Performance of American Native Grass Cultivars *in the Canadian Prairie Provinces*

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ABSTRACT

The cultivation of native grass cultivars developed for Montana and North Dakota has been proposed in the prairie region of western Canada. Cultivars of 6 warm-season and 4 cool-season grass species that had been selected for North Dakota or Montana were evaluated at a range of sites in western Canada for stand establishment, persistence, aboveground biomass, seed yield, and competitive ability. Warm-season grass cultivars were not adapted to sites above 51 °N latitude. At locations below this latitude, cool-season grasses produced more biomass than warm-season grasses. The occurrence of these warm-season grasses in native rangeland of this region is frequent but often restricted by landscape position or soil texture. Thus, they will likely have a minor role in revegetation seedings. Mammoth wildrye exhibited the highest biomass production on the highest productivity sites. All native cool-season grass cultivars evaluated were adapted to the prairie region of western Canada.

KEY WORDS: biomass, seed yield, competition, C_4 grasses, C_3 grasses, *Elymus lanceolatus, Leymus racemosus, Bouteloua curtipendula, Pascopyrum smithii, Nassella viridula, Andropogon gerardii, Calamovilfa longifolia, Panicum virgatum, Sorghastrum nutans, Schizachyrium scoparium,* Poaceae

NOMENCLATURE: (plants) Alderson and Sharp (1994); (soils) Agriculture Canada (1987)

Native grass species of the Canadian prairie provinces (the northern boundary of the Northern Great Plains of North America) are of renewed interest for revegetation of marginal or degraded farmland. These species may provide wildlife habitat (Wark and others 1995), forage resources for beef cattle or exotic livestock grazing in summer or fall (Abougendia 1995), or energy production from plant biomass (Vogel 1996). Canadian cultivars of native grasses are not currently available for most species because of limited cultivar development and inadequate seed availability for Canadian cultivars of native wheatgrasses (Abougendia 1995). American cultivars, particularly those adapted to Montana and North Dakota, have been identified by conservation groups, such as Ducks Unlimited Canada, as potential seed sources for use in Canada (Wark and others 1995).

Native rangelands of the prairie provinces are dominated by cool-season grasses (Budd and others 1979) that exhibit the three-carbon (C_3) photosynthetic biochemistry. However, many warm-season grasses that exhibit the four-carbon (C_4) photosynthetic biochemistry are found in the region, particularly in southern Manitoba and southeastern Saskatchewan. At some locations, the occurrence of warm-season grasses is favored by soil type or other edaphic factors. Warm-season grasses reach maturity and peak biomass during July and August while cool-season grasses mature by June (Abougendia 1995). Thus, warm-season grasses can provide forage resources for grazing ruminant livestock during the summer period after spring grazing of cool-season grasses. Switchgrass, *Panicum virgatum* L. (Poaceae), has been extensively studied for biofuel production in the US (Vogel 1995) and its use has been proposed in Canada for both biofuel and fiber production, particularly as an alternative use to annual crops on marginal soils (Samson and others 1997). Kilcher and Looman (1983) reported poor establishment and subsequent biomass productivity at Swift Current, Saskatchewan, of warm-season grasses imported from the US. Seeds were imported from Kansas and may have lacked adaptation to the latitude of this site. Native warm-season grass cultivars have demonstrated a latitudinal range of adaptation that restricts the use of southern-adapted cultivars in northern locations within the US (Tober and Chamrad 1992).

Our study objective was to evaluate cultivars of 10 grass species that were selected for adaptation to North Dakota or Montana environments at 7 sites in the prairie region of western Canada by determining plant establishment from seeds, persistence, biomass productivity, seed yield, clover competition, and weed competition. A secondary objective was to compare the adaptation of cool-season species to warm-season species.

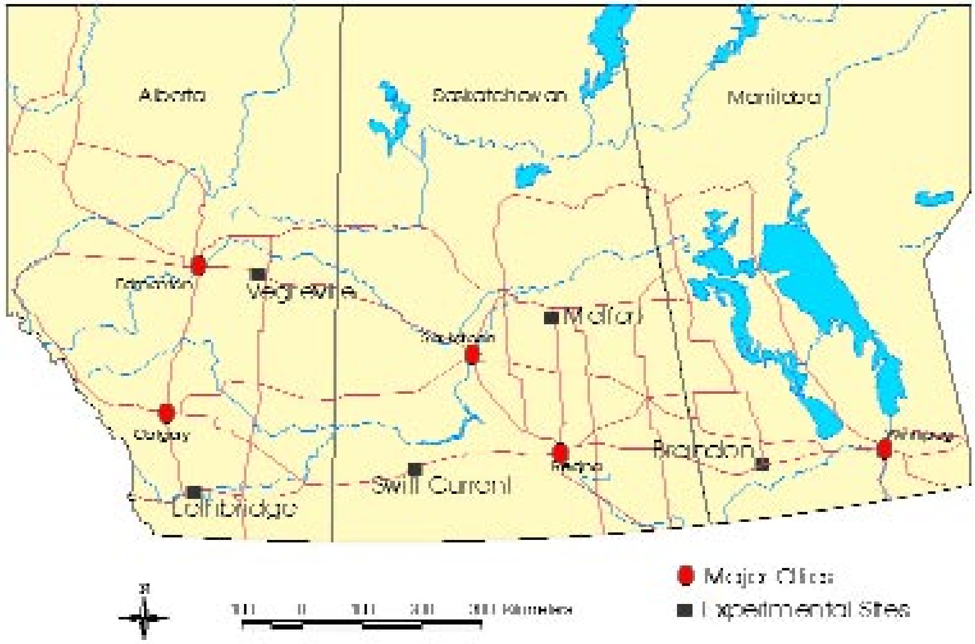

Figure 1 • Map of 3 prairie provinces of Canada with major cities and experimental sites.

MATERIALS AND METHODS

Seeds of native species representing cultivars or experimental lines were obtained from the USDA Natural Resources Conservation Service, Plant Materials Center, Bismarck, North Dakota. These entries represented the northern-most adapted seed sources of several warm-season grasses (Poaceae), namely: 'Dacotah' switchgrass, *Panicum virgatum* L; 'Tomahawk' indiangrass, *Sorghastrum nutans* (L.) Nash; Badlands little bluestem, *Schizachyrium scoparium* (Michx.) Nash; 'Bison' big bluestem, *Andropogon gerardii* Vitman; 'Goshen' and ND-95 prairie sandreed, *Calamovilfa longifolia* (Hook.) Scribn.; and 'Killdeer' sideoats grama, *Bouteloua curtipendula* (Michx.) Torr. Seeds of several cool-season native species were also obtained, namely: 'Rodan' and 'Rosana' western wheatgrass, *Pascopyrum smithii* (Rydb.) A. Love; 'Lodorm' green needlegrass, *Nasella viridula* (Trin.) Barkworth (synonym = *Stipa viridula* Trin.); and 'Critana' thickspike wheatgrass, *Elymus lanceolatus* (Scribn. & J.G. Sm.) (synonym = *Agropyron dasystachyum* (Hook.) Scribn.& J.G. Sm.) (Canadian common name is northern wheatgrass). One introduced grass, ND-691 mammoth wildrye (*Leymus racemosus* (Lam.) Tzvelev (synonym = *Elymus giganteus* Vahl.), from the former USSR was included for study as it was deemed to have wildlife habitat potential. Mammoth wildrye has been seeded for soil conservation on sand dunes and other dry sites in Washington state (Alderson and Sharp1994). Purple prairie clover (*Petalostemon purpureum* (Vent.) Rydb. [Fabaceae]) was included as a native legume. Each of the native species occurs in native rangeland of the Canadian prairie provinces (Budd and others 1979) but switchgrass and indiangrass were described as occurring rarely in this region. The seeding rate was approximately 300 pure live seed (PLS) per m^2 (3.3 ft^2) for the grasses and 100 PLS per m^2 (3.3 ft^2) for the purple prairie clover.

Experimental design at each site was a split plot with legume treatments, with or without purple prairie clover, as main plots and 12 grass cultivars as subplots with 4 replications. The sites were Brandon, Manitoba; Melfort, Saskatchewan; Swift Current, Saskatchewan; Vegreville, Alberta; and Lethbridge, Alberta (Figure 1). Additional sites were added for the comparison of 2 soil types, sandy soil and clay soil at Brandon, and an irrigated and a dryland site at Swift Current, for a total of 7 experimental sites (Table 1).

Trials were seeded in May or June of 1992 or 1993 depending on the site. Ground cover of each plot was determined by visual evaluation at all sites except Melfort during the establishment year. At Lethbridge, Swift Current, and Vegreville, stand density was visually estimated in the spring of each sampling year.

Weed Control

Weed control during establishment of the trials varied among sites depending on labor availability and weed problems. Hand weed removal was practiced at Brandon sites and Melfort. At Lethbridge, hand weeding was used in the establishment year (1992) followed with 2,4-DB (4-(2,4-dichlorophenoxy)-butyric acid) at 2.2 l/ha (30 oz/ac) in the spring of 1994. At Vegreville, hand weeding was used in the establishment year (1993) followed with MCPA (2.4-dichlorophenoxy) acetic acid at 0.66 l/ha (9 oz/ac)

TABLE 1

Site descriptions and characteristics for 7 locations across western Canada

Location name	Latitude	Longitude	Soil type[a]	Plot dimension (m)[b]	Row spacing (m)
Brandon, MB	49° 50' N	99° 57' W	Black Chernozem 'Souris' fine sandy loam	1.8 X 5.0	0.30
Brandon MB	49° 50' N	99° 57' W	Black Chernozem 'Assiniboine' clay	1.8 X 5.0	0.30
Swift Current, SK (dryland)	50° 16' N	107° 44' W	Brown Chernozem 'Swinton' loam	1.8 X 6.0	0.30
Swift Current, SK (irrigation)	50° 16' N	107° 44' W	Alluvial clay loam	1.8 X 6.0	0.30
Lethbridge, AB	49° 42' N	112° 49' W	Dark Brown Chernozem silty clay loam	1.07 X 6.0	0.18
Vegreville, AB	53° 30' N	112° 03' W	Eluviated Black Chernozem 'Malmo'	1.2 X 5.0	0.20
Melfort, SK	52° 52' N	104° 37' W	Black Chernozem silty clay	1.2 X 6.0	0.30

[a] Agriculture Canada (1987).
[b] Conversion: 1 m = 3.3 ft.

and Lontrel (3.6-dichloro-2-pyridine carboxylic acid) at 0.5 l/ha (7 oz/ac) in 1996. At Swift Current sites, weeds were controlled in the establishment year with Buctril M (2,4-DB and bromoxynil (3.5-dibromo-4-hydroxy benzonitrile)) at 1 l/ha (13.5 oz/ac). At the Swift Current irrigation site in 1995, additional application of 2,4-DB plus Banvel (diglycolamine) at 0.25 l/ha (3 oz/ac) was made to the trial and atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) at 1.1 kg/ha (1 lb/ac) was applied to warm-season grass plots only. Weed content was determined by manual separation of grass, clover, and weeds at Swift Current sites. At all other sites, weed content was small and deemed to have no influence on biomass estimates obtained.

Biomass Production

Biomass productivity was estimated by hand clipping at the Swift Current sites, by use of a Carter (Carter Manufacturing, Brookston, Indiana) flail harvester at the Brandon and Lethbridge sites, by use of a Swift (Swift Machine and Welding, Swift Current, Saskatchewan) flail harvester at Vegreville and by use of a Haldrup (J Haldrup Logstor, Denmark) harvester at Melfort. At all sites, a subsample of biomass was weighed, dried in forced-air (45 to 60 °C [113 to 140 °F]) ovens to a constant weight, and reweighed to determine dry matter content. The biomass productivity estimates were converted to dry matter yield.

Harvesting dates ranged from early September to early October. Brandon sites, Vegreville, and Melfort were sampled for 3 y (1994 to 1996) while Swift Current and Lethbridge were monitored for 4 y (1994 to 1997 and 1993 to 1996, respectively).

Purple Prairie Clover Content

The purple prairie clover content of harvested biomass was determined by hand separation of grass and legume at Brandon, Swift Current, and Lethbridge. Each component was dried and weighed to calculate its contribution to biomass. At Vegreville, clover content was visually estimated from the proportion of purple prairie clover plants within a plot.

Seed Production

Seeds were hand-harvested at maturity, air-dried in paper bags, threshed, and cleaned to determine seed yield at Swift Current, Lethbridge, Melfort, and Vegreville. Seed harvest dates ranged from August to October and depended on species maturity.

Statistics

The ground cover variable (%) and weed content variable (%) for all locations were transformed by calculating $Y=\arcsin((X/100)^{0.5})$ where X is the original scale variable. The grass biomass, purple prairie clover biomass, and seed yield were transformed by calculating $Y=\log_{10}(X+1)$ where X is the original scale variable. Both transformations reduced the heterogeneity of variances as determined by a Bartlett's test (Steel and Torrie 1980) and the coefficient of variation in the ANOVA compared to the original scale data. The ANOVA was calculated by the MIXED procedure of SAS (Littell and others 1996) with sites, grasses, and legume mixture considered as fixed effects and replications within sites considered as a random effect and significance declared at $\alpha = 0.05$. The analysis of mean annual yield removed the year effect from the ANOVA. However, years will differ due to variable weather conditions within a site. We were interested in species adaptation rather than weather-driven variation in biomass among years within sites. Means for presentation were back-transformed. The change in ground cover estimates from the seeding year to the last year of each trial was calculated and also subjected to ANOVA to examine the persistence of grasses over time. In this case, the change in ground cover variable included negative values (stand decline) and positive values (stand increase) so a transformation was not done. Means were compared to Least Significant Difference (LSD) at $\alpha = 0.05$ when the ANOVA F test was significant.

RESULTS AND DISCUSSION

Establishment

Grass species differed in stand establishment at each site (Table 2). Western wheatgrass and thickspike wheatgrass established better than 85% ground cover at all 6 sites. Green needlegrass establishment ranged from 79% at Vegreville to 98% at Swift Current-dryland. We expected that green needlegrass establishment would be less than other cool-season grasses because it exhibits a strong seed dormancy and requires low temperature for adequate germination. Mammoth wildrye establishment ranged from 56% at Brandon-clay soil site to 87% at Swift Current-dryland site. Seedling vigor and stand establishment had been identified as a weakness of this species in previous trials in North Dakota and Montana (Tober 1999).

Grass stand establishment was affected by purple prairie clover competition only at Vegreville with a legume X grass interaction present only at this site (Table 2). We concluded that there was inadequate evidence of a purple prairie clover effect on grass establishment. Establishment of cool-season grasses was better than warm-season grasses at 5 of 6 sites

TABLE 2

Mean ground cover of 10 grasses in the year after seeding at 7 locations across western Canada. Probability values for effects in analysis of variance and a contrast are shown

		Location					
Species	Cultivar or line	Brandon clay soil	Brandon sandy soil	Lethbridge	Swift Current dryland	Swift Current irrigation	Vegreville
		%					
Cool-season grasses							
Thickspike wheatgrass	'Critana'	100	100	91	98	89	88
Green needlegrass	'Lodorm'	79	97	91	98	96	79
Mammoth wildrye	ND-691	56	79	61	88	81	84
Western wheatgrass	'Rodan'	100	100	85	93	94	85
	'Rosana'	100	99	88	96	97	92
Warm-season grasses							
Big bluestem	'Bison'	97	99	87	89	75	22
Switchgrass	'Dacotah'	80	99	86	86	72	9
Prairie sandreed	'Goshen'	2	80	79	66	36	18
	ND-95	14	96	76	68	46	33
Sideoats grama	'Killdeer'	80	98	76	55	24	22
Little bluestem	Badlands	62	91	55	42	9	6
Indiangrass	'Tomahawk'	44	52	66	12	13	4
$LSD_{0.05}$		5	14	4	5	4	5
P value - Legume (L)		NS[a]	NS	NS	NS	NS	< 0.01
P value - Grass (G)		< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01
P value - L X G		NS	NS	NS	NS	NS	0.01
P value - cool versus warm		< 0.01	NS	< 0.01	< 0.01	< 0.01	< 0.01

[a] NS = not significant at $\alpha = 0.05$. Statistical probabilities from ANOVA on transformed data ($Y = \arcsin((X/100)^{0.5})$ where X was ground cover %) are presented. Values were back-transformed. LSD values were calculated from ANOVA of original data scale.

TABLE 3

Change in ground cover of 10 grass species over 3 y after seeding at 4 locations across western Canada. Probability values for effects in analysis of variance and a contrast are shown

Species	Cultivar or line	Location: Lethbridge	Swift Current dryland	Swift Current irrigation	Vegreville
		%			
Cool-season grasses					
Thickspike wheatgrass	'Critana'	-4[a]	-1	-10	-27
Green needlegrass	'Lodorm'	-14	4	-2	32
Mammoth wildrye	ND-691	20	-9	-8	-21
Western wheatgrass	'Rodan'	-6	-10	-3	-45
	'Rosana'	-8	-6	-1	-24
Warm-season grasses					
Big bluestem	'Bison'	4	4	12	20
Switchgrass	'Dacotah'	3	-3	23	3
Prairie sandreed	'Goshen'	13	5	30	12
	ND-95	10	-10	31	19
Sideoats grama	'Killdeer'	15	-16	8	26
Little bluestem	Badlands	39	-3	6	11
Indiangrass	'Tomahawk'	20	-24	-23	3
$LSD_{0.05}$		4.9	4	5.9	8.9
P value - Legume (L)		NS[b]	NS	NS	< 0.01
P value - Grass (G)		< 0.01	< 0.01	< 0.01	< 0.01
P value - L X G		< 0.01	NS	NS	NS
P value - cool versus warm		< 0.01	NS	< 0.01	< 0.01

[a] Negative values indicate stand decline.
[b] NS = not significant at α = 0.05.

(Table 2). All warm-season grasses exhibited poor establishment at Vegreville (Table 2) and Melfort. Apparently the northern-most locations in this study were outside the area of adaptation of these species and this observation agrees with Tober and Chamrad (1992). At the 5 southern sites, big bluestem establishment ranged from 75% to 99% while switchgrass establishment ranged from 72% to 99%. The establishment of prairie sandreed, big bluestem, and little bluestem at Swift Current-dryland was superior to that previously reported at this site (Kilcher and Looman 1983). Prairie sandreed, sideoats grama, little bluestem, and indiangrass exhibited inadequate stand establishment at one or more sites. However, the poor establishment of prairie sandreed at Brandon-clay soil and Swift Current-irrigation might be related to soil type. Both sites have clay soils, but this species is best adapted to sandy soils (Alderson and Sharp 1994) where its rhizomatous growth form can be expressed. Sideoats grama and little bluestem have been described as rare in the prairie region of western Canada (Budd and others 1979) and their range of adaptation appears to be less extensive than big bluestem and switchgrass. Establishment of warm-season grasses was generally better at the 2 Brandon sites than at higher latitude locations with establishment success decreasing as the latitude of the testing site increased ($r = -0.85$, $P < 0.05$, df = 5). There was no relationship to latitude for the cool-season species ($r = -0.20$, NS, df = 5). The results indicate that there was a limitation to the northern movement of the warm-season species on the Canadian prairies. Canadian cultivars of some native warm-season grass species are being developed, but it remains to be determined whether these genetic resources will have a more northern range of adaptation.

Persistence

We also examined the change in ground cover over 3 y within 4 sites to evaluate stand persistence. Only 4 sites were evaluated for ground cover because change in cover was not significant at Brandon-sandy soil and it was not recorded at Brandon-clay soil site. Cool-season grasses generally had little or no ground cover losses over time except at the Vegreville site while warm-season grasses generally had increased ground cover (Table 3). Mammoth wildrye and indiangrass exhibited both increased and decreased ground cover depending on the site. Decreased ground cover among species could be attributed to sensitivity to defoliation. However, western wheatgrass is tolerant of defoliation at the time of year that it was harvested (Haferkamp and others 1998) and yet its ground cover declined at Vegreville. The decline of cool-season grass ground cover at Vegreville suggests that these cultivars will establish easily but not persist at this latitude (53 °N).

Biomass

The ANOVA across sites for mean grass biomass indicated that there was a site X grass interaction. To examine the interaction, grass biomass differences were determined within each site (Table 4). Grass species were significantly different at every site except Brandon-sandy soil site where all grass produced similar biomass yield. The soil limitations at this site (lower fertility, lower water holding capacity) compared to Brandon-clay soil may explain the low biomass yields observed. Cool-season grasses produced more biomass than warm-season grasses at every site except Brandon-sandy soil. Mammoth wildrye produced significantly more biomass than other cool-season grasses at Brandon-clay soil, Lethbridge, and Swift Current-irrigation sites and these biomass observations were 46%, 91%, and 26% greater than the next highest species. These sites were the most productive sites as other grasses also exhibited higher biomass production than at other sites. Edaphic factors, such as soil type, fertility, or available soil water may have contributed to the high biomass production at Brandon-clay and Lethbridge while irrigation allowed for yield potential expression at Swift Current-irrigation.

Big bluestem and switchgrass produced the greatest biomass among the warm-season grasses (Table 4) with the exception of higher biomass for prairie sandreed at Lethbridge and Swift Current-dryland. Sideoats grama, little bluestem, and indiangrass biomass production ranged from zero to 5.6 Mg/ha (2.5 t/ac) depending on the site. The biomass productivity of the best warm-season grasses was similar to the wheatgrasses at Brandon-clay but this was expected since Brandon is geographically closest to the tall grass prairie region.

A site X grass interaction ($P < 0.01$) existed for purple prairie clover biomass (data not shown) therefore, clover biomass was analyzed within site. There was a grass cultivar effect on clover biomass productivity at 4 of 6 locations (Table 5). Clover biomass ranged from zero at Swift Current-irrigation to 1.0 Mg/ha (0.4 t/ac) at Brandon-sandy soil site. The very low clover biomass values contributed to high coefficients of variation at some sites. While these observations are low, the purple prairie clover grown with warm-season grasses produced

TABLE 4

Mean annual biomass production of 10 grasses over 3 or 4 y at 7 locations in western Canada. Probability values for effects in analysis of variance and a contrast are shown

Species	Cultivar or line	Location: Brandon clay soil	Brandon sandy soil	Lethbridge	Melfort	Swift Current dryland	Swift Current irrigation	Vegreville
		Mg/ha [a]						
Cool-season grasses								
Thickspike wheatgrass	'Critana'	7.2	1.2	6.7	2.7	2.7	4.0	1.0
Green needlegrass	'Lodorm'	4.8	1.6	7.5	2.1	2.0	5.3	0.5
Mammoth wildrye	ND-691	10.5	2.4	15.8	3.0	2.2	6.6	1.5
Western wheatgrass	'Rodan'	6.9	2.0	7.7	3.3	2.2	5.2	1.0
	'Rosana'	6.0	1.7	8.8	2.1	2.5	5.4	1.1
Warm-season grasses								
Big bluestem	'Bison'	6.2	1.6	5.5	0.1	1.1	3.0	0.0
Switchgrass	'Dacotah'	6.5	1.7	7.0	0.1	1.0	4.3	0.0
Prairie sandreed	'Goshen'	0.0	1.8	9.5	0.2	1.1	2.4	0.0
	ND-95	0.3	2.2	7.9	0.0	1.4	3.1	0.1
Sideoats grama	'Killdeer'	3.7	1.1	3.4	0.5	0.2	0.4	0.0
Little bluestem	Badlands	5.7	1.5	3.5	0.1	0.4	0.2	0.0
Indiangrass	'Tomahawk'	4.8	0.1	4.7	C	0.1	0.2	0.0
$LSD_{0.05}$		0.6	–	0.7	0.3	0.2	0.4	0.1
P value - Legume (L)		NS [b]	NS	NS	NS	NS	NS	< 0.01
P value - Grass (G)		< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
P value - L X G		NS	NS	NS	NS	NS	NS	< 0.01
P value - cool versus warm		< 0.01	NS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

Conversion: Mg/ha = 0.44 t/ac.
NS = not significant at $\alpha = 0.05$. Statistical probabilities were generated by ANOVA on transformed data ($\log_{10}$ (X + 1) values where X was biomass kg/ha). Values are back-transformed. LSD values were taken from ANOVA of original data scale.

more biomass than clover grown with cool-season grasses at 5 of 6 sites. Low productivity of the grass species was not necessarily associated with high productivity of purple prairie clover. The Vegreville site produced low warm-season grass biomass and low clover biomass. The lack of establishment or competitive ability of the purple prairie clover may have contributed to the observed differences among the grasses. However, we interpret these results to mean that the warm-season grasses are less competitive in mixture with purple prairie clover than the cool-season species. Clover or other native legumes would be desirable in seedings with native grasses due to the symbiotic N_2 fixation of the legume and the improved ruminant diet quality and animal performance.

Seed Production

Mean seed yield ranged from 9 kg/ha (8 lb/ac) at Vegreville to 297 kg/ha (265 lb/ac) at Lethbridge (Table 6) with inconsistent species responses over sites. There was a legume mixture effect and grass X legume interaction at Vegreville but not at other sites, so we focus our discussion on grass species differences that were significant at every site except Swift Current-dryland. Warm-season grasses produced more seeds than cool-season grasses at Lethbridge while the reverse was true at Swift Current-irrigation, Melfort, and Vegreville. The grass species differences at Swift Current-irrigation were due to the seed yield difference between big bluestem and indiangrass. All the grass species exhibited variation over sites but this was expected since seed yield of native grasses is subject to more environmental variation than aboveground biomass. Commercial seed production of these native grasses appears feasible at higher productivity sites such as Lethbridge and Swift Current-irrigation. Some commercial production has occurred in southern Manitoba with good seed yield achieved for several warm-season grasses.

Weed Content

A site X grass interaction for weed content existed despite the limited number of sites (2) with available data. Grass species exhibited differences in the weed content of the biomass and warm-season grasses had higher weed content than cool-season grasses at both sites (Table 7). The interaction was likely the result of greater weed content of switchgrass and mammoth wildrye at Swift Current-dryland compared to Swift Current-irrigation. Switchgrass exhibited more competitiveness with weedy species when irrigated than when grown on dryland. Sideoats grama, little bluestem, and indiangrass were not competitive with weedy species at either site. Weed content of other sites was minimal and was considered to have no effect on biomass comparisons.

General

Seed multiplication of 'Killdeer' sideoats grama has been discontinued by the Plant Materials Center, NRCS, Bismarck, North Dakota (Northland News 1999/2000). This selection was similar to another cultivar ('Pierre') in performance and adaptation and there has been little demand for 'Killdeer' although there has been "grown from" seed commercially available. The prairie sandreed strain ND-95 has been released as a germplasm, rather than cultivar, for further selection and development (Northland News 1999/2000). The other cultivars in this study continue to be recommended in North Dakota and Montana.

The use of native species for reclamation, revegetation, wildlife habitat, and ruminant grazing is projected to increase in the prairie region of western Canada. This mirrors changes in rangeland management trends in the US where the use of native species on public lands has been encouraged (Brown and Amacher 1999) although implementation has been hampered by seed availability and cost (Richards and others 1998). Ideally, locally adapted seed sources should be used to minimize the risk of establishment failures. However, the use of seeds imported from some distance away reflects economic reality provided the species possesses ecological adaptation to the revegetation site (Jones and Johnson 1998). We conclude that cool- and warm-season native grass cultivars adapted to North Dakota and Montana can be utilized at southern locations of the Canadian prairie region.

Conclusions

Stand establishment, biomass productivity, and seed yield indicate that warm-season grasses from North Dakota and Montana cannot be successfully cultivated at sites above 51 °N latitude in western Canada, as

TABLE 5

Mean annual biomass of purple prairie clover in mixture with 12 grasses at 6 locations [a] and grass companion. Probability values for effects in analysis of variance and one contrast are shown

		Location					
Species	Cultivar or line	Brandon clay soil	Brandon sandy soil	Lethbridge	Swift Current dryland	Swift Current irrigation	Vegreville
		kg/ha [b]					
Cool-season grasses							
Thickspike wheatgrass	'Critana'	0	430	10	0	0	20
Green needlegrass	'Lodorm'	10	860	0	10	0	0
Mammoth wildrye	ND-691	90	1120	0	0	0	20
Western wheatgrass	'Rodan'	20	1150	10	0	0	10
	'Rosana'	0	810	0	0	0	10
Warm-season grasses							
Big bluestem	'Bison'	100	960	20	10	0	0
Switchgrass	'Dacotah'	190	1020	20	10	0	0
Prairie sandreed	'Goshen'	150	900	160	400	0	0
	ND-95	900	2250	20	390	0	0
Sideoats grama	'Killdeer'	790	790	60	30	0	0
Little bluestem	Badlands	940	1230	10	50	0	0
Indiangrass	'Tomahawk'	1520	1210	140	50	0	0
$LSD_{0.05}$		150	260	–	40	–	80
P value - Grass (G)		< 0.01	< 0.01	NS [c]	< 0.01	NS	< 0.01
P value - cool versus warm		< 0.01	< 0.01	–	< 0.01	–	< 0.01

[a] Melfort site was excluded as purple prairie clover biomass was not recorded.
[b] Conversion: kg/ha = 0.9 lb/ac.
[c] NS = not significant at $\alpha = 0.05$. Values are back-transformed after ANOVA on transformed data ($Y = \log_{10}(X + 1)$ values where X was biomass kg/ha). LSD values were taken form ANOVA of original data scale.

TABLE 6

Mean annual seed production over 3 or 4 y of 12 grasses or cultivars at 5 locations [a]. Probability values for effects in analysis of variance and one contrast are shown

Species	Cultivar or line	Location: Lethbridge	Melfort	Swift Current dryland	Swift Current irrigation	Vegreville
		kg/ha [b]				
Cool-season grasses						
Thickspike wheatgrass	'Critana'	183	188	130	252	38
Green needlegrass	'Lodorm'	357	15	152	290	61
Mammoth wildrye	ND-691	373	22	13	186	11
Western wheatgrass	'Rodan'	5	129	112	214	7
	'Rosana'	5	69	65	109	7
Warm-season grasses						
Big bluestem	'Bison'	274	3	12	119	3
Switchgrass	'Dacotah'	645	5	28	335	4
Prairie sandreed	'Goshen'	188	4	7	60	1
	ND-95	202	2	8	80	3
Sideoats grama	'Killdeer'	427	3	9	56	4
Little bluestem	Badlands	168	6	11	10	1
Indiangrass	'Tomahawk'	258	B	4	6	2
$LSD_{0.05}$		32	25	12	35	5
P value - Legume (L)		NS [c]	NS	NS	NS	< 0.01
P value - Grass (G)		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
P value - L X G		NS	NS	NS	NS	< 0.01
P value - cool versus warm		< 0.01	< 0.01	NS	< 0.01	< 0.01

[a] Brandon-sandy soil and Brandon-clay soil sites were excluded due to very low seed biomass.
[b] Conversion: kg/ha = 0.9 lb/ac.
[c] NS = not significant at $\alpha = 0.05$. Values are back-transformed after ANOVA on transformed data ($Y = \log_{10}(X + 1)$ values where X was biomass kg/ha). LSD values were taken form ANOVA of original data scale.

represented by Melfort and Vegreville. At more southerly locations such as Lethbridge and Swift Current, some warm-season grass cultivars have potential for cultivation, particularly on high productivity sites, but may require 2+ y to become established. Warm-season grass cultivars from North Dakota were best adapted in Brandon.

Mammoth wildrye exhibited the highest biomass productivity of any species tested, particularly at high productivity sites, despite exhibiting variation among sites in stand establishment. Thickspike wheatgrass, western wheatgrass, and green needlegrass were adapted to all sites, including low biomass production sites such as Swift Current-dryland.

Big bluestem and switchgrass exhibited some adaptation to southern locations and further development of northern adapted germplasm could result in new cultivars with better adaptation to this region.

Prairie sandreed, sideoats grama, little bluestem, and indiangrass exhibited variation in establishment and productivity at southern locations. Further investigations into the site requirements of these species is required to understand their niche in this region.

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TABLE 7

Mean weed content over 4 y of 10 grasses at 2 locations. Probability values for effects in analysis of variance and one contrast are shown

Species	Cultivar or line	Location: Swift Current dryland	Location: Swift Current irrigation
		%	%
Cool-season grasses			
Thickspike wheatgrass	'Critana'	4	13
Green needlegrass	'Lodorm'	5	2
Mammoth wildrye	ND-691	27	11
Western wheatgrass	'Rodan'	4	4
	'Rosana'	4	1
Warm-season grasses			
Big bluestem	'Bison'	29	22
Switchgrass	'Dacotah'	42	12
Prairie sandreed	'Goshen'	37	40
	ND-95	41	27
Sideoats grama	'Killdeer'	88	80
Little bluestem	Badlands	71	87
Indiangrass	'Tomahawk'	88	91
$LSD_{0.05}$		5	6
P value - Legume (L)		NS [a]	NS
P value - Grass (G)		< 0.01	< 0.01
P value - L X G		NS	NS
P value - cool versus warm		< 0.01	< 0.01

[a] NS = not significant at $\alpha = 0.05$. Statistical probabilities were generated by ANOVA on transformed data (Y=arcsine-1($(X/100)^{0.5}$) where X was percent weed content). Values are back-transformed. LSD values were taken from ANOVA of original data scale.

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