

# The influence of harvest management and fertilizer application on seasonal yield, crude protein concentration and N offtake of grasses in northeast Saskatchewan

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McCartney, D. H., Bittman, S. and Nuttall, W. F. 2004. **The influence of harvest management and fertilizer application on seasonal yield, crude protein concentration and N offtake of grasses in northeast Saskatchewan.** *Can. J. Plant Sci.* **84**: 205–212. The goal of pasture management is to match quantity and quality of herbage to the requirement of the grazing animal. The objective of this study was to examine the effects of harvest management and fertilizer application on annual and seasonal production, protein concentration and N-offtake by eight grass species adapted to the central Aspen Parkland. In this 3-yr split-split-plot experiment, grasses were either fertilized annually (50 and 13 kg ha<sup>-1</sup> of N and P, respectively) or left unfertilized, and cut either twice annually (two-cut) in early July and late September, or three to four times annually (multi-cut), in early June, early July, early August and late September if there was sufficient herbage. The grasses used in this study were Altai wildrye [*Leymus angustus* (Trin.) Pilger], creeping red fescue (*Festuca rubra* L. var. *rubra*), meadow brome (*Bromus riparius* (Rehmann)), Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski], smooth brome (*Bromus inermis* Leyss.), crested wheatgrass (*Agropyron cristatum* L. Gaertn.), intermediate wheatgrass [*Elytrigia intermedia* (Host) Nevski] and green needlegrass [*Nassella viridula* (Trin.) Barkworth]. Fertilizer increased yield of the two-cut treatment 15% ( $P < 0.05$ ) more than the multi-cut treatment. On average, the multi-cut treatment had 32% higher protein concentration than the two-cut treatment throughout the season. Fertilizer significantly increased protein concentration only in the first harvest of the multi-cut clipped plots, probably because the application rate was low. Nitrogen offtake of the multi-cut treatment averaged 24% higher than the two-cut treatment, even though the latter yielded more. Meadow brome showed the most uniform seasonal distribution of yield among the high-yielding grasses under all management systems while smooth brome and crested wheatgrass were generally the poorest. Crested wheatgrass had significantly more first cut production than all other grasses. Meadow brome herbage also had the lowest protein concentrations throughout the growing season among the high producing grasses. Since the protein concentrations were generally higher than required by grazing beef cattle, the meadow brome herbage was the most suitable for this class of cattle. Green needlegrass also showed potential for use in pastures.

**Key words:** Pasture, hay, protein yield, *Bromus*, *Elytrigia*, *Nassella*, *Agropyron*, *Festuca*, *Psathyrostachys*, *Leymus*

McCartney, D. H., Bittman, S. et Nuttall, W. F. 2004. **Influence des pratiques de récolte et de l'application d'engrais sur le rendement saisonnier, la concentration de protéines brutes et le soutirage de l'azote chez les graminées du nord-est de la Saskatchewan.** *Can. J. Plant Sci.* **84**: 205–212. L'idée derrière la gestion des pâturages consiste à adapter la quantité et la qualité des herbages aux besoins des animaux. La présente étude devait établir l'incidence des pratiques de gestion des pâturages et de l'application d'engrais sur la production annuelle et saisonnière d'herbages, sur la concentration de protéines et sur le soutirage de l'azote chez huit graminées acclimatées à la zone des forêts-parcs à trembles. Dans le cadre d'une expérience de trois ans sur des parcelles doublement divisées, les auteurs ont fertilisé annuellement (50 et 13 kg de N et de P par hectare, respectivement) ou pas les parcelles et récolté les graminées deux fois (double coupe, au début de juillet et à la fin de septembre) ou trois ou quatre fois l'an (coupe multiple, au début de juin, au début de juillet, au début d'août et à la fin de septembre) quand la quantité d'herbages le permettait. À cette fin, ils ont utilisé l'élyme étroite [*Elymus angustus* (Trin.) Pilger], la fétuque rouge traçante (*Festuca rubra* L., var. *rubra*), le brome des prés [*Bromus riparius* (Rehmann)], l'élyme de Russie [*Psathyrostachys juncea* (Fisch.) Nevski], le brome inerme (*Bromus inermis* Leyss.), l'agropyre à crête (*Agropyron cristatum* L. Gaertn.), l'agropyre intermédiaire [*Elytrigia intermedia* (Host) Nevski] et la stipe verte [*Nassella viridula* (Trin.) Barkworth]. Les engrais augmentent le rendement du régime à double coupe de 15 % ( $P < 0,05$ ) comparativement à celui du régime à coupe multiple. En moyenne, le régime à coupe multiple produit 32 % de protéines de plus que celui à coupe double durant la période végétative. Les amendements n'augmentent sensiblement la concentration de protéines qu'à la première récolte, sur les parcelles faisant l'objet d'une coupe multiple, sans doute à cause du faible taux d'application. Les parcelles à coupe multiple donnent en moyenne 24 % plus d'azote que celles qu'on récolte deux fois, malgré le rendement supérieur de ces dernières. Le brome des prés avait le rendement saisonnier le plus uniformément réparti des graminées à haut rendement, sans égard au système de gestion, alors que le brome inerme et l'agropyre à crête avaient généralement le rendement le plus mal réparti. L'agropyre à crête donne

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sensiblement plus d'herbages que les autres graminées à la première coupe. Durant la saison végétative, le brome des prés s'est caractérisé par la plus faible concentration de protéines de toutes les graminées à fort rendement. La concentration de protéines étant généralement supérieure aux besoins des bovins mis à l'herbe, le brome des prés reste l'espèce la plus intéressante pour le bétail de ce genre. La stipe verte présente aussi un certain potentiel pour la paissance.

**Mots clés:** Pâturage, foin, rendement protéique, *Bromus*, *Elytrigia*, *Nassella*, *Agropyron*, *Festuca*, *Psathyrostachys*, *Leymus*

The yield response by forage grasses to application of N and other nutrients in the Aspen Parkland region of the northern Great Plains has been demonstrated in several studies (Nuttall 1980, 1985; Mahli et al. 1986; Ukrainetz and Cambell 1988; Ukrainetz et al. 1988; Fairey 1991; Nuttall et al. 1991; McCaughey and Simons 1996, 1998; Bittman et al. 1997). Many of these reports relate to the response of grasses harvested for hay. There are approximately 3 million ha of improved grassland in this region, which are used primarily for pasture, and most of these pastures are used for cow-calf operations and are on marginal lands. Research conducted near Brandon, MB, Melfort, SK, and Beaverlodge, AB, showed that frequent harvesting of grasses (simulated grazing) resulted in lower yield but greater late-season growth than harvesting grasses under a typical two-cut hay system (Fairey 1991; McCaughey and Simons 1996, 1998; Bittman et al. 2000). These studies showed that grasses respond differently to frequent cutting. For example, frequent cutting reduced yield of smooth brome (*Bromus inermis* Leys.) more than meadow brome (*Bromus riparius* (Rehman)), and yield of meadow brome was often higher than that of smooth brome under frequent cutting.

Typically, yields are lower on pastures than hay land. Thus, there is a need to evaluate the response of pastures to nutrients. McCaughey and Simons (1996) and Bittman et al. (2000) showed that frequent harvesting often reduces the yield response to applied N. There was, similarly, a tendency for N use efficiency and recovery of fertilizer N to be somewhat lower for multi-cut than for hay management, although in a study by McCaughey and Simons (1998), there did not appear to be any more nitrate-N left in the soil of the frequently cut grass plots than hay-cut plots in autumn. In contrast, herbage N concentrations were generally higher under frequent harvest, because the plants were less mature at harvest, whereas the total N offtake could be higher or lower with frequent harvesting depending on species, soil, and year (Fairey 1991; McCaughey and Simons 1996, 1998). These studies reported that mean annual protein concentrations of frequently cut herbage ranged from 119 to 187 g kg<sup>-1</sup> in Manitoba and from 140 to 230 g kg<sup>-1</sup> in Alberta, although no information was provided on seasonal distribution of protein concentration. Proportion of crude protein actually consumed by grazing animals is likely to be higher than values obtained from machine-harvested herbage due to selective grazing. These reported values for concentration of crude protein are in excess of the 115 g kg<sup>-1</sup> required by nursing cows [National Research Council (NRC) 1996]. Indeed, any surplus N consumed is excreted in urine at a metabolic cost to the ruminant (NRC 1996) while much of the N in the urine patches is lost to the atmosphere as ammonia and even contributes to emissions of nitrous oxide (Vermoesen et al. 1997; Whitehead 2000).

These issues and the possibility that, when frequently clipped or grazed, grasses may take up more applied N than when harvested for hay further indicate the need for additional study on fertilizer application for grass pastures.

Prior to the 1990s, the most widely seeded grass in the parkland region, for both hay and pasture, was smooth brome. While smooth brome generally persists for many years under hay management, it gradually dies out in pastures because the grass is susceptible to defoliation during the stem elongation phase when root reserves are low (Vogel et al. 1996) and there are few tiller buds formed. In the pastures of northeast Saskatchewan, smooth brome is replaced by short, grazing-tolerant grasses with shallow root systems, such as bluegrass species (mainly *Poa pratensis* L.), which volunteers naturally, and creeping red fescue (*Festuca rubra* L. var. *rubra*). These grasses have become endemic from provincial government pasture seeding and development programs that took place before the mid-sixties (S. Bittman, unpublished data). These grasses will replace smooth brome particularly when there is an imbalance of N, P, and S in the soil (Bittman et al. 1997).

Since these grazing-tolerant grasses have shallow root systems and poor growth, especially in mid-summer when the soil is dry, there is a need to identify new grass species that are better suited to grazing. In addition to persistence, these grasses should have low growing points, rapid regrowth after defoliation, uniform seasonal production and season-long nutritional quality that meets the animal requirements. The objective of this study was to compare annual and seasonal productivity, protein concentration and N offtake by several adapted grasses as influenced by harvest management and fertilizer application in the central Aspen Parkland.

## MATERIALS AND METHODS

The study was initiated in 1980 on a Gray wooded luvisolic soil (Typic Cryoboralf) near Pathlow in the Aspen Parkland of northeastern Saskatchewan, Canada (lat. 52.75°N, long. 105°W). In September 1979, prior to the seeding year, the experimental area was sprayed with 2.5 kg a.i. ha<sup>-1</sup> of glyphosate [*N*-(phosphonomethylglycine)] to kill the existing sward, then cultivated with a heavy-duty roto plough in mid-October. Just prior to seeding in May 1980, the seedbed was prepared by cultivating with a light tandem disc and fertilizer (monoammonium phosphate) was incorporated to a depth of 5 cm at a rate of 11N–22P kg ha<sup>-1</sup> only in the fertilized main plot areas. Prior to seeding the soil contained 24.7 kg ha<sup>-1</sup> NH<sub>4</sub>-N, 6.2 kg ha<sup>-1</sup> NO<sub>3</sub>-N, 9.7 kg ha<sup>-1</sup> NaHCO<sub>3</sub>-P, 25.4 kg ha<sup>-1</sup> CaCl<sub>2</sub>-S and 248 kg ha<sup>-1</sup> of ammonium acetate-K. The trial was seeded in early June 1980. The entire area was clipped in fall of 1980 and July and September of 1981 but yields were not determined until

**Table 1. Grass species and cultivars sown at Pathlow in 1980, including rates of seeding**

Species	Cultivars	Scientific names	Seeding rate <sup>z</sup> kg ha <sup>-1</sup>
Smooth brome grass	Magna	<i>Bromus inermis</i> Leyss.	8
Crested wheatgrass	Parkway	<i>Agropyron cristatum</i> L. Gaertn.	7
Intermediate wheatgrass	Chief	<i>Elytrigia intermedia</i> (Host) Nevski	15
Green needlegrass	Lodorm	<i>Nassella viridula</i> (Trin.) Barkworth	25
Altai wildrye	Prairieland	<i>Leymus angustus</i> Trin. Pilger	17
Creeping red fescue	Boreal	<i>Festuca rubra</i> L. var <i>rubra</i>	10
Meadow brome grass	Regar	<i>Bromus riparius</i> (Rehmann)	13
Russian wildrye	Swift	<i>Psathyrostachys juncea</i> (Fisch.) Nevski	7

<sup>z</sup>Saskatchewan Forage Guide (1980).

1982 to allow all grasses to become well established and nutrients to stabilize after cultivation.

The field layout was a split-split-plot with four replicates. The two main plots consisted of an unfertilized "control" treatment and a "fertilizer" treatment that received broadcast applications of 50 kg N ha<sup>-1</sup> and 13 kg P ha<sup>-1</sup> as urea and monoammonium phosphate each April. This fertilizer rate was chosen based on data from earlier research and on-farm experience. The sub-plots comprised of eight grasses: creeping red fescue, meadow brome grass, Russian wild rye [*Psathyrostachys juncea* (Fisch.) Nevski], Altai wildrye (*Elymus angustus* Trin.), smooth brome grass, crested wheatgrass (*Agropyron cristatum* L.), intermediate wheat grass [*Elytrigia intermedia* (Host) Nevski] and green needlegrass (*Nassella viridula* Trin.). Grasses were seeded at seeding rates (Table 1) recommended for the parkland region of Saskatchewan (Saskatchewan Forage Guide 1980). All grasses were seeded in 30-cm row spacing, except for creeping red fescue, which was seeded in 15-cm rows because its short stature would leave a very open canopy at the wider spacing. The sub-sub-plots, measuring 2.1 × 6.1 m, comprised two harvesting systems, a two-cut system representing a typical hay system and a multiple-cut system (three to four cuts) intended to represent a grazing system. Beginning in 1982, the two-cut treatment was harvested in early July and in the third week of September. The multi-cut treatment were harvested in the first week of June (soon after cows would typically start to graze), the first week in July, the first week of August, and the third week of September if there was sufficient herbage. Strips of 1.5 × 5.5 m were harvested in each plot at a 5-cm height with a sickle-bar forage plot harvester and weighed. At each harvest, a herbage sample weighing approximately 300 g was collected from each plot, weighed, dried at 70°C to constant weight, and re-weighed, to determine dry matter content. The concentrations of N were determined in samples ground through a 2-mm screen by micro-Kjeldahl procedure described by Nuttall (1985). Offtake of N was calculated by multiplying N concentration × yield. Crude protein was calculated as concentration of Kjeldahl N × 6.25 (Association of Official Analytical Chemists 1990).

The combined data for the 3 yr were analyzed as a split-split-plot in space and time (Steel and Torrie 1960) using PROC GLM of SAS (SAS Institute, Inc. 1989). All treatments including year were considered to be fixed. Fisher's protected LSD was used to test species differences. Significance level was set a priori at 0.05.

**Table 2. Significance levels of experimental treatments affecting annual dry matter yield, crude protein concentration and N-offtake in herbage harvested in 1982 to 1984 at Pathlow Saskatchewan**

	Yield	Crude protein	N-offtake
Fertilizer	0.01	NS	0.01
Species	0.01	0.01	0.01
Fertilizer × Species	NS <sup>z</sup>	NS	NS
Harvest	0.01	0.01	0.01
Fertilizer × Harvest	0.01	0.01	0.01
Species × Harvest	0.01	0.02	0.02
Fertilizer × Species × Harvest	NS	NS	NS

<sup>z</sup>not significant at ( $P < 0.05$ ).

## RESULTS AND DISCUSSION

The year effect produced significant two-way and three-way interactions with all treatments in this trial. The basis of the interaction is that the multi-cut harvesting system performed better relative to the two-cut system in 1982 than in 1983 or 1984 (data not shown). The reason for this pattern may be that 1982 received more uniform precipitation than the other years. The distribution of rainfall may have also affected the relative yield of species under the different harvesting systems. Generally lower yields and poorer response to application of fertilizer in 1984 may reflect the low rainfall in July and August and perhaps the fact that the stand was ageing. The average responses over years are discussed below.

### Yield

There was a significant species × harvest management interaction for annual yield (Table 2). For example, crested wheatgrass yielded about 25% less under the multi-cut than the two cut system whereas Russian wildrye yielded somewhat more under the multi-cut system (Table 3). On the other hand, the grasses responded similarly to fertilizer application (no interaction) (Table 2) as reported earlier in Manitoba (McCaughy and Simons 1996) but in contrast to results in Alberta (Fairey 1991). Under both two-cut and multi-cut treatment, fertilizer approximately doubled herbage yield ( $P < 0.01$ ) (Table 3), although the yield gain was greater under two-cut management (significant fertilizer × harvest management interaction, Table 2). The calculated efficiency of N-use (kg dry matter yield increase per kg N applied; P not considered) averaged over fertilizer, species, and years, was 26.0 for the two-cut treatment and 20.2 for the multi-cut treatment. McCaughy and Simons (1998) also reported higher N use efficiency for two-cut hay

**Table 3. The effect of harvest management and fertilizer on mean annual DM yield, crude protein concentration, total N-offtake in harvested herbage of several grass species from 1982 to 1984 at Pathlow, Saskatchewan**

Factor	Harvest management					
	2-cut			Multi-cut		
	Yield (kg ha <sup>-1</sup> )	Crude protein (g kg <sup>-1</sup> )	N-offtake (kg ha <sup>-1</sup> )	Yield (kg ha <sup>-1</sup> )	Crude protein (g kg <sup>-1</sup> )	N-offtake (kg ha <sup>-1</sup> )
<i>Fertilizer</i>						
Unfertilized	1060	95	15.9	980	137	22.2
Fertilized	2360	97	36.2	2000	144	46.5
LSD (0.05)	200	NS <sup>z</sup>	3.0	200	NS <sup>z</sup>	5.1
<i>Species</i>						
Smooth brome grass	1900ab	103ab	31.4a	1480bc	154ab	36.8abc
Crested wheatgrass	2000a	90c	28.5b	1540b	161a	40.7a
Intermediate wheatgrass	1670bc	92c	24.6cd	1470bc	132cd	33.5bc
Green needlegrass	1930a	86c	26.6bc	1750a	135bcd	36.9abc
Altai wildrye	1510cd	111ab	26.7bc	1340bcd	151abc	32.5c
Creeping red fescue	1390de	92c	20.8e	1190d	122d	24.0d
Meadow brome grass	2040a	83c	27.2bc	1880a	119d	38.3ab
Russian wildrye	1240e	113a	22.7de	1290cd	158a	32.0c
Mean	1710	96	26.0	1500	142	34.4
LSD (0.05)	0.25	10	2.7	0.2	20	4.8
	Yield (kg ha <sup>-1</sup> )	Crude protein (g kg <sup>-1</sup> )	N-offtake (kg ha <sup>-1</sup> )			
Harvest LSD (0.05)	60	5.0	1.2			
Species × Harvest LSD (0.05)	169	1.5	3.3			
Fertilizer × Harvest LSD (0.05)	857.0	1.6				

*a-e* Values not having the same letters are significantly different at ( $P < 0.05$ ).

type system than for a simulated pasture multi-cut system, although their values varied a great deal between years and soil types.

Four of the grasses tested (Altai and Russian wildryes, creeping red fescue and meadow brome grass) were considered to be adapted to pastures because they possess some desirable attributes such as low growing points, tendency to re-grow rapidly after cutting (Bittman 1985; Fairey 1991; Knowles et al. 1993; Lawrence and Heinrichs 1985) and persistence under grazing (McCartney and Bittman 1994). These pasture-type grasses yielded 330 kg ha<sup>-1</sup> less on average than the other grasses under two-cut treatment but only 135 kg ha<sup>-1</sup> less on average under multi-cut treatment (Table 3). All unfertilized grasses except crested wheatgrass and smooth brome grass, which are the two main hay grasses in Saskatchewan, yielded more when two cuts were taken by the first week of July compared to only one cut (Table 4). While four grasses had similarly high yields under the two-cut system (crested wheatgrass, green needlegrass, and smooth and meadow brome grasses), meadow brome grass and green needlegrass yielded most under multi-cut treatment (Table 3). The high yield of green needlegrass under both harvesting systems suggests that this grass deserves consideration for greater use.

There were significant interactions between years and treatments for each harvest (not shown). These interactions reflect the differences in seasonal rainfall described above. Fertilizer application significantly increased yield in all cuts of both harvesting systems, with the greatest response in cut 1 in the two-cut system and cuts 1 and 2 in the multi-cut system (Table 4).

Crested wheatgrass produced the most in first cut under both cutting and fertility treatments (note significant fertilizer × species interaction Table 4). However, crested wheatgrass yielded significantly less than all other grasses except Russian wildrye in the second harvest of the fertilized two-cut system. In contrast, meadow brome grass and green needlegrass had the greatest regrowth in both fertilized and non-fertilized two-cut systems. Under multiple cutting for both fertilized and non-fertilized treatments, several grasses had good second cuts (smooth brome grass, intermediate wheatgrass, green needlegrass, and meadow brome grass), but meadow brome grass had the best yield in cut 3 and cut 4. Meadow brome grass (followed by Russian wildrye and creeping red fescue) had the least seasonal variation in yield, while smooth brome grass, crested wheatgrass and intermediate wheatgrass had the most seasonal variation. In the multi-cut system, the combined re-growth (cuts 2 to 4) of the native (Looman and Best 1979) green needlegrass was similar to that of meadow brome grass. These findings suggest that green needlegrass might be seeded more widely for pastures, particularly to increase native floristic diversity in seeded pastures. However, in some cases, poor seedling vigour might be a problem (Schaff and Rogler 1960).

#### Protein Concentration in Herbage

In contrast to yield, mean annual crude protein concentrations were significantly higher (46 g kg<sup>-1</sup>) under multiple harvests than under the two-cut system (Tables 2 and 3). These results are similar to those reported by Fairey (1991), McCaughey and Simons (1996, 1998) and Bittman et al. (2000). There was a significant fertilizer × harvest interac-

**Table 4. The effect of harvest management and fertilizer on seasonal distribution of dry matter yield of several grass species from 1982–1984 at Pathlow, Saskatchewan**

Species	2-cut system		Multi-cut system			
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3	Cut 4 <sup>z</sup>
	kg ha <sup>-1</sup>					
<i>Without fertilizer</i>						
Smooth brome grass	801	368	309	484	135	27
Crested wheatgrass	1029	277	478	380	183	13
Intermediate wheatgrass	590	353	210	465	221	17
Green needlegrass	747	527	322	572	333	60
Altai wildrye	577	418	286	323	254	35
Creeping red fescue	364	277	178	235	128	38
Meadow brome grass	786	523	364	502	376	89
Russian wildrye	505	310	323	346	245	48
Mean	675	382	309	413	234	41
<i>With fertilizer</i>						
Smooth brome grass	2010	623	699	1105	181	35
Crested wheatgrass	2256	445	1122	653	235	39
Intermediate wheatgrass	1785	617	638	1106	247	75
Green needlegrass	1807	779	611	1117	454	72
Altai wildrye	1431	599	574	823	347	70
Creeping red fescue	1550	582	669	740	329	107
Meadow brome grass	1878	890	804	1058	513	134
Russian wildrye	1195	466	613	654	303	88
Mean	1739	625	716	907	326	77
LSD <sup>y</sup> (0.05)	276	125	132	154	88	46
<i>Significance levels</i>						
Fertilizer	0.01	0.01	0.01	0.01	0.01	0.01
Species	0.01	0.01	0.01	0.01	0.01	0.01
Fertilizer × Species	0.01	0.05	0.01	0.01	0.02	NS

<sup>z</sup>Mean of 1982 and 1983 (no yield was obtained in 1984).

<sup>y</sup>Fisher's protected least significant difference for species across fertility treatments.

tion for annual crude protein concentrations (Table 2) since fertilizer increased mean protein concentration of herbage by only 3 g kg<sup>-1</sup> under the two-cut treatment compared to 10 g kg<sup>-1</sup> under the multi-cut treatment (Table 5). There was no significant fertilizer × species interaction (Table 2); under both harvest systems high protein concentrations were found in Russian wildrye, Altai wildrye and smooth brome grass, while low concentrations were found in meadow brome grass, green needlegrass, intermediate wheatgrass, and creeping red fescue (Table 3). For example, under the two-cut treatment, protein concentrations averaged over the year were 83 and 92 g kg<sup>-1</sup> for meadow brome grass and creeping red fescue, compared to 103 and 113 for smooth brome grass and Russian wildrye, respectively (Table 3). Under the multi-cut treatment, annual protein concentrations averaged 119 and 122 g kg<sup>-1</sup> for meadow brome grass and creeping red fescue compared to 154 and 158 g kg<sup>-1</sup> for smooth brome grass and Russian wildrye (Table 3).

The mean concentration of crude protein in both the first and second harvests of the two-cut system (averaged over species) ranged from 88 to 100 g kg<sup>-1</sup> and was not affected by fertilizer (Table 5). In contrast, the mean protein concentration in unfertilized herbage under multiple-cutting ranged from 127 to 148 g kg<sup>-1</sup>, while fertilized herbage ranged from 118 to 166 g kg<sup>-1</sup>. In the multi-cut treatment, cut 1 responded significantly to the application of fertilizer. There was no difference in protein concentration between fertil-

ized and unfertilized treatments in cuts 2 to 4 of the multi-cut system. There was a trend for higher crude protein concentration in the last cut of the multi-cut system. We found the crude protein concentration was generally lower for meadow brome grass and green needlegrass than for both wildryes and smooth brome grass in all harvests of both cutting systems. Intermediate wheatgrass was the only grass that did not respond with a crude protein concentration increase to added fertilizer in cut 1 of the multi-cut system.

In general, there was little difference in protein concentration between the species but there was a significant interaction between cutting management and species (Table 2). Under fertilized two-cut management, Russian and Altai wild rye contained the most protein in first cut and smooth brome grass and Russian wildrye contained the most protein in second cut (Table 5). Under the fertilized, multi-cut treatment, the two wildrye species and smooth brome grass generally contained the most crude protein through the season, ranging from 125 to 196 g kg<sup>-1</sup>. Meadow brome grass and creeping red fescue generally contained the lowest crude protein concentrations of the grasses under both cutting systems, ranging from 77 to 92 g kg<sup>-1</sup> under two-cut and 97 to 159 g kg<sup>-1</sup> under multi-cut treatment. In cuts 1 to 3, which provided 95% of the annual yield, herbage of multi-cut meadow brome grass had crude protein concentrations between 112 and 123 g kg<sup>-1</sup> when no fertilizer was applied and 112 to 147 g kg<sup>-1</sup> when fertilizer was applied (Table 5).

**Table 5. Effect of harvest management and fertilizer on seasonal distribution of crude protein concentration in several grass species from 1982–1984 in Pathlow, Saskatchewan**

Species	2-cut system		Multi-cut system			
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3	Cut 4 <sup>z</sup>
	(g kg <sup>-1</sup> )					
<i>Without fertilizer</i>						
Smooth brome	90	115	136	146	139	169
Crested wheat	78	98	124	148	130	142
Intermediate wheat	105	83	145	146	135	156
Green needle	98	68	135	126	115	148
Altai wildrye	100	96	157	130	143	136
Creeping red fescue	91	81	116	121	104	133
Meadow brome	87	77	123	115	112	146
Russian wildrye	123	88	145	152	131	155
Mean	96	88	135	135	127	148
<i>With fertilizer</i>						
Smooth brome	103	102	173	152	132	190
Crested wheat	92	87	160	143	120	173
Intermediate wheat	93	95	146	132	116	173
Green needle	90	76	159	120	110	167
Altai wildrye	118	83	196	143	131	126
Creeping red fescue	92	88	142	116	97	159
Meadow brome	89	77	147	120	112	159
Russian wildrye	121	107	187	156	125	183
Mean	100	89	164	135	118	166
LSD <sup>y</sup> (0.05)	11	12	11	12	11	17
<i>Significance levels</i>						
Fertilizer	NS	NS	0.01	NS	NS	NS
Species	0.01	0.01	0.01	0.01	0.01	0.01
Fertilizer × Species	0.01	0.01	0.01	0.04	NS	NS

<sup>z</sup>Mean of 1982 and 1983 (no yield was obtained in 1984).

<sup>y</sup>Fisher's protected least significant difference for species across fertilizer treatments.

In contrast, smooth brome had crude concentrations of 136 to 146 g kg<sup>-1</sup> without fertilizer and 132 to 173 g kg<sup>-1</sup> with fertilizer. The low protein content in meadow brome relative to smooth brome and crested wheat is consistent with the results in Manitoba (McCaughy and Simons 1998) although, in Alberta, meadow brome had equal or slightly higher N concentrations than smooth brome, timothy, and meadow foxtail (Fairey 1991).

These results show that animals grazing on pasture in northeast Saskatchewan are probably provided with a higher protein concentration than that fed to them in a feedlot as hay. The protein levels on pasture, particularly when fertilized, are far greater than required by beef cows (NRC 1996). Yearling cattle weighing approximately 400 kg and gaining 1.3 kg d<sup>-1</sup> require a diet containing only 98 g kg<sup>-1</sup> crude protein. Nursing cows weighing 550 to 650 kg require herbage containing 110 to 115 g kg<sup>-1</sup> crude protein. Excess N consumed as protein is excreted by the animal mainly in urine and is both an energy burden to the cow (NRC 1996) and a source of environmental pollution because of the high rates of emission of ammonia and nitrous oxide (Vermeesen et al. 1997; Whitehead 2000). Further addition of N fertilizer to pastures may cause a further increase emission of ammonia (Bussink 1994). Thus, the relatively low protein concentration of meadow brome and creeping red fescue under multi-cut treatment is an advantage for grazing beef cattle. In contrast,

dairy cows consuming this herbage would require supplementation of protein or higher rates of fertilizer. Others studies have shown that protein concentration of hay can be increased with high rates of fertilizer to meet the elevated requirements certain classes of livestock (Ukrainetz and Campbell 1988; McCaughy and Simons 1998).

### N-Offtake

Total annual N offtake more than doubled when grasses were fertilized (Tables 3) as previously reported by McCartney et al. (1998). Nitrogen-offtake was greater under multi-cut than under two-cut treatment on both fertilized and unfertilized plots, even though the multi-cut treatment yielded less (Table 3). The multi-cut plots recovered more of the applied N, which resulted in a significant fertilizer × harvest interaction (Tables 2 and 3). Creeping red fescue had much lower N-offtake than most species under both harvest regimes. Crested wheat and smooth brome had the highest N offtake under both systems (Table 3). Meadow brome and Russian wildrye took up about 10 kg ha<sup>-1</sup> more N under the multi-cut than under the two-cut system. Overall, the pasture-type grasses took up 4 to 5 kg ha<sup>-1</sup> less N than the other grasses under both cutting regimes and both groups took up more N under the multi-cut than under the two-cut treatment.

Higher N-offtake under multi-cut simulated pasture management has been observed previously by Fairey (1991) and

McCaughey and Simons (1998), but the effect was not consistent in these studies. In the former study, only one of the four species (meadow foxtail- *Alopecurus pratensis* L.) took up more N under multiple harvests, and in the latter study the effect was noted in only 1 of 3 yr. Plants commonly used for hay have larger root systems and crowns and more of the plant N is contained below clipping height compared to plants that are adapted to grazing. Although some of the consumed N is recycled to the soil on pastures through the excretion of grazing animals, N cycling on pastures is known to be inefficient (Whitehead 2000). This raises the possibility that pastures may be more prone to depletion of N than hay fields.

### CONCLUSIONS

This study confirmed previous reports that meadow bromegrass has both high yield and relatively uniform seasonal production, making it a desirable grass for pastures in the central Parkland region. It also offered the most late-season yield. The high yield of green needlegrass under multiple harvests suggests that this grass may also deserve consideration for use in pastures; green needlegrass is of particular interest because it is native to the prairie and parkland regions of Canada. Crested wheatgrass was clearly the best of all the grasses for early season production in this study. Using fertilized crested wheatgrass for early grazing, would allow farmers to take their cattle off expensive winter-feed earlier. However, Russian wildrye is used for early grazing in the drier southern prairies. Russian wildrye does not compete in moist areas of the northeast Saskatchewan due to difficulties in stand establishment.

This study showed that meadow bromegrass herbage had lower protein concentrations than other productive grasses throughout the growing season, with or without fertilizer. This is a desirable attribute for pastures to be used by grazing beef cows and steers because the protein requirement for these classes of ruminants is low. In contrast, the other grass commonly seeded on pasture, smooth bromegrass, had excessive N concentration particularly in first cut when fertilizer had been applied. While spring-applied fertilizer boosted yield in cuts 1 to 3, effect on protein concentration was mostly confined to first cut. To prevent ingestion of surplus N in a grazing system, perhaps some or all of the fertilizer should be applied immediately after first harvest, taking advantage of the high probability of rainfall in June and early July. Delaying fertilizer application will also improve late-season production. While there could be a risk of elevated tissue nitrate levels soon after application, this is not likely to be a problem to grazing livestock at low fertilizer levels. Grasses removed more N under multiple cutting than under two-cut management most likely due to the fact that the herbage in the multi-cut system was vegetative while the herbage was more mature in the two-cut system.

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