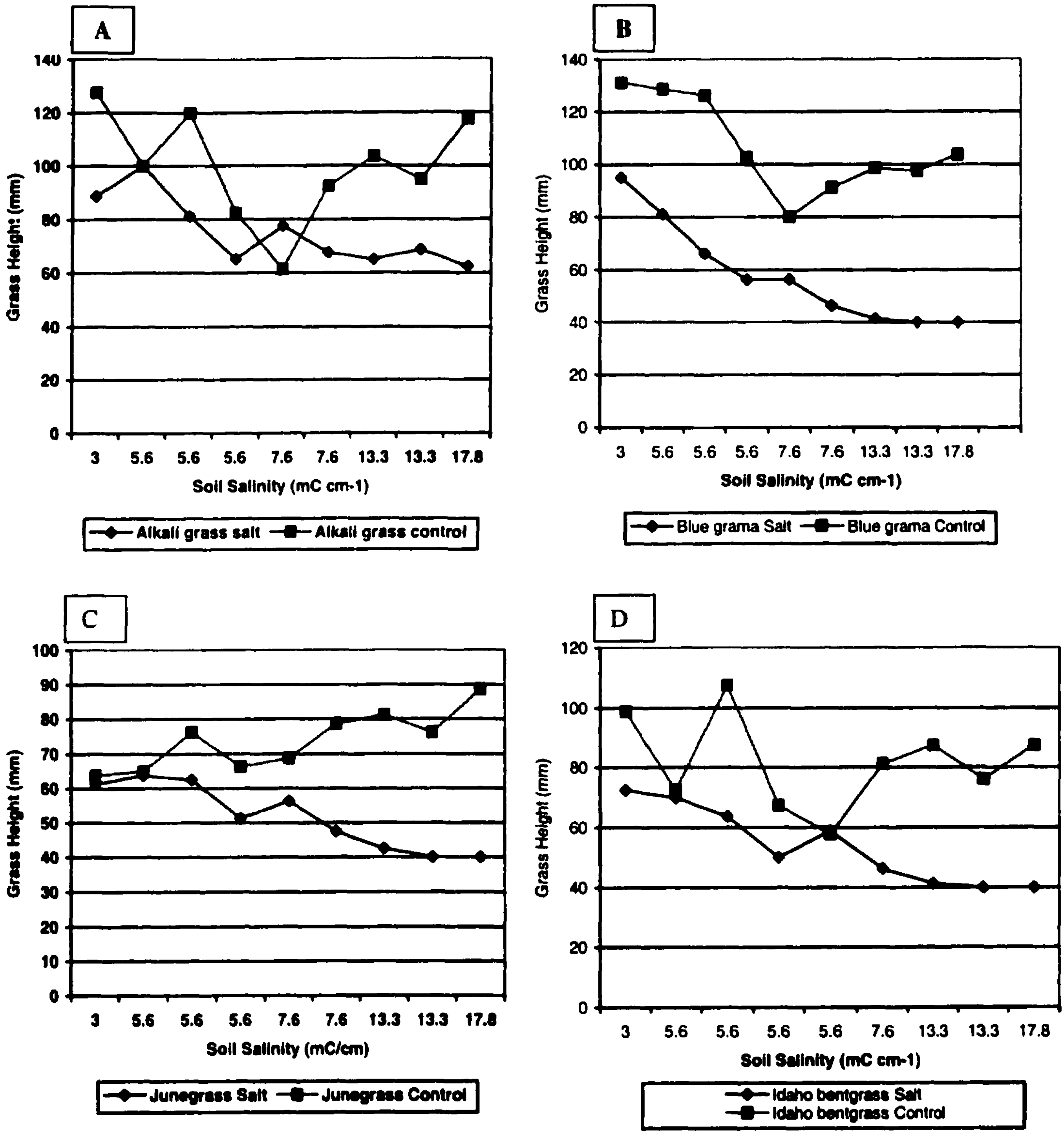


Figure 12.0.Experiment I. The effect of increasing soil salinity on regrowth of four native grass entries compared to regrowth of a control. Measured one week after weekly clipping at 38 mm. Entries: (A)alkali grass, (B) Bad River blue grama, (C) Barkoel prairie junegrass, (D) Golfstar Idaho bentgrass. Regrowth measurements recorded weekly for the duration of the experiment.

Manuscript 3:

Drought Tolerance of Several Native Grasses

Abstract

With more and more cities across North America restricting water use, the demand for more drought tolerant turfgrasses has increased. Grasses native to North America are being investigated since many of these grasses have evolved in drought prone regions. The objective of this research was to determine the drought tolerance of several native grass species. The following native grasses were included: 'Bad River' blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), 'Sharps Imp. II' buffalograss (*Buchloe dactyloide* [Nutt.] Engelm.), 'Barkoel' prairie junegrass (*Koelaria marcrantha* [Ledeb.] Schultes), Alberta ecotype prairie junegrass, 'Seaborne' rough hairgrass (*Agrostis scabra* Willd.), 'Golfstar' Idaho bentgrass (*Agrostis idahoensis*) and 'Nortran' tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.). Native grasses were evaluated in (1) a field experiment on a well drained, sand based research golf green with limited irrigation, and (2) greenhouse lysimeters with various levels of soil moisture. Measurements of turfgrass quality and regrowth were used to determine drought tolerance. The field and greenhouse experiments showed that Barkoel prairie junegrass had moderate drought tolerance. Barkoel's rapid root establishment may have been a factor in its drought tolerance and quick recovery. Field experiments showed buffalograss and blue grama (warm season grasses) extremely drought tolerant. They maintained their green colour during periods of extreme drought, while the remaining cool season grass entries "browned off". These experiments confirmed the extreme drought tolerance of buffalograss and blue grama and suggest they can be recommend for drought prone turfgrass areas.

Manuscript 3 - Drought Tolerance of Selected Native Grasses

Introduction

With drought conditions occurring more often throughout North America and the public pressure on the turfgrass industry to become more sustainable, the need for low-maintenance, drought tolerant turfgrass cultivars is greater than ever (Koski, 1999). Many of the turfgrass species that are traditionally planted across the Great Plains region require inputs of water to maintain competitiveness (Aronson et al, 1987; Ebdon et al, 1999). Species such as Kentucky bluegrass (*Poa pratensis* L.) and creeping red fescue (*Festuca rubra* L.) brown off under the extreme dry weather conditions that occur during the summer. Researchers have started to explore the untapped potential of grasses native to the Great Plains region of North America for low-maintenance, drought tolerant turfgrasses. A drought tolerant turf will maintain turfgrass quality, colour and density in extreme moisture deficient conditions.

Native grasses have evolved under the low moisture and extreme temperature conditions of the Great Plains region. Most drought tolerant studies have concentrated on the traditional turfgrass species, tropical warm season grasses and buffalograss (*Buchloe dactyloide* [Nutt.] Engelm.) (Biran et al, 1981; Bowman et al, 1998; Feldhake et al, 1983, 1984; Fry and Butler, 1989; Hook et al, 1992; Huang et al, 1997). Specific drought tolerance of many native grasses has not yet been studied, with the exceptions stated above. The objective of this research was to determine relative potential drought tolerance of several native grass species.

Material and Methods: Experiment 1-Field Drought Tolerance Study

A field drought study was seeded 25 June 1997 on a USGA specification golf putting green (research golf green) using the following native grass entries: 'Bad River' blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), 'Sharps Imp. II' buffalograss, 'Barkoel' prairie junegrass (*Koelaria marcrantha* [Ledeb.] Schultes), 'Seaborne' Rough hairgrass (*Agrostis scabra* Willd.), 'Golfstar' Idaho bentgrass (*Agrostis idahoensis*) and 'Nortran' tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.). The blue grama and buffalograss entries are warm-season grasses and the remainder are cool-season grasses. The research golf green site (Plant Science Department's Fort Garry research station, Winnipeg, MB) was selected for its sand media with its low water holding capacity and ideal drainage. Without supplemental irrigation, drought conditions will definitely occur during the growing season. The research golf green profile consisted of a base system of drainage tile covered with 20cm of 5mm pea gravel and then covered with 30-60 cm of 80% 2 mm course sand and 20% peat soil mix.

Seeding rate for all entries was 10 g m^{-2} with the exception of Idaho bentgrass, which was seeded at 5 g m^{-2} due to its smaller seed size. With the exception of the rough hairgrass and buffalograss, all entries showed adequate emergence. Plots were fertilised in mid-August 1997 with a soluble fertiliser at the rate of 50kg N, 50kg P, 50kg K ha $year^{-1}$. The entire experiment was sprayed with snow mold fungicide at the recommended turfgrass rate in September 1997 and covered with Famcomat (fiberglass mat cover manufactured by AAF International, Lousiville, KY, USA) over the winter to provide insulation from extreme winter temperatures.

Plot dimensions were 1x2m with 4 replicates, oriented in a randomised complete block design. Mowing was weekly at a height of 38mm with clippings removed. This height simulated the height between a golf course rough and fairway in order to provide sufficient mowing stress to the plants. In 1998, fertiliser was applied on 7 May, 30 June and 11 August 1998 for a total application of 100 kg N, 50 kg P, 75 kg K, ha^{-1} $year^{-2}$.

Rainfall was the source of water with two exceptions. Some moisture was supplied by snowmelt and when soil moisture dropped below 30% of field capacity, 25mm of irrigated water was added. A low soil water condition occurred on 1 August and 10 August 1998 and irrigation was applied on 2 August and 11 August 1998. Irrigation was applied to prevent entries from becoming excessively drought stressed and to avoid unacceptable levels of plant mortality before the field season was complete. Soil water holding capacity was monitored closely, with soil samples obtained every two weeks during the drier periods of the summer (July and August 1998). Samples were dried to determine soil moisture content and compared to the known soil-water field capacity.

Measurements of turfgrass quality, colour and percent ground cover were recorded monthly on 1 June, 2 July, 4 August, 30 August and 28 September 1998. Quality and colour were measured using the NTEP (National Turfgrass Evaluation Program) visual assessment rating system from 1 to 9. Turf visual quality ratings were 1=poor turfgrass, and 9=ideal turfgrass; turf colour ratings were 1=brown, 5=light green, 7=blue-green, and 9=dark green. Visual turfgrass quality ratings involve the factors of turfgrass colour, texture, density and overall environmental stress (plant mortality and disease) of the grass. A rating of 5-6 indicates an adequate turfgrass quality, while a rating of 9 indicates the ideal turfgrass quality desired in the specific study. Percent visual ground cover ranged from 0-100 percent. Root mass was measured from 0-15cm and 15-30 cm soil core samples obtained on 4 June, 6 July, 6 August and 10 September 1998. Soil cores had the roots washed with water to remove soil with a 2mm wire screen used to collect any root material dislodged from the root mass. No sand remained in the root material that could have biased root weights, because the sized sand grains all passed through the 2mm screen.

Monthly data were analysed as randomised complete blocks keeping dates separate for turfgrass quality, colour and percentage ground cover since an analysis combining all dates had a significant interaction between dates and could not be pooled together. Root core data was log transformed to normalise the data and dates were combined for these data since interactions between dates was not significant. Data were analysed at every measurement date between entries using analysis of variance (ANOVA) with the statistical analysis system (SAS, 1991).

Results and Discussion: Experiment 1-Field Drought Tolerance Study

As mentioned previously, this experiment was established on a research golf green with a soil composition of 80% sand and 20% peat based. Buffalograss prefers growing on heavier soil types (Musser, 1962) and as a result was very slow to establish on the sand based green. Buffalograss plots had less than 50% plot ground cover until late fall of 1998, almost 2 years after seeding. This low ground cover percentage lowered the turfgrass quality ratings for buffalograss. All other entries, with the exception of Barkoel prairie junegrass, had poor (<60% ground cover) or very slow establishment on the sand green. The rate of establishment for all entries were lower than expected from previous turfgrass evaluation studies seeded on a clay-loam soil at the same location (Mintenko and Smith 1998, 1999). Whether the sand soil hindered establishment, or other factors were involved, has not been determined. For the cool-season grasses, establishment was further hindered in 1998 by low moisture conditions, causing increased plant mortality and therefore a reduction or no increase in ground cover. All entries drought stress was pushed to their extreme limits, resulting in increased plant mortality rates for the cool-season grass entries.

The poor ground cover ratings had a definite negative impact on quality, therefore turfgrass colour ratings provided a better method to help determine drought tolerance. In periods of extreme drought most grasses will go dormant and begin "browning off". This situation can be observed at the 4 August 1998 when all cool-season grasses, with the exception of rough hairgrass, showed lower colour ratings than in June/ July 1998 when soil moisture was adequate (Table 15). The two warm-season grasses, blue grama and buffalograss, both known as a drought tolerant species, maintained their desired turfgrass colour (Table 15) (Figure 13.0).

The warm-season grasses in this experiment, buffalograss and blue grama, showed tremendous drought tolerance, remaining green while the cool-season entries browned off (Table 15) (Figure 14.0). If these entries had established better on the sand green, their turfgrass quality would have been at near ideal levels. Barkoel prairie junegrass had high percentage ground cover (Table 16) and showed quick recovery from extreme drought stress as indicated by its low colour ratings on 4 August and high colour rating on 30 August 1998 (Table 15). Rough hairgrass showed adequate drought tolerance, maintaining green colour even during the period of extreme drought (4 August 1998). Unfortunately, its very thin appearance and low percentage ground cover resulted in poor turfgrass quality ratings (Tables 14 and 16). Rough hairgrass is common on the prairies on moist areas and may prefer heavier soils for establishment (Looman, 1982). Previous evaluations of this species have shown successful establishment on clay loam soils (Mintenko and Smith, 1998, 1999). The lack of competition between individual grasses of rough hairgrass throughout the plots may explain why rough hairgrass was able to maintain a green colour during drought. There may have been sufficient soil moisture present at these low plot density levels that drought stress was limited. Other entries with similar low percent ground cover were patchy in appearance compared to the uniform thin density of rough hairgrass. Given the low percent ground cover, each plant had greater soil volume to extract water.

Idaho bentgrass had excellent turfgrass colour (Table 15), adequate ground cover (Table 16) and turfgrass quality (Table 14) until the late summer drought period. At this point severe browning off occurred reducing turfgrass quality from adequate to poor levels (Table 14). Recovery from the August drought stress did not take place until the onset of cooler temperatures in late September (Figure 15.0).

Soil core measurements reflect the extent to which each entry had established an extensive rooting system from the soil surface to 30cm. Turfgrass roots are usually limited to the top 10cm of the soil column as a result of mowing (Madison, 1971). Cool season grasses that are drought tolerant tend to have extensive and deep rooting systems to extract maximum soil water. Warm season grasses tend to have shallower rooting systems than cool season grasses, but are more efficient users of available water (Qian et al, 1997).

Soil core samples for all entries only showed significant root mass in the 0-15cm zone. Any roots contained in the 15-30cm soil core were either absent or washed through the 2mm screen used to capture the roots during soil removal. Barkoel prairie junegrass had double the root weight in 0-15cm zone of the soil sample compared to all other entries. This may have contributed to its quick recovery from drought stress. However, the less extensive root system of the warm-season grass entries did not to hinder drought tolerance. Low root mass in Idaho bentgrass and tufted hairgrass may have been factor for their low drought tolerance and slow recovery to drought stress (Table 17).

Summary: Experiment 1-Field Drought Tolerance Study

Overall, this experiment verified the excellent drought tolerance of buffalograss and blue grama. These species can be recommended for drought prone situations on clay and loam soils. Buffalograss and blue grama provide useful comparisons in drought tolerance studies involving cool season grasses. Rough hairgrass also showed adequate drought tolerance. However, due to its low establishment success on the sand green, further drought studies need to be conducted before any recommendations can be made for this species. Future drought studies should be conducted over a range of different soil types to help clarify the drought tolerance of these entries.

Figure 13.0. Field drought study showing extreme differences in drought tolerance. Green plots are blue grama and buffalograss and the brown / yellow plots are the cool-season grass entries. August 1998, Winnipeg, MB.

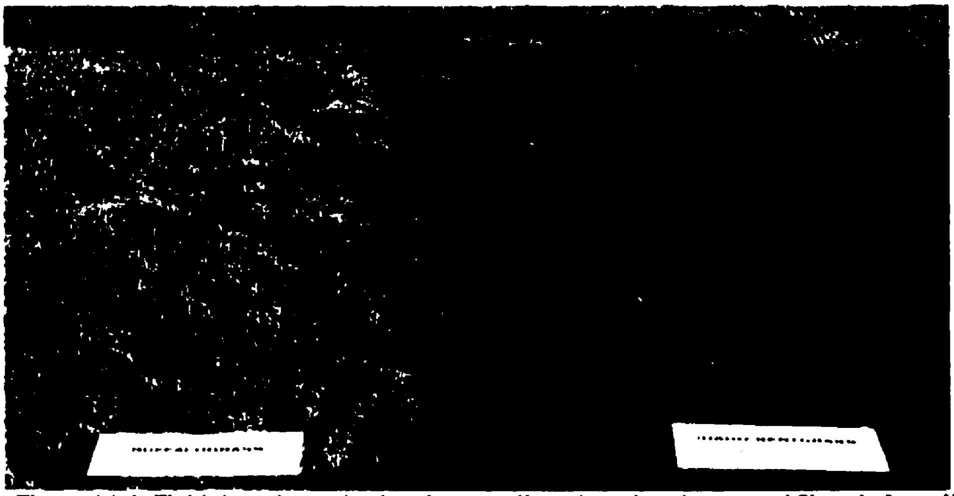


Figure 14.0. Field drought study showing excellent drought tolerance of Sharp's Imp..II buffalograss with its typical blue-green colour (left), compared to the poor drought tolerance and browning off of Golfstar Idaho bentgrass (right). August 1998, Winnipeg, MB.

Table 14. Turfgrass quality of 6 native grasses evaluated on a research golf green mowed weekly at 38mm for the 1998 field season at Winnipeg, MB.

Entry	Measurement Date				
	01-Jun	02-Jul	04-Aug	30-Aug	28-Sep
	---------- 1-9 Scale† ----------				
Bad River blue grama	4.00b	4.50b	4.00b	5.00a	5.00ab
Barkoel prairie junegrass	7.25a	7.50a	5.00a	4.50a	5.25a
Golfstar Idaho bentgrass	4.00b	4.50b	2.00c	2.50b	4.00c
Nortran tufted hairgrass	4.25b	3.75b	2.00c	2.00b	3.00d
Rough hairgrass	4.00b	3.50bc	2.00c	4.25a	4.25bc
Sharp's Imp. II buffalograss	2.75c	2.50c	4.00b	4.75a	3.50cd
Soil Water Conditions‡	adequate	adequate	limited	limited	limited

† Means in the same column followed by the same letters are not statistically different at P=0.05. Turfgrass quality scale 1-9, 1=poor quality and 9=ideal quality.
‡ Soil water conditions determined by field soil water analysis and monthly precipitation amounts.

Table 15. Turfgrass colour of 6 native grasses evaluated on a research golf green mowed weekly at 38mm for the 1998 field season at Winnipeg, MB.

Entry	Measurement Date				
	01-Jun	02-Jul	04-Aug	30-Aug	28-Sep
	1-9 Scale†				
Bad River blue grama	6.25c	7.00c	7.00a	7.00a	7.00c
Barkoel prairie junegrass	8.00b	8.00b	2.25c	7.00a	8.25b
Golfstar Idaho bentgrass	9.00a	9.00a	2.00c	4.00b	9.00a
Nortran tufted hairgrass	8.00b	7.00c	2.25c	4.00b	8.00b
Rough hairgrass	6.25c	7.00c	7.00a	7.00a	7.00c
Sharp's Imp. II buffalograss	4.75d	7.00c	6.25b	7.00a	5.00d
Soil Water Conditions‡	adequate	adequate	limited	limited	limited

† Means in the same column followed by the same letters are not statistically different at P=0.05. Turfgrass colour scale 1-9, 1=brown and 9=dark green.
‡ Soil water conditions determined by field soil water analysis and monthly precipitation amounts.

Table 16. Percent ground cover of 6 native grasses evaluated on a research golf green mowed weekly at 38mm for the 1998 field season at Winnipeg, MB.

Entry	Measurement Date				
	01-Jun	02-Jul	04-Aug	30-Aug	28-Sep
	%				
Bad River blue grama	57.50bc	60.00b	57.50bc	60.00bc	60.00b
Barkoel prairie junegrass	77.50a	82.50a	83.75a	88.75a	72.50a
Golfstar Idaho bentgrass	60.00b	61.25b	61.25b	65.00bc	57.50b
Nortran tufted hairgrass	62.50b	55.00bc	58.75bc	67.50b	55.00b
Rough hairgrass	52.50c	50.00c	52.50cd	57.50c	58.75b
Sharp's Imp. II buffalograss	37.50d	33.75d	50.00d	57.50c	58.75b
Soil Water Conditions‡	adequate	adequate	limited	limited	limited

† Means in the same column followed by the same letters are not statistically different at P=0.05. Ground cover rating scale 0-100 percent.

‡ Soil water conditions determined by field soil water analysis and monthly precipitation amounts.

Table 17. Root mass from soil core samplings to a depth of 30 cm of 6 native grasses evaluated on a research golf green mowed weekly at 38mm for the 1998 field season at Winnipeg, MB.

Entry	Measurement Date				
	4-June	6-July	6-Aug.	10-Sept.	Average
	g				
Bad River blue grama	2.89a†	3.04b	2.84b	5.34b	3.71b
Barkoel prairie junegrass	5.06a	19.69a	19.29a	24.37a	17.16a
Golfstar Idaho bentgrass	5.77a	4.87b	4.67b	4.39b	4.92b
Nortran tufted hairgrass	6.81a	5.96b	5.29b	5.01b	5.77b
Rough hairgrass	4.75a	6.64b	4.70b	5.72b	5.46b
Sharp's Imp. II buffalograss	3.58a	3.26b	2.42b	6.08b	3.65b

† Means in the same column followed by the same letters are not statistically different at P=0.05. Significance based on transformed data (log(x+1)),but values reported are actual heights.

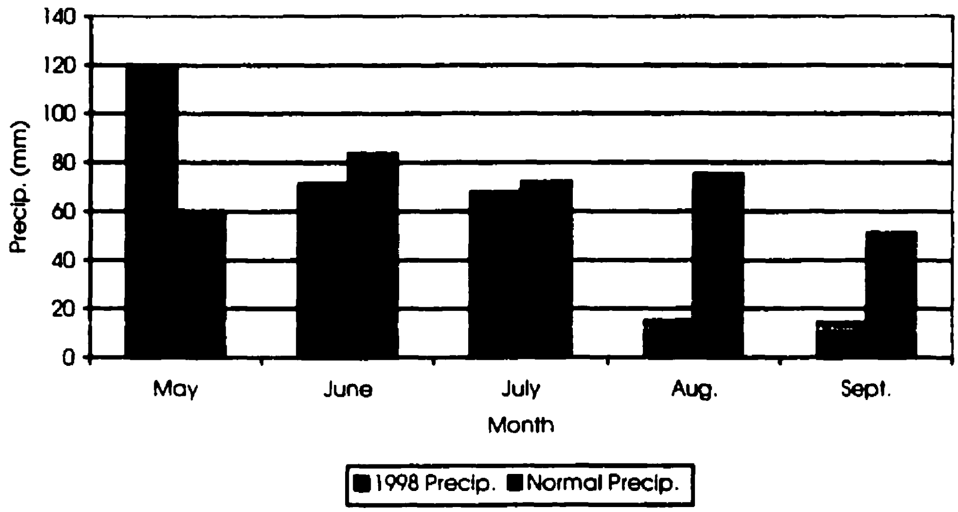


Figure 15.0. Monthly precipitation at Winnipeg, Manitoba, Canada for 1998 field season and 1961-1990 average. 1998 field season precipitation data from University of Manitoba Plant Science's weather station and average monthly precipitation 1961-1990 data from Environment Canada's Winnipeg International Airport weather station.

Material and Methods : Experiment 2- Greenhouse Drought Tolerance Study

A controlled environmental drought tolerance experiment was conducted in the Department of Plant Science greenhouse research facilities at the University of Manitoba. Entries included Bad River blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths) and Barkoel junegrass (*Koeleria macrantha* [Ledeb.] Schultes) and a prairie junegrass (*Koeleria macrantha* [Ledeb.] Schultes) native to Alberta. Space and equipment limited the number of entries studied. The experimental design was a randomised complete block with five replicates and soil moisture treatments were randomised within each replicate for each entry. The first two entries were selected as a result of their exceptional quality in the turfgrass evaluation of native grasses study being conducted presently at the University of Manitoba (Mintenko and Smith, 1998, 1999). The last entry, a prairie junegrass ecotype from Alberta, was used in this experiment to determine the drought tolerance potential of this North American prairie junegrass. Barkoel prairie junegrass was selected from northern Europe and has been through an intensive turfgrass selection and breeding program. Bad River blue grama was an ecotype selected from central South Dakota and is a known drought tolerant species.

Using lysimeters, 5 equally spaced grass seedlings were planted at a radius of 7 cm on 2 March 1998. Grass seeds were first germinated in petri plates and transplanted when roots were approximately 1 cm long. During the first two weeks of the study any dead seedlings were replaced. The soil moisture treatments included: 1) well-watered, 2) semi-drought, and 3) drought conditions. The well-watered treatment was initially kept under near optimum conditions (near field capacity) but several weeks into the study this was found to be excessive and watering was restricted to 95% of field capacity from 19

May 1998 until the end of the study. The semi-drought treatment lysimeters were maintained at 50% field capacity and the drought treatments at 30% field capacity.

Lysimeters consisted of 55cm plastic tubes, 20cm diameter with a plastic cap to seal the bottom. A 75cm long, 2cm diameter plastic pipe was added to the middle of the soil column to allow more uniform moisture distribution when small amounts of water were added. This pipe had holes drilled from 5cm to 45cm down its length and the bottom plugged with a plastic cap. Cotton broadcloth was wrapped around the pipe to prevent soil erosion from occurring around it and to act as a wick (Figure 16.0). All tubes were dropped lightly three times for even bulk density (Bonner, 1997).

All plants were kept at near field capacity for the initial 33 days before treatments were initiated (2 March to 4 April 1998). A sandy loam soil (10% clay, 45% sand, 45% silt) was used with an application of a soluble fertiliser applied one week before treatments were initiated at the rate of 50 kg N, 50kg P, 50kg K ha year^{-1}. Field capacity of the soil was determined using a 20cm diameter, 55cm long plastic tube with a porous bottom, that was filled 2/3 full with the sandy loam soil. The tube was then filled with water until excess water began to flow through the tube base. After 24 hours the soil was weighed then oven dried and weighed again. To calculate field capacity, the dry weight of the soil minus wet weight of the soil was calculated (gravimetric water content of the soil).

The plants were clipped weekly at 38mm with clippings removed and weighed and shoot regrowth measured 7 days later (Figure 17.0). These measurements were recorded and the lysimeters were watered weekly on 14, 20, 27 April; 11, 19, 25 May; 1, 15, 22, 29 June 1998. The experiment was concluded after 79 treatment days, aboveground biomass was weighed, and the soil was washed from the roots to determine total root biomass and root length. Turfgrass quality throughout the experiment was recorded for all entries and treatments. Maximum daily temperatures in the greenhouse averaged between 25-35°C for the duration of the treatment period (Figure 18.0). Daylength was supplemented with artificial lighting for a 16 hour light and 8 hour dark period.

Data were analysed as randomised complete blocks keeping dates separate for the regrowth and leaf weight data since there was an interaction between dates. All data was analysed at every measurement date within treatments and within entries using analysis of variance (ANOVA) with the statistical analysis system (SAS, 1991). To normalise the regrowth and leaf weight data, both were transformed with a log transformation (Little and Hills, 1978). Significance values shown in the tables were based on transformed data, but results shown are original data means.

Results and Discussion: Experiment 2- Greenhouse Drought Tolerance Study

Turfgrass quality remained at near ideal quality levels for all entries and soil moisture levels with no significant changes over the entire study period. Analysis of the data showed no differences in regrowth or leaf weight for either Bad River blue grama and Alberta prairie junegrass across soil moisture levels (Tables 18 and 19). Barkoel prairie junegrass showed a reduction in regrowth and clipped leaf weight for the drought treatment in 5 of the 6 measurement dates. The well-watered and semi-drought treatments for Barkoel junegrass had higher regrowth and leaf weights compared to the drought treatment for the majority of the measurement dates (Tables 18 and 19). The similarity between the well-watered and semi-drought treatments indicate adequate drought tolerance of this entry. These results are consistent with field evaluations that have shown Barkoel prairie junegrass to be moderately drought tolerant (Mintenko and Smith, 1998, 1999). Visual quality of Barkoel junegrass was the same for all treatments, however, the lower regrowth at the drought treatment may reduce wear tolerance in lawn situations.

Barkoel prairie junegrass, a cultivar that was developed after years of breeding and selection, showed rapid emergence and development compared to the Bad River blue grama and Alberta prairie junegrass. Barkoel junegrass plants were substantially larger and better established for all replicates, with over twice the above and below ground biomass compared to the Bad River blue grama and Alberta prairie junegrass (Tables 20 and 21). Treatments were not significantly different for the latter two entries due to their small size and lower plant biomass which resulted in all treatment levels having sufficient water available for growth. These results indicate that future drought studies using this method should only use mature and well established plants.

The rapid establishment of the Barkoel prairie junegrass showed the potential improvements that are possible from a turfgrass breeding and selection program. Both the Bad River blue grama and Alberta prairie junegrass entries have not been selected for turfgrass use and are essentially ecotypes collected from their respective areas of origin. These two entries are both potential candidates for turfgrass selection programs.

Summary Drought Tolerance Experiments 1 and 2

These experiments have provided useful information on the relevant drought tolerance of a number of native species. Experiment 1 verified that the warm-season grasses, buffalograss and blue grama, are drought tolerant species. The ability to maintain an ideal turfgrass colour while the cool-season species browned, indicates that these species can be recommended for drought prone turfgrass areas. Experiments 1 and 2 demonstrated the rapid establishment characteristics of Barkoel prairie junegrass. The early and extensive root growth of Barkoel prairie junegrass allowed this cultivar to have moderate drought tolerance and an ability to quickly recover from drought stress.

More research needs to be initiated with many more native grass species to determine their potential use as low-maintenance and low-input turfgrass. For many native grass species geographical origin can be an important factor in determining tolerance to drought or other environmental stresses. The wide adaptation and range of many of these native grasses (e.g. blue grama ranges from western Canada down to Mexico) mean that their tolerance to environment stress may change with place of origin. Turfgrass breeding and selection programs with blue grama and northern sourced buffalograss need to be initiated to fully exploit the potential of these species as low-maintenance turfgrasses for western Canada and the north central USA.

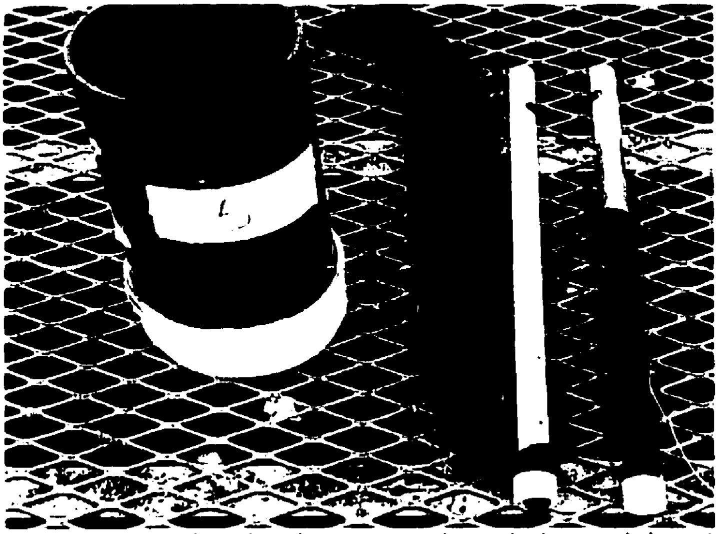


Figure 16.0. Greenhouse drought tolerance experiment lysimeter (left) and watering pipes (right).

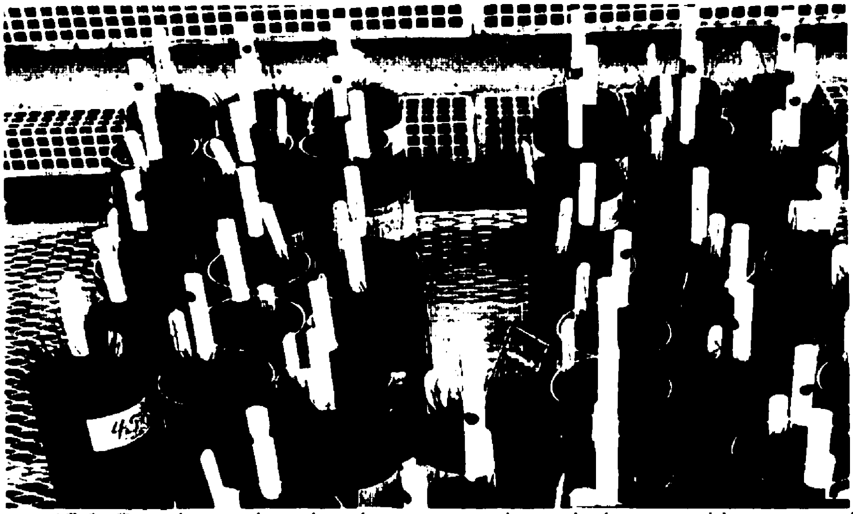


Figure 17.0. Greenhouse drought tolerance experiment lysimeters with grasses subjected to three different soil moisture treatments over 79 days. Treatments: well-watered, semi-drought and drought conditions.

Table 18. Regrowth of three native grasses seven days after clipping (38mm) when subjected to three soil moisture treatments in greenhouse lysimeters.

Entry-Treatment†	Measurement Date					
	25-May	01-Jun	08-Jun	15-Jun	22-Jun	29-Jun
	---------- mm ----------					
Barkoel prairie junegrass						
drought	61.00a‡	66.00a	74.00a	73.00a	76.00a	68.00a
semi-drought	64.00a	68.00a	90.87b	86.12b	87.00a	87.12b
well-watered	80.00b	90.00b	94.00b	93.00b	87.00a	90.00b
Bad River blue grama						
drought	135.00a	103.00a	101.00a	129.00a	127.00a	144.00a
semi-drought	144.00a	98.00a	93.00a	123.00a	115.00a	141.00a
well-watered	150.00a	102.00a	114.00a	118.00a	114.00a	145.00a
Alberta prairie junegrass						
drought	51.00a	57.00a	60.00a	58.00a	54.00a	64.00a
semi-drought	58.00a	55.86a	61.81a	66.36a	70.77a	68.90a
well-watered	60.00a	62.00a	60.00a	62.00a	68.00a	62.00a

† Soil moisture treatments were maintained at 30%, 50% and 95% field capacity for drought, semi-drought and well-watered treatments respectively.

‡ Means in the same column and entry rows followed by the same letters are not statistically different at P=0.05. Significance based on transformed data (log(x+1)),but values reported are actual heights.

Table 19. Leaf weight of three native grasses seven days after clipping (38mm) when subjected to three soil moisture treatments in greenhouse lysimeters.

Entry-Treatment†	Measurement Date					
	25-May	01-Jun	08-Jun	15-Jun	22-Jun	29-Jun
	g					
Barkoel prairie junegrass						
drought	0.212a‡	0.198a	0.306a	0.414a	0.386a	0.400a
semi-drought	0.314ab	0.340a	0.616b	0.746ab	0.724b	0.824b
well-watered	0.466b	0.586b	0.750b	0.902b	0.758b	0.838b
Bad River blue grama						
drought	0.238a	0.122a	0.168a	0.218a	0.184a	0.220a
semi-drought	0.184a	0.080a	0.134a	0.180a	0.118ab	0.174a
well-watered	0.156a	0.064a	0.124a	0.168a	0.074b	0.116a
Alberta prairie junegrass						
drought	0.058a	0.50a	0.120a	0.154a	0.106a	0.146a
semi-drought	0.058a	0.060a	0.130a	0.116a	0.940a	0.122a
well-watered	0.100a	0.062a	0.170a	0.156a	0.192a	0.178a

† Soil moisture treatments were maintained at 30%, 50% and 95% field capacity for drought, semi-drought and well-watered treatments respectively.

‡ Means in the same column and entry rows followed by the same letters are not statistically different at P=0.05. Significance based on transformed data (log(x+1)),but values reported are actual weights.

Table 20. Final above and below ground biomass of three native grasses subjected to three soil moisture treatments in greenhouse lysimeters.

Treatment†	Entry	root length	root weight	above ground weight
		----cm----	---------- g	----------
Drought				
	Barkoel prairie junegrass	24.04a‡	1.57a	4.82a
	Bad River blue grama	22.04a	0.42ab	1.93b
	Alberta prairie junegrass	18.24a	0.15b	1.21b
Semi-drought				
	Barkoel prairie junegrass	26.88a	4.19a	7.27a
	Bad River blue grama	23.86a	0.59b	1.77b
	Alberta prairie junegrass	16.72a	0.18b	1.03b
Well-watered				
	Barkoel prairie junegrass	21.96a	2.93a	7.08a
	Bad River blue grama	21.90a	0.64b	1.97b
	Alberta prairie junegrass	16.16b	0.16b	0.84b

† Soil moisture treatments were maintained at 30%, 50% and 95% field capacity for drought, semi-drought and well-watered treatments respectively.
‡ Means in the same column and treatment rows followed by the same letters are not statistically different at P=0.05.

Table 21. Final above, below ground biomass and total root length of three native grasses subjected to three soil moisture treatments in greenhouse lysimeters.

Entry	Treatment†	root length	root weight	above ground weight
		---cm---	--------------- g	---------------
Barkoel prairie junegrass				
	drought	4.82a†	1.57a	24.04a
	semi-drought	7.27b	4.19ab	26.88a
	well-watered	7.08b	2.93b	21.96a
Bad River blue grama				
	drought	18.24a	0.18a	1.21a
	semi-drought	16.72a	0.16a	1.03a
	well-watered	16.16a	0.15a	0.84a
Alberta prairie junegrass				
	drought	22.04a	0.42a	1.93a
	semi-drought	23.86a	0.59a	1.77a
	well-watered	21.90a	0.64a	1.97a

† Soil moisture treatments were maintained at 30%, 50% and 95% field capacity for drought, semi-drought and well-watered treatments respectively.

‡ Means in the same column and treatment rows followed by the same letters are not statistically different at P=0.05.

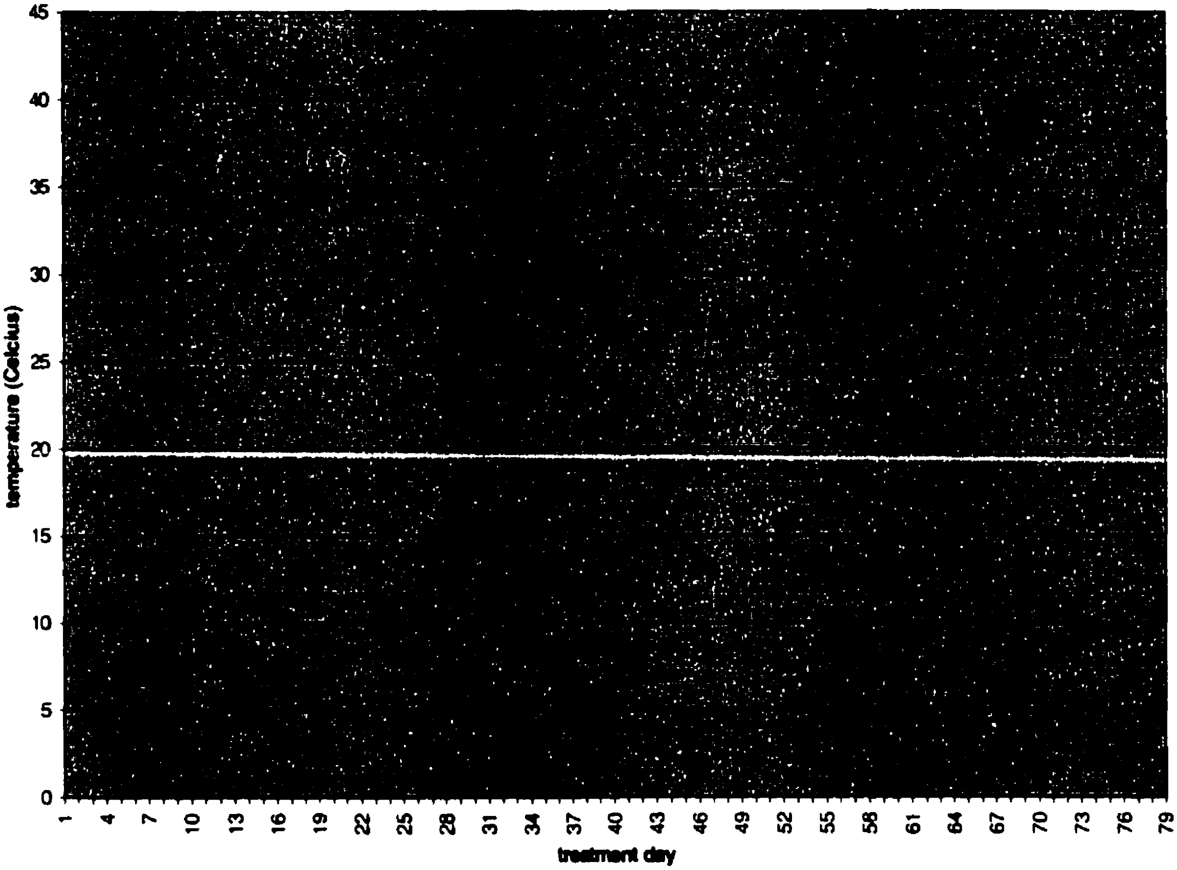


Figure 18.0. Daily maximum temperatures in the greenhouse for the native grass drought study over the 79 day treatment period (14 April to 29 June 1998).

Summary and Conclusion

This research has been successful in identifying several native grass species that have the potential to become low-maintenance turfgrass for western Canada and north central USA. Important management information was also developed including procedures for its establishment, mowing adaptability, disease problems, input requirements and tolerance of environmental stresses.

Under mowing stress, the native grass entries of blue grama, buffalograss, Barkoel prairie junegrass and Golfstar Idaho bentgrass all had high quality, desirable colour and good density. The latter three entries are the result of turfgrass breeding and selection programs, and the success of such programs has been confirmed in this research. Results from the non-mown study showed the suitability of several entries for typical low-maintenance conditions such as golf course roughs and highway right-of-ways. The non-mown experiment also acted as a "control" for the mowed experiment. For example, Canada bluegrass had low quality under all of the mowing heights. The non-mown experiment confirmed that Canada bluegrass leaf growth occurred above the highest mowing height (62mm) used. The buffalograss and blue grama entries maintained low leaf heights even with the absence of mowing, providing acceptable aesthetics for golf course roughs and highway right-of-ways. These entries represent true low-maintenance turfgrasses that would only require one or two mowings a year.

Results from the mowing experiment helped to determine the best turf entries for successive drought and salinity tolerance experiments. The salt tolerance experiments showed that Barkoel prairie junegrass, Bad River blue grama and Idaho bentgrass tolerate moderate saline soil conditions. The drought experiments showed that Barkoel prairie junegrass had moderate drought tolerance and Bad River blue grama and Sharp's Imp.II buffalograss had excellent drought tolerance. These experiments confirmed what was being observed in both the mowed and non-mown studies.

One reason native grasses have not been investigated for turfgrass use has been the common perception that they are difficult to establish as a result of low percent viable seed, low germination and emergence rates as a result of seed dormancy and other factors. These negative impressions have been created because most native seed has been collected from natural stands. Seed used in these experiments came from seed companies or conservation organizations. These native grasses have been subjected to field seed increases and as a result contain a higher percentage of seed from plants with good seed yields and viability. The mowed experiment was hand seeded, covered and irrigated to provide the perfect conditions for seed emergence as would be done with any standard turfgrass seed. No seed priming techniques were used for any of the native grass seed, with the exception of Sharp's Imp.II buffalograss, and yet emergence and establishment were excellent. Repeated successful establishment of these experiments destroys the myth that native grasses are difficult to establish. This may be the most important result from this research, by helping to improve the negative image turfgrass researchers and the general public have had of establishing native grasses.

This research has succeeded in identifying several species that are good candidates for turfgrass breeding and selection programs such as: inland desert saltgrass, alkali grass, blue grama, prairie junegrass, rough hairgrass, tufted hairgrass and fowl bluegrass. These species had entries with adequate turfgrass quality or other attributes (e.g. salt tolerance) worthy of future turfgrass research.

The most surprising discovery from this research has been the high quality of the blue grama. It adapted to mowing stress and infrequent mowing regimes. Other traits desired in a low-maintenance turfgrass include low-growth habit, low fertility and water requirements, pest/ disease tolerant and competitiveness. These traits are also present in blue grama and buffalograss, which explains the success of buffalograss in the USA as a low-maintenance turfgrass. Blue grama, although recommended in popular literature for low-maintenance lawns, has not been thoroughly examined or identified by turfgrass researchers for such use. This research has scientifically shown blue grama to be suitable as a low-maintenance turfgrass. Blue grama can be improved further through a breeding and selection program.

Future Research

Research must continue with the promising entries identified by the present study. A breeding and selection program for blue grama has already been initiated at the University of Manitoba Department of Plant Science. In selecting a low-maintenance turfgrass many management studies need to be completed before any cultivar is released to the public (i.e. long term mowing and wear tolerance).

Other management studies evaluating native grass for turfgrass should examine fertility requirements, optimum seeding rates, mowing heights and water inputs required to maintain a competitive, sustainable long-term turf. Native grasses have the potential for use in unique turfgrass situations (low-input and highly stressed environments) where traditional turfgrasses (e.g. Kentucky bluegrass) fail. Research to find and develop native grasses to fill these special turfgrass niches must be the focus of any breeding and selection program.

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Appendix I: Case Studies Integrating Native Plants into Landscape Design

There are numerous examples of where native plants have been used in landscape design from a variety of areas, ranging from parks, residential yards and industrial sites.

1.0 Texas Highway Department Wildflower Program

Texas has had a long and successful native plant preservation program for its highway right-of-ways since the 1930's. In the 1930's newly formed highway right-of-ways were first colonized by the bluebonnet flower (Texas state flower) and other annual wildflowers. The highway department and garden clubs recognized this valuable and beautiful resource. The highways department changed their mowing timing until after the wildflowers had set seed. The hay from these areas was also spread onto other sites, extending the wildflower habitat (Steffens, 1990).

The Texas highway department has stated that its priorities are foremost highway safety, maintenance and finally aesthetics. This last priority is part of a vegetation management system which works with nature to reduce maintenance costs (mowing) as much as safety allows. This department does not have the "front yard syndrome" of other highway departments where every blade of grass must be mowed down. They believe it is acceptable for grasses to be taller and change with the seasons (Steffens, 1990).

How could other areas start a program similar to Texas? They could first start small, using test areas and compare visual appearance and maintenance costs. Only one or two highway supervisors need to be convinced. Any success and positive feedback they will receive from the program can generate interest from others. In reality mown safety corridors are only required in a 10-12 foot strip off the road shoulder and around signs and other obstructions. In the unmown areas, remaining wildflowers appear distinct and not weedy. Mowing schedules should be similar to the areas beyond the right-of ways. For example, in urban areas mowing should occur regularly and in rural areas mowing can be infrequent or absent. By mowing at higher levels, native plants grow and store resources better to out compete weeds. Savings from a reduced mowing program can be used to build better highways.

Ecological succession can be allowed to occur in non-mowed areas, such as letting trees and shrubs colonize areas where safety concerns are not an issue. Weeds should be removed using selective herbicides that have the least impact on native plants. In areas requiring reseeding, a mix of grasses and forbes should be planted that flower in succession to avoid extensive periods of brown vegetation (Steffens, 1990).

2.0 Ducks Unlimited - Prairie Management and Restoration

Ducks Unlimited (DU) is a conservation organization committed to preserving and expanding the native grass prairies of western Canada and the north-central U.S. (i.e. northern great plains). Although DU's primary interest is to protect and expand waterfowl nesting habitats, it recognizes that the entire ecology of the prairie must be understood for this goal to be successful. In recent years, DU has been very committed to an entire ecosystem approach.

Through rehabilitation of native pasture, restoration, and revegetation of new areas, DU has gained much expertise on native plantings and native seed production. One approach to ecologically revegetate an area is known as sculptured seeding. This concept was first suggested by the USDA-Natural Resource Conservation Service in the U.S.A. and is based on the natural vegetation of the area and matching the plant species with the appropriate environmental zones of a site. By correlating soil type, topography, and moisture levels of an area with native species that thrive in these areas, a successful native habitat can be reestablished (Jacobson, 1994). Ducks Unlimited has purchased thousands of acres of wetlands and surrounding uplands which require an efficient and highly successful method of native plant restoration. Ducks Unlimited also manages these areas using fire, grazing, flood and rest. They replicate the factors in nature that kept the prairies healthy when prairie fires and bison were common. Through their work DU has provided a good base for others interested in prairie restoration and preservation (Lyseng, 1993).

3.0 Meewasin Valley Authority - City of Saskatoon Riverbank Program

The Meewasin Valley Authority studies and implements redevelopment programs along the riverbanks of the city of Saskatoon. Most of the riverbanks in the city are public lands and therefore are looked upon as a resource the city can use for park and recreational purposes. Through various manuals and studies they have classified the various flora and fauna and cultural areas that exist along the river (Prevost, 1984).

The "Riverbank Restoration Study" sets out the problems and solutions in preserving and utilizing the riverbanks. Meewasin also recognizes the importance of conserving and expanding native plant natural areas. A species inventory of natural areas is used as a guide for native plants for use in the landscape. However, in the early 1980's when this began, little native seed or planting expertise existed, so expanding native habitats was complex (Hilderman et al, 1987). Meewasin recognizes that natural areas require less maintenance than traditional parks as they are self-sustaining and provide nature interpretive opportunities. A balance between recreational parks and natural areas has been established by Meewasin, both of which are important to the citizens of Saskatoon.

4.0 The Canadian Wilds Project - Calgary Zoo

The Canadian Wilds project in Calgary attempts to recreate five unique habitats found in Western Canada, containing native plants and animals. The habitats are aspen woodlands, Rocky mountains, northern forests, grassland and arctic shores. Since Calgary is a transition zone between the shortgrass prairie and the Rocky mountain foothills, many of the native plants for the habitats can be obtained locally. This should ensure a higher survival rate for the plants as long as the zoo animal pressures are not excessive. The designers hope that the animals will act as they would in the wild, ignoring the public in their "natural" wilderness. The goal of this design is to show the public a functioning ecosystem, in which animals and plants are interlinked. As well, the "wilderness" is an improvement for the zoo animals which have more activities and act naturally. This is seen as a new way to design zoos, a more humane treatment of its animals and greater education value to the public. It is hoped that these various habitats will create a greater awareness of conserving wilderness and promote native plants and animals and the natural landscape. The landscape designers avoided using "perfect" horticultural plants in favour of bent and crooked naturally appearing plants (Arid, 1993). This project is a continuation of Calgary citizen's desire for wilderness areas of the city to be preserved, protected and appreciated.

5.0 Xeriscaping

Xeriscaping is the word coined to describe high quality, creative landscapes which conserve water. This design saves water, maintenance, money and is environmental friendly. The main principles of xeriscaping are appropriate planning and design, limited traditional lawn areas, appropriate plant selection, efficient irrigation, mulches, healthy soil and low maintenance. By analyzing the site's topography and microclimates and determining the wet and dry areas, proper planning and design can occur. Plants are grouped according to water needs and use appropriate plant selections for the site moisture conditions present. A site can be modified to conserve water via shelter, changing the grade of site to catch run-off and/or the use of mulches to slow soil drying. Soil moisture holding capacity can be improved by increasing soil organic matter content. Incorporating compost or peat moss increases water penetration and infiltration into the soil. As mentioned above, another basic principle in this design is to reduce lawn areas. Lawns are high consumers of water and their total space must be justified. Any irrigation must be efficient with no run-off (Williams, 1997).

Plants used should be selected for low water use. Williams (1997) mentions that introduced or native species can be used if they are low water users and any landscape design style (formal or informal) can be used (Williams, 1997). However, it would seem logical to use native plants almost exclusively since they have adapted best to the climatic conditions of their regions.

6.0 Industrial Production and the Enhancement of the Regional Ecology-Petro-Canada Refinery in Clarkson, ON

Native plants were integrated into an industrial site by a Petro-Canada refinery in Clarkson, Ontario next to Lake Ontario in the 1970's. This project re-establishes native plants to the area and provides links to nearby wetland and wilderness areas. The refinery is surrounded by residential and commercial development with both groups consulted during the re-naturalization of the site. The landscape has been restored with woodlands, ponds, wetlands and meadow habitats using appropriate native flora. Natural succession is allowed to occur on the site and it is treated as a wilderness. The only maintenance is mowing along residential boundaries and around equipment (Hough, 1990).

Wildlife has returned to the area, to the satisfaction of residents and refinery workers. The company conducts tours of its oil processes and the natural preserve. The company has shown the public that industry has a role to play in creating a healthy, diverse environment and that their presence can enhance the ecology of a region. The public associates the company with environmental conservation in a positive light and as a net benefit to the community (Hough, 1990).

7.0 Winnipeg Wild Program - Local Initiatives to Integrate Native Plants

The Winnipeg Wild program was set up by the Fort Whyte Centre in an attempt to address the problems of ecology, sustainability and lack of regional identity in the landscape of Winnipeg. Through education, seminars and school programs, Winnipeg Wild programs hope to alert urban residents that the city is an interconnected wildlife habitat that can be assisted by them to be more diverse biologically and more sustainable.

I will briefly outline their numerous programs developed to achieve these goals. Foremost is a program setting up the home yard as a wildlife habitat by the owner. This is accomplished by planting local native flora in a naturalistic planting design. Winnipeg Wild believes that access to nature close to home is the first step to create a more sustainable landscape (Fort Whyte, 1996).

The use of native plants and the many benefits of such plantings, are promoted through various workshops and publications, along with business and school nature groups. These programs are attempting to start a grassroots movement with the public and school children which can influence municipal and provincial government policies. It is believed that with the public taking the first step to bringing nature and native plants back to the landscape, that governments will follow. The more home yards that are converted to sustainable landscaping, the easier it will be to break the front lawn syndrome that exists on private and public lands (Fort Whyte, 1996).

Appendix B: Glossary

infrequent mown turf- turfgrass areas (e.g. low-maintenance lawns) that are only mown once or twice a year for safety or maintenance reasons.

managed turfgrass- turfgrass that is subjected to turfgrass maintenance including fertilizing, aeration, mowing, irrigation, pest control and top dressing.

non-mowed turf- turfgrass areas (e.g. highway right-of-way) that are not mowed .

vegetative propagation- nonsexual reproduction through the regeneration of tissues and plant parts (e.g. runners, stolons or rhizomes) (Salisbury and Ross, 1992).

visual turfgrass quality- a visual evaluation rating system of turf quality that is influenced by the combination of the following factors of turfgrass colour, texture, density and overall environmental stress (plant mortality and disease) of the grass.