The influence of harvest management and fertilizers on herbage yields of cool-season grasses grown in the Aspen Parkland of northeastern Saskatchewan

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Bittman, S., McCartney, D. H., Horton, P. R., Hiltz, M. and Nuttall, W. F. 2000. **The influence of harvest management and fertilizers on herbage yields of cool-season grasses grown in the Aspen Parkland of northeastern Saskatchewan.** Can. J. Plant Sci. **80**: 747–753. This study was conducted to evaluate the impact of harvest and fertilizer management on the herbage yield of various grass cultivars grown in the Aspen Parkland region of northeastern Saskatchewan. A series of three experiments were set out: site 1 at Pathlow, Gray Luvisolic soil, 1980; site 2 at Melfort, Deep Black Chernozemic soil, 1979; and site 3 at Pathlow, 1986. At site 1, the design was a split-split plot with fertilizer treatments as mainplots (unfertilized and fertilized, initially with 11N-22P kg ha^{-1} incorporated 5 cm into soil and thereafter, 50N-13P kg ha^{-1} broadcast each year). Ten grass cultivars were seeded as subplots and harvest systems as subsubplots (two-cut and four-cut). At site 2 Melfort, the experimental design was similar to site 1, but without the fertilizer treatments. Fertilizer was applied to all plots at the same rates as site 1. At site 3, Pathlow, 14 grass cultivars were seeded with the same experimental design as site 2, but 10 kg S ha^{-1} was applied each year with the N and P fertilizer. At site 1 Pathlow, the only experiment with the unfertilized control, fertilizer increased the average herbage yield to 2.47 t ha^{-1} from 1.42 t ha^{-1} for unfertilized control plots. Frequent cutting (four-cut system) showed reduced annual yields of 1.70, 5.28 and 1.93 t ha^{-1} compared with 2.19, 7.08, and 2.87 t ha^{-1} (two-cut system), respectively, for sites 1, 2 (5-yr period) and 3 (7-yr period). A greater response to fertilizer was observed with the 2-cut system, 1.19 t ha^{-1}, than with the four-cut system, 0.91 t ha^{-1}, which resulted in a fertilizer × cutting management interaction at site 1. With some exceptions, most of the species were not significantly different in ranking based on herbage yield over the three test sites, but meadow bromegrass [*Bromus biebersteinii* (Roem & Schult.)] ranked higher in yield on the less fertile Pathlow Gray Wooded soil sites than on the more fertile Melfort Deep Black soil site. Crested wheatgrass (*Agropyron cristatum* L.) ranked high in herbage yield at all three sites. Crested wheatgrass, smooth bromegrass (*Bromus inermis* Leyss.) and meadow bromegrass, the most commonly grown species in Saskatchewan, yielded well under the simulated hay and pasture conditions. Other cultivars such as Clarke intermediate wheatgrass [(*Elytrigia intermedia* (Host) Nevski], Elbee northern wheatgrass [*Elymus lanceolatur* (Scribn. and Smith)] and Lodorm green needlegrass (*Stripa viridula* Trin.) should be considered for pasture and hay by farmers and ranchers in northern Saskatchewan.

Key words: Grass, harvest management, pasture, hay, fertilizer

Bittman, S., McCartney, D. H., Horton, P. R., Hiltz, M. et Nuttall, W. F. 2000. **Influence du régime d'exploitation et de la fumure sur le rendement herbager des graminées de saison courte dans la Tremblaie boréale canadienne du nord-est de la Saskatchewan**. Can. J. Plant Sci. **80**: 747–753. L'objet de nos travaux était d'évaluer les incidences des modalités de récolte et du régime de fumure sur le rendement herbager de divers cultivars de graminées dans la Tremblaie du nord-est de la Saskatchewan au Canada. Nous considérions trois expériences implantées l'une en 1980 à Pathlow (emplacement 1) sur Luvisol gris, la seconde en 1979 à Melfort sur chernozem noir profond (emplacement 2) et la dernière en 1986 à Pathlow (emplacement 3). À l'emplacement 1, le protocole expérimental était disposé en parcelles bi-divisées, les traitements de fumure formant les grandes parcelles : sans fumure ou fumure de départ de 11 kg N/22 kg P ha^{-1} en incorporation et 50 kg N-3 kg P ha^{-1} à la volée chaque année par la suite. Dix cultivars de graminées constituaient les sous-parcelles et les régimes d'exploitation (2 ou 4 coupes) les parcelles du second degré. À l'emplacement 2, l'expérience était disposée en parcelles divisées simples, un seul régime de fumure étant appliqué à toutes les parcelles aux mêmes doses qu'à l'emplacement 1. L'emplacement 3, conçu suivant le même dispositif qu'à l'emplacement 2 comportait 14 cultivars de graminées et la fumure annuelle incluait 10 kg S ha^{-1} en plus des doses de N et P utilisées aux deux autres emplacements. À l'emplacement 1, la seule expérience avec témoins non fertilisés, la fumure poussait le rendement herbager moyen à 2,47 t ha^{-1} contre, 1,42 t seulement dans les parcelles témoins. Des fauches fréquentes (régime de 4 coupes) se soldaient par des rendements annuels respectifs de 1,70, 5,28 et 1,93 t ha^{-1} contre 2,19, 7,08 et 2,87 t ha^{-1} en régime de 2 coupes aux emplacements 1, 2 (5 ans) et 3 (7 ans). Une plus forte réponse à la fumure était observée avec le régime à 2 coupes, soit 1,19 t ha^{-1} contre seulement 0,91 t en régime à 4 coupes, ce qui donnait lieu à une interaction fumure × régime d'exploitation à l'emplacement 1. À quelques exceptions près, le classement de la plupart des espèces selon le rendement était sensiblement le

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même aux 3 emplacements, sauf que le brome des prés (*Bromus biebersteinii* (Roem & Schult.) se classait plus haut sur Luvisol gris boisé moins fertile que sur le chernozem profond plus fertile. L'agropyre à crête (*Agropyron cristatum* L.) conservait un classement supérieur aux trois emplacements. Cette dernière espèce le brome inerme (*B. inermis* Leyss.) et le brome des prés, les 3 espèces principales cultivées en Saskatchewan, fournissaient un bon rendement tant en régime simulé de fauche (2 récoltes) ou de pâture (4 récoltes). Les autres graminées, notamment l'agropyre intermédiaire cv Clarke (*Elytrigia intermedia* (Host) Nevski), l'agropyre du nord cv Elbee (*Elymus lanceolatus* (Scribn. Et Smith) et le stipa vert cv Lodorm (*Stipa viridula* Trin.) mériteraient d'être envisagés pour la fauche et la pâture par les agriculteurs et les grands éleveurs du nord de la Saskatchewan.

Mots clés: Graminées, régime de récolte, pâturage, fauche, fumure

The influence of harvest management on hay and pasture herbage yield has not been assessed for most of the species and cultivars of recommended grasses under northern Aspen Parkland conditions. The Aspen Parkland extends from northern Alberta, across Saskatchewan and southeast to southern Manitoba. The harvesting of grasses for hay in this vast area is usually limited to two cuts. With alfalfa and bromegrass mixtures, maximum production was obtained with a first cut in late June or early July and a second cut the third week in August (Bittman et al. 1991, Nuttall et al. 1991). Optimum precipitation and temperature conditions appear to favor a first cut in the latter part of June, but inadequate moisture results in a lower-yielding second cut the third or fourth week of August. Farmers who have annual crops to harvest in late August or early September prefer to make hay early in August or will put cattle out to graze after the first cut.

Four-cut harvest systems have been used to simulate grazing to evaluate forage species for pasture (Lawrence 1978; Fairey 1991). The persistence of forage species in pasture stands has been evaluated using the mob-grazing technique (Mislevy et al. 1982; McCartney and Bittman 1994). This method of evaluating grass species was deemed superior to mechanical harvesting in estimating pasture persistence because of the animal effects of pulling, treading, manure deposition and reduced stubble height. The mob grazing study of McCartney and Bittman (1994) did not evaluate actual yield of the forage species, but used percentage of ground cover to evaluate persistence and effectiveness of each species as a pasture crop. Grazing experiments to evaluate species for pasture production (Robertson et al. 1979; Ocumpaugh 1990) cannot be undertaken without a high investment in the management of animals. Mechanical cutting can be used more efficiently as a harvest management technique in evaluating a large number of forage species for pasture. Accordingly, a series of experiments was set out on Luvisolic and Deep Black Chernozemic soils to determine the effects of fertilizer and harvest management on recommended pasture crops on two contrasting soils in the Aspen Parkland region of northeastern Saskatchewan.

MATERIALS AND METHODS

A series of three experiments was conducted to determine the effects of cutting management systems on pasture cultivar yields (Table 1). The experiments were conducted at the Pathlow pasture on a Gray Wooded Luvisolic Waitville loam soil (sites 1 and 3, lat. 53°N) and at the Melfort Research Farm on a Deep Black Chernozemic Melfort silty clay soil (lat. 53°N) in northeastern Saskatchewan (site 2). In September (1979 and 1985, respectively), the experimental plot areas at Pathlow were sprayed with 2.5 kg a.i. ha^{-1} of glyphosate [(N-phosphonomethyl)glycine] to kill the sward, then cultivated with a Rome plow in mid-October. The seed bed was prepared in May the next year by cultivation with a light tandem disc. The site at Melfort was summerfallowed in 1978 with a heavy duty cultivator and then disced lightly and harrowed before seeding the next spring. Grass species, cultivars and seeding rates for all sites are shown in Table 1. Treatments were applied to the three sites as follows:

Site 1: At this Pathlow site, the experimental design was a split-split plot with four replicates. Main plots were fertilizer rates (unfertilized and fertilized), grass species were subplots, and two harvest management systems, two-cut and four-cut per season, were subsubplots. Prior to seeding, phosphate fertilizer was incorporated in the soil to a depth of 5 cm at a rate of 11N-22P kg ha^{-1} in the fertilized main plot areas. Thereafter, 50 kg N and 13 kg P ha^{-1} were broadcast each year on the fertilized main plot areas in the spring. Ten grass species were seeded with a double-disc plot seeder in 1980 in plots 2.1 m wide and 6.1 m long. A row spacing of 30 cm was used except for the low growing Kentucky bluegrass and creeping red fescue, which were spaced at 15 cm. According to the treatment, the herbage in each plot was harvested either in two-cut or three to four-cut intervals per year, depending on whether there was enough herbage for a fourth cut, throughout the growing seasons from 1981 to 1985.

Site 2: At Melfort, the experimental design was a split plot with grass species as main plots and harvest management, two-cuts and four-cuts per season, as subplots with four replicates. Prior to seeding, phosphate fertilizer was incorporated in the soil to a depth of 5 cm at a rate of 11N-22P kg ha^{-1} and thereafter, each year, 50 kg N and 10 kg P ha^{-1} were broadcast. Ten grass species were seeded with a double disc-plot seeder in 1979 at a row spacing of 30 cm in plots 2.1 m wide and 6.1 m long. The row spacing for Kentucky bluegrass and creeping red fescue was 15 cm. The herbage in each plot was harvested in two-cut and three to four-cut intervals per year depending on whether there was enough herbage to be cut in a fourth cut from 1981 to 1986.

Site 3: At this Pathlow site, the experimental design was a split plot with grass species and cultivars as the main plot treatments, and harvest management (two-cut and four-cut per season) as the subplot treatments with four replicates. Prior to seeding, phosphate fertilizer was incorporated in the soil to a depth of 5 cm at a rate of 11N-22P kg ha^{-1} in the fertilized main plot areas and thereafter, each spring, 50 kg N, 10 kg P and 10 kg S ha^{-1} were broadcast. Fourteen grass cultivars were seeded in 1986 at a row spacing of 30 cm in

Table 1. Grass species and cultivars sown at sites 1, 2, and 3 from 1979 to 1986, including rates and dates of seeding

Species, Cultivars	Scientific names	Site 1[z]& 2[y] Pathlow & Melfort	Site 3[x] Pathlow	Seeding rate ($kg\ ha^{-1}$)
Altai ryegrass	*Elymus angustus* Trin.			
Prairieland		x	x	17,17,14[w]
Smooth bromegrass	*Bromus inermis* Leyss.			
Baylor			x	8
Carlton			x	8
Magna		x		8
Creeping red fescue	*Festuca rubra* L.			
Boreal		x		10
Crested wheatgrass	*Agropyron cristatum* L.			
Ephraim			x	7
Hycrest			x	7
Parkway		x	x	7
Intermediate wheatgrass	*Elytrigia intermedia* (Host) Nevski			
Clarke			x	11
Chief		x		15
Kentucky bluegrass	*Poa pratensis* L.			
Troy		x		10
Meadow bromegrass	*Bromus biebersteinii* (Roem & Schult.)			
Fleet			x	10
Regar		x	x	13
Pubescent wheatgrass	*Agropyron trichophorum* (Link) Richt			
Greenleaf		x		13
Russian wildryegrass	*Psathyrostachys juncea* (Fisch.) Nevski			
Swift		x	x	7,7,12[w]
Green needlegrass	*Stripa viridula* Trin.			
Lodorm		x	x	25,25,14[w]
Northern wheatgrass	*Elymus lanceolatus* (Scribn. & Smith)			
Elbee			x	10
Wheatgrass hybrid,	*Elytrigia repens* L. × *Elytrigia spicata* Pursh			
RS1			x	7
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Love			
Walsh			x	11

[z]Seeding date was 4 June, 1980, harvest years 1981 to 1985.
[y]Seeding date was 1 June, 1979, harvest years 1981 to 1985.
[x]Seeding date was 29 May, 1986, harvest years 1987 to 1993.
[w]Seeding rates for sites 1, 2 and 3, respectively.

plots 2.1 m wide and 6.1 m long . The herbage in each plot was cut in two-cut and four-cut intervals throughout the growing seasons from 1987 to 1993.

At all three experimental sites, for the two-cut harvest system, the first cut was taken in the last week of June and the second in the third week of September. Harvest times for the four-cut system were as follows: the first cut was taken the first week of June; the second cut in the first week of July; the third cut in the first week of August and the fourth cut, if taken, in the third week of September. An area of 1.5 m × 5.5 m was harvested for each plot at a clipping height of 5 cm using a "Haldrup" forage plot harvester. After harvest, for all sites, a 300 g forage sample from each plot was dried at 70°C for 12 h, weighed and dry matter yields were calculated. The amount of weeds and other grasses were determined by hand separation of the sampled sward. Results were analyzed statistically by analysis of variance using SAS (SAS Institute Inc. 1989).

RESULTS

The effects tested by analysis of variance at the three experimental sites from 1981 to 1993 were significant for most treatments and interaction terms (Table 2). The significant effects included fertilizer, cutting management, cultivars and years. Comparisons were made among different species or cultivars of a particular species. For simplicity of presentation, cultivars will be the term used in referring to different species-cultivar treatments. The cultivar × cutting and cultivar × fertilizer interactions at site 1 at Pathlow were the only effects that were not significant. The yield results of these treatment effects are presented in Tables 3 and 4.

Cultivar Yields

The yield of grass herbage grown at site 1 on a Luvsolic soil was increased by approximately 40% over the first 2 yr (1981–1982) and approximately 25% over the years 1981 to 1985 with the application of N and P fertilizer (Table 3). Weeds comprised less than 5% of the total yield and are not reported. The two-cut system, which corresponds to typical harvesting for hay, produced a significantly higher yield of 3.16 $t\ ha^{-1}$ compared with the four-cut system yield of 2.59 $t\ ha^{-1}$ over the years 1981 to 1982. Similarly, for the years 1981 to 1985 the two-cut system yielded 2.19 $t\ ha^{-1}$ vs. 1.70 $t\ ha^{-1}$ for the four-cut. Meadow bromegrass, crested wheatgrass, smooth bromegrass, intermediate wheatgrass and pubescent wheatgrass ranked highest in yield overall, and were significantly higher than the other grass species. Over the 1981 to 1982 period, Prairieland Altai ryegrass response

Table 2. Analyses of variance over years showing the effects of cutting management and fertilizer on dry matter (DM) yield of grass cultivars at three sites in northeastern Saskatchewan

Source of variation	1 Pathlow 1981–1985		2 Melfort 1981–1985		3 Pathlow 1987–1993	
	df	*F* value	df	*F* value	df	*F* value
Fert	1	252.0**				
Rep	3	3.4NS	3	6.4**	3	7.0**
Species-cv	9	20.8**	9	49.2**	13	3.5**
Cutting	1	135.0**	1	400.6**	1	713.9**
Fert × species-cv	9	1.5NS				
Fert × cutting	1	11.8**				
Species-cv × cutting	9	1.4NS	9	6.7**	13	4.1**
Year	4	44.4**	4	353.1**	6	252.9**
Fert × year	4	50.9**				
Species-cv × year	36	15.9**	36	5.0**	78	3.9**
Cutting × year	4	38.8**	4	102.5**	6	21.5**
Fert × spec-cv × yr	36	2.4**				

Effects on DM yield at three experimental sites,

** *F* test significant at 1% probability level.
NS, *F* test not significant at 5% probability level.

Table 3. The effect of management on forage DM yields of several species of grasses at three sites in northeastern Saskatchewan

Factor	1 Pathlow[z] 1981–1982	1 Pathlow[z] 1981–1985	2 Melfort[z] 1981–1982	2 Melfort[z] 1981–1985	3 Pathlow[y] 1987–1988	3 Pathlow[y] 1987–1993
	Forage DM yield (t ha^{-1} y^{-1})					
Cutting						
Hay (2 cut)	3.16	2.19	7.96	7.08	2.77	2.87
Sim. grazing (4 cut)	2.59	1.70	5.66	5.28	2.00	1.93
LSD (0.05)	0.15	0.10	0.23	0.21	0.09	0.07
Fertilizer						
Unfertilized	2.38	1.42				
Fertilizer	3.37	2.47				
LSD (0.05)	0.29	0.21				
Species, cultivars (Cv)						
Altai ryegrass						
Prairieland	2.43*c*	1.67*c*	7.85*a*	6.95*a*	2.63*a*	2.64*a*
Smooth bromegrass						
Magna	3.32*a*	2.21*a*	7.62*a*	7.02*a*		
Creeping red fescue						
Boreal	2.40*c*	1.61*c*	5.08*e*	4.63*e*		
Crested wheatgrass						
Parkway	3.46*a*	2.38*a*	7.96*a*	7.12*a*	2.84*a*	2.78*a*
Intermediate wheatgrass						
Chief	3.33*a*	2.08*a*	8.18*bb*	7.28*a*		
Kentucky bluegrass						
Troy	2.09*c*	1.56*c*	4.21*f*	3.47*f*		
Meadow bromegrass						
Regar	3.52*a*	2.36*a*	6.87*c*	6.24*c*	2.46*a*	2.53*a*
Pubescent wheatgrass						
Greenleaf	3.31*a*	2.09*a*	6.56*c*	5.94*d*		
Russian wildryegrass						
Swift	2.05*c*	1.43*c*	7.46*a*	6.78*a*	1.62*b*	1.90*b*
Green needlegrass						
Lodorm	2.85*b*	2.05*a*	6.31*d*	6.37*c*	1.93*a*	2.46*a*
LSD (0.05)	0.34	0.22	0.54	0.51	0.60	0.40
	P > *F*					
Cutting × fertilizer	0.08	0.01				
Cv × cutting	NS	NS	0.01	0.01	0.01	0.01
Cv × fertilizer	0.03	NS				

Experimental sites

[z]Forage yields with the letter *a* are not significantly different from smooth bromegrass ($P < 0.05$).
[y]Forage yields with the letter *a* are not significantly different from meadow bromegrass ($P < 0.05$).

Table 4. Effect of simulated grazing management on grass species yield over years at site 3, Pathlow pasture area

Species, Cultivars[z]	Dry matter yield 1987–1993[z] 2 cut	1987–1993[z] 4 cut	1987 4 cut	1988 4 cut	1989 4 cut	1990 4 cut	1991 4 cut
	(t ha^{-1} y^{-1})[y]						
Smooth bromegrass							
Baylor	2.91*a*	1.90*a*	2.81*a*	1.09*a*	2.11*a*	1.78*a*	1.91*a*
Carlton	3.12*a*	2.04*a*	2.80a	1.16a	2.42a	2.07a	1.83a
Crested wheatgrass							
Ephraim	2.33*b*	1.56*b*	1.83*b*	0.88*a*	1.54*c*	1.69*a*	1.68*a*
Hycrest	3.26*a*	1.83*a*	2.93*a*	1.42*a*	2.01*b*	1.95*a*	1.77*a*
Parkway	3.47*a*	2.08*a*	3.09*a*	1.42*a*	2.17*a*	2.13*a*	2.18*a*
Intermediate wheatgrass							
Clarke	2.87*a*	2.13*a*	3.48*a*	1.35*a*	2.43*a*	2.75*a*	1.94*a*
Meadow bromegrass							
Fleet	3.09*a*	2.14*a*	3.37*a*	1.46*a*	2.28*a*	2.29*a*	2.15*a*
Regar	2.84*a*	2.23*a*	3.01*a*	1.51*a*	2.42*a*	2.40*a*	2.20*a*
Russian wildryegrass							
Swift	2.21*b*	1.59*b*	1.95*b*	1.09*a*	1.91*b*	1.82*a*	1.70*a*
Green needlegrass,							
Lodorm	2.91*a*	2.02*a*	2.00*a*	1.55*a*	2.35*a*	2.39*a*	2.19*a*
Northern wheatgrass							
Elbee	2.75*a*	2.05*a*	3.19*a*	1.24*a*	2.25*a*	2.04*a*	2.48*bb*
Wheatgrass hybrid,							
RS1	2.66*b*	1.68*b*	2.49*a*	1.36*a*	1.97*b*	2.09*a*	1.54*a*
Western wheatgrass							
Walsh	2.49*b*	1.74*a*	2.06*a*	0.95*a*	1.94*b*	1.74*a*	2.09*a*
LSD (0.05)	0.50	0.38	0.89	0.46	0.32	0.74	0.43
Means	2.84	1.92	2.69	1.27	2.14	2.09	1.97

[z]Cultivar × cutting significant at probability level of 0.05.
[y]Yields with the letter *a* are not significantly different from smooth bromegrass, Carleton.

to fertilizer was 0.39 t ha^{-1}, but Chief intermediate wheatgrass response to fertilizer was 1.58 t ha^{-1}, which contributed to a significant fertilizer × cultivar interaction. All other cultivars responded to fertilizer within the range of these yields. Over the 1981 to 1985 period, the cutting management × fertilizer effect was significant. The percentage yield response to fertilizer was approximately the same (174%) for both cutting management systems. Similarly, the percentage yield increase of the two-cut system over the four-cut was approximately the same (28%) for both fertilizer treatments. Because of the higher absolute yields of the two-cut system (1.59 t ha^{-1}, control; 2.78 t ha^{-1}, fertilized) compared to the four-cut (1.25 t ha^{-1}, control; 2.16 t ha^{-1}, fertilized) a significant fertilizer × cutting management interaction was observed.

At site 2, a similar experiment conducted on a Deep Black Chernozemic soil showed that the two-cut system produced higher herbage yields than the four-cut system, 7.60 vs. 5.66 t ha^{-1}, over the period of 1981 to 1982 and 7.08 vs. 5.28 t ha^{-1} averaged over 1981 to 1985 (Table 3). The yields on this site were substantially higher than on site 1, a Luvisolic soil, although the experiment was conducted over the same time period under similar weather conditions. Chernozemic soils generally are more fertile with higher soil moisture holding capacity than Luvisolic soils and under these conditions, the herbage yields of the grass species were more than double the yields at site 1. Intermediate wheatgrass, crested wheatgrass and Altai wild ryegrass ranked highest in yield, but smooth bromegrass and Russian wild ryegrass were not significantly lower yielding than crested wheatgrass and Altai wild ryegrass. The two-cut system yield of Troy Kentucky bluegrass was 1.15 t ha^{-1} higher than the four-cut system. In contrast, the two-cut system yield of Magna smooth bromegrass was 3.83 t ha^{-1} higher than the four-cut system in 1981 to 1982. Similarly, over the period of 1981 to 1985, the yield under the two-cut system for bluegrass was 0.69 t ha^{-1} higher than the four-cut system, whereas, the two-cut system yield of Parkway crested wheatgrass was 3.24 t ha^{-1} higher than the four-cut system. These differences in yield of cultivars between cutting systems resulted in significant cultivar × cutting management interactions (Table 3). The data for the two cutting systems yields are averaged and not shown for the individual cultivars in the table.

At site 3, the next experiment in the series was conducted over a later time period, 1987 to 1993 (Tables 3 and 4), with more grass cultivars than in the previous tests. The yields of the grass cultivars were similar over the two time periods, 1987 to 1988 and 1987 to 1993 (e.g., average yields for the five cultivars compared in Table 3 were 2.30 vs. 2.46 t ha^{-1}, respectively, for the above time periods). Parkway crested wheatgrass, Praireland Altai wild ryegrass and Regar meadow bromegrass were significantly higher in yield than Swift Russian wild ryegrass over both time periods. Lodorm green needlegrass was not significantly lower in yield than Regar meadow bromegrass over the period 1987 to 1988 and over the period 1987 to 1993.

In Table 4, comparisons are made of 13 cultivars on the basis of two-cut and four-cut systems at site 3. Parkway crested wheatgrass ranked highest in yield, but was not significantly higher than Hycrest and several other cultivars, namely, Fleet and Regar meadow bromegrass, Clarke intermediate wheatgrass, Carlton and Baylor smooth bromegrass, Lodorm green needlegrass and Elbee northern wheatgrass over the period from 1987 to 1993. Ephraim crested wheatgrass yielded significantly less than Hycrest and Parkway. Over the period 1987 to 1993, the two-cut system yield of Carlton smooth bromegrass was 1.08 t ha^{-1} greater than the four-cut system, but the two-cut system yield of Swift Russian wild rye was only 0.62 t ha^{-1} greater than the four-cut system which contributed to a significant cultivar × cutting interaction. The four-cut herbage yields are shown for the years 1987 to 1991 so that a comparison could be made with the same cultivars and years in an experiment with mob grazing (McCartney and Bittman 1994). The years 1992 and 1993 were not included because the size of the table could not be fitted onto a single page.

At site 3, dry matter yields of the four-cut system were only 67.6% of the two-cut system, on average, over the years 1987 to 1993. Yields of cultivars under the four-cut system generally followed a similar ranking as the two-cut system, with yields having the same significance in difference from Carlton smooth bromegrass for both harvesting systems (Table 4). An exception was Walsh western wheatgrass which ranked significantly lower in the two-cut system than the four-cut. The significant difference in ranking of this cultivar between the harvest systems contributed to a cultivar × cutting system interaction (Table 4).

DISCUSSION

The forage production of cultivars is affected by the genetic ability of the cultivars to compete with other species (Knowles et al. 1987, McCartney and Bittman 1994), the nutrient status of the soil, available soil moisture (Simons et al. 1985; Ukrainetz et al. 1988; Nuttall et al. 1991) and the cutting and pasture management used to harvest the crop. With this series of experiments on two contrasting soils in northeastern Saskatchewan, we are able to discuss, in detail, the effect of harvest management on cultivar yields.

Cultivar Yields

Forage crops grown on Gray Wooded soils require inputs of N, P and S fertilizer to produce optimum yields. Yield response to fertilizer has been as much as 100% depending on soil nutrient status (Nuttall et al. 1991, McCartney et al. 1998). In this study, fertilizer increased the yield and ranking of creeping red fescue above that of Russian wild ryegrass and contributed to a species × fertilizer interaction. Strain or cultivar × fertilizer interaction effects were not significant in affecting alfalfa yields (Bittman et al. 1991). Certain cultivars or species are more likely to respond to fertilizer than others. Few forage trials evaluating cultivars examine the effect of combinations of fertilizer because the experiments would be too large. Consequently, there is little information on how plant nutrition affects the relative yields of forage cultivars. The soil type, and hence the nutrition and available moisture supply, had a dramatic effect on the potential yield of the forage species. The Deep Black Chernozemic soil is more fertile and has higher soil moisture holding capacity, more organic matter and more available nutrients than the Luvisolic soil (Nuttall et al. 1991, McCartney et al. 1998). The relative ranking of the species changed with the location. For example, meadow bromegrass and pubescent wheatgrass, which ranked among the highest yielding cultivars at Pathlow, dropped to an intermediate yield level under the high nutrition of the Melfort soil. In contrast, Altai wild ryegrass ranked among the highest in yield at the Melfort site, but was intermediate in ranking in the first experiment at Pathlow. In the first experiment at Pathlow, S had not been applied and this difference in nutrition may have affected the yield and thus the ranking of the cultivars, even though average yields were similar between the two Pathlow sites.

Many grass cultivars have been tested for yield and persistence in southwestern Saskatchewan (Lawrence and Ratzloff 1985). Lawrence (1978) tested 30 grass populations and determined that crested wheatgrass and bromegrass species were adapted to the dry climate of southern Saskatchewan. The climate in northeastern Saskatchewan, on average, has lower temperatures and higher precipitation than southern Saskatchewan (Nuttall et al. 1991). Therefore, with less soil moisture stress, one would expect that a different range of grasses would be suitable for hay and pasture in this region. Certainly, crested wheatgrass and bromegrass do very well. Other cultivars such as Clarke intermediate wheatgrass, Elbee northern wheatgrass and Lodorm green needlegrass should be considered for use by farmers and ranchers in northern Saskatchewan. The cultivar Lordorm, a selection for reduced seed dormancy, is a native perennial bunch grass (Larson and Carter 1970). The species is quite common in North Dakota and was a dominant species in rangelands before the drought in the 1930s (Personal communication, 1998, John D. Berdahl, Mandan, ND). As a native grass, this species should be considered for use in northern grasslands because it compares well with other species such as bromegrass, particularly under intensive grazing (McCartney and Bittman 1994).

Comparison of Harvest Systems

Harvest systems for hay (two-cut) and pasture (four-cut), as well as plant ground cover determined by cross-transect, have been used to evaluate forage cultivars for yield and growth persistence (Fairey 1991; McCartney and Bittman 1994; McCaughey and Simons 1996). Good stand establishment of cultivars in rows or in solid stands usually will improve productivity. Under dry conditions, however, herbage yields are often better with fewer plants per unit of area (Lawrence and Heinrichs 1968). When comparing different species or different cultivars, the yield per plant (correlated with ground cover estimated by cross-transect) may not be the same for each cultivar. Percentage ground cover is often reduced over years with mob grazing (McCartney and Bittman 1994), but yields in the four-cut grazing system in this study were not reduced too much, approximately

25% on average. The mob grazing system was a more intensive defoliation method of testing grass cultivars than clipping to a 5-cm height. With the four-cut system, frequent cutting reduces the amount of leaf area for each forage plant and may reduce photosynthesis resulting in less plant growth and lower yields (Lorenz et al. 1961; Wolf and Smith 1964; Cooke et al. 1965). Other conditions, such as available soil moisture, which is influenced by temperature and precipitation, hours of sunshine, and vapor pressure deficit also affect growth. The distribution of these effects over the growing season on plant growth may have a variable effect on plant species or cultivars. For example, if rainfall is heavier in July and August than in May and June then a first cut in June may not yield as well as a cut made in July. A much later cut in September may not benefit from the higher moisture conditions of July and August. After cutting, growth appears to be stimulated more in certain forage species, such as meadow bromegrass, but adequate growing conditions must prevail. In the experiments reported here, lower yields of meadow bromegrass relative to smooth bromegrass averaged over two- and four-cut harvest systems were observed on fertile soils at Melfort. At the Pathlow site, smooth bromegrass was not significantly higher in herbage yield than meadow bromegrass under the two-cut system. As well, at this site, meadow bromegrass was not significantly higher in herbage yield than smooth bromegrass under the four-cut system. Generally, meadow bromegrass is considered to be higher yielding under frequent cutting or pasture than smooth bromegrass, and vice versa, smooth bromegrass yields are higher under hay or two-cut harvesting systems (personal communication, B.E. Coulman, Agriculture and Agri-Food Canada, Saskatoon, SK). McCaughey and Simons (1996) showed that in some cases under the four-cut system meadow bromegrass was higher in herbage yield than smooth bromegrass. Fairey (1991) observed that herbage yield of smooth bromegrass was reduced more by frequent cutting (four-cuts) than meadow bromegrass in pure stands or with companion legumes. The relatively poor yield of meadow bromegrass compared with smooth bromegrass on the richer soil at Melfort was unexpected based on the general view that meadow bromegrass is less drought tolerant than smooth bromegrass. In conclusion, several cultivars are suitable for hay or pasture production in northeastern Saskatchewan soils. Plot techniques using two-cut and four-cut systems give a suitable evaluation of these cultivars. Also, long term trials of more than 3 yr are not necessary to evaluate grass cultivars for pasture and hay production in monoculture studies.

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