

Yield, quality and cost effectiveness of using fertilizer and/or alfalfa to improve meadow bromegrass pastures

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Kopp, J. C., McCaughey, W. P. and Wittenberg, K. M. 2003. **Yield, quality and cost effectiveness of using fertilizer and/or alfalfa to improve meadow bromegrass pastures.** Can. J. Anim. Sci. **83**: 291–298. A 4-yr study was conducted to determine the effects of forage type and fertilization on yield and quality of dryland pastures on the Canadian prairies. Pastures contained either meadow bromegrass (*Bromus biebersteinii* Roem & Schult.) (G) or alfalfa (*Medicago sativa* L.)-meadow bromegrass (A) and were either unfertilized (U) or fertilized (F) in order to increase the availability of essential plant nutrients to recommended levels. Average pasture yields (1995–1998) of AF, AU, GF and GU treatments were 3.88, 3.12, 3.95 and 1.94 ± 0.19 t DM ha⁻¹ and average carrying capacities were 200.4, 163.9, 208.7 and 127.6 ± 3.3 cow-days ha⁻¹, respectively. Alfalfa content declined ($P < 0.05$) over the 4 yr from 75.4 and 84.1% in 1995 to 32.5 and 40.3% in 1998 for AF and AU pastures, respectively. Simple incorporation of alfalfa into grass pastures (AU) improved carrying capacity by 28% and met the nutritional requirements of lactating beef cows at no additional cost. Fertilization of meadow bromegrass pastures (GF) improved the carrying capacity by 64% and met the nutrient requirements of lactating beef cows. Incorporating alfalfa with fertilization (AF) improved carrying capacity of pasture by 57% and met the nutrient requirements of lactating beef cows. Both the AF and GF treatments entailed significant financial risk as they were only cost-effective strategies when precipitation was not limiting. The AU treatment did not entail financial risk and was always a cost-effective treatment.

Key words: Alfalfa, meadow bromegrass, productivity, forage quality, grazing

Kopp, J. C., McCaughey, W. P. et Wittenberg, K. M. 2003. **Rendement, qualité et rentabilité des prés de brome améliorés par application d'engrais ou intégration de la culture de luzerne.** Can. J. Anim. Sci. **83**: 291–298. Pendant quatre ans, les auteurs ont étudié l'incidence de l'espèce fourragère et de la fertilisation sur le rendement et la qualité des pâturages arides dans les Prairies canadiennes. Ils ont fertilisé (F) ou pas (U) des pâturages de brome des prés (*Bromus biebersteinii* Roem & Schult.) (G) ou de luzerne (*Medicago sativa* L.) et de brome des prés (A) de façon à porter la concentration d'éléments nutritifs essentiels aux taux recommandés. Les pâturages AF, AU, GF et GU ont donné un rendement moyen (de 1995 à 1998) respectif de 3,88, 3,12, 3,95 et 1,94 ± 0,19 t de matière sèche par hectare pour une capacité de charge moyenne de 200,4, 163,9, 208,7 et 127,6 ± 3,3 jours-vaches par hectare. Au cours des quatre années de l'étude, la proportion de luzerne est respectivement passée ($P < 0,05$) de 75,4 % et de 84,1 % en 1995 à 32,5 % et à 40,3 % en 1998 dans les pâturages AF et AU. L'incorporation de luzerne aux prés de graminées (AU) améliore à elle seule la capacité de charge de 28 % et permet de répondre aux besoins nutritifs des vaches de boucherie en lactation, sans coût supplémentaire. L'amendement des pâturages de brome (GF) relève la capacité de charge de 64 % et permet lui aussi de satisfaire les besoins nutritifs des vaches de boucherie en lactation. Combinée à la fertilisation, l'addition de luzerne (AF) augmente la capacité de charge des pâturages de 57 %, ce qui satisfait les exigences nutritives des animaux. Les traitements AF et GF entraînent toutefois des risques financiers sensibles, ces stratégies n'étant rentables que lorsque les précipitations sont suffisantes. Le traitement AU n'engendre aucun risque financier et est toujours rentable.

Mots clés: Luzerne, brome des prés, productivité, qualité des fourrages, paissance

There are a number of agronomic strategies that can improve the yield and quality of cultivated pastures. These strategies include application of inorganic fertilizers and incorporation of legumes such as alfalfa into grass-based pastures. Both strategies may improve pasture yield, increase protein crude concentration and extend the period of active plant growth.

In recent years, meadow bromegrass (*Bromus biebersteinii* Roem & Schult.) has become a popular pasture grass species for the moister areas of the Canadian prairies. This is because meadow bromegrass regrows rapidly after grazing and is palatable to cattle (McCaughey 1998). Because meadow bromegrass has short rhizomes it is not as competitive with alfalfa as other grasses such as smooth

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Abbreviations: ADF, acid detergent fibre; AF, alfalfa-grass fertilized; AU, alfalfa-grass unfertilized; CGD, cow grazing days; CP, crude protein; GF, grass-only fertilized; GU, grass-only unfertilized; NDF, neutral detergent fibre; R1, rotation one; R2, rotation two

bromegrass (*Bromus inermis* Leyss.) (Pearen and Baron 1996). Also, meadow bromegrass maintains a high density of small vegetative tillers that regrow quickly from growing points that are located below the grazing height, making it less vulnerable to frequent defoliation (Pearen and Baron 1996; Van Esbroeck et al. 1995; Knowles et al. 1993). Meadow bromegrass is also quite responsive to fertilization. McCaughey and Simons (1996) observed that while yield increased by only 14–18% in the year after establishment, yield increased by 104–149% in the third year after establishment when meadow bromegrass was fertilized at a rate of 120 kg N ha⁻¹. Grass pastures become more responsive to N fertilizer once N becomes limiting to plant growth, 2 to 3 yr after establishment.

Fertilization is not the only way to improve the yield and quality of pastures. Legumes such as alfalfa can also improve pasture yield and quality. Alfalfa is a valued pasture plant as it yields well, fixes atmospheric N, has a high nutritive value, is well suited for cattle production and is adapted to many climatic and soil conditions (Van Keuren and Matches 1988). However, when planted in mixtures, grass competition and frequent defoliation may decrease alfalfa longevity (Pearen and Baron 1996). Grasses are generally more tolerant than alfalfa to frequent cutting (Hoveland et al. 1995).

The advantages of alfalfa-grass mixtures include: increased soil and water conservation, enhanced control of weedy species, minimized loss of production from thinning legume stands and reduced risk of bloat in grazing animals (Casler and Walgenbach 1990). A disadvantage of alfalfa-grass mixtures is that many grass species are very competitive when planted with alfalfa (*Medicago sativa* L.) (Hoveland et al. 1995; Pearen and Baron 1996) and as alfalfa persistence declines, a loss of nutritive value occurs relative to pure alfalfa stands (Smith et al. 1992). Also, fertilization of mixed species pastures has been observed to increase the competitiveness of grasses causing the persistence of legumes to decline (Russelle 1992; Pearen and Baron 1996).

The objective of the present study was to determine the effects of alfalfa incorporation and fertilizer use on pasture yield, quality and botanical composition of meadow-bromegrass-based pastures and to evaluate the cost effectiveness of these treatments on dryland pastures on the Canadian prairies.

MATERIALS AND METHODS

Pastures

A 4-yr trial was conducted near Brandon, Manitoba, Canada (49°52'N; 99°59'W; 363 m above sea level) on a Class 5 infertile Orthic Black Chernozemic Souris fine sandy loam soil (Ehrlich et al. 1957). Eight, 3.7-ha experimental pastures were randomly assigned to one of four treatments: alfalfa-meadow bromegrass-fertilized (AF), alfalfa-meadow bromegrass-unfertilized (AU), meadow bromegrass-fertilized (GF) and meadow bromegrass unfertilized (GU). Each pasture treatment combination was replicated twice. In the spring of 1994, four 3.7-ha pastures were sown to meadow bromegrass (cv. Paddock; 10 kg ha⁻¹) and four 3.7-ha pas-

tures were sown to a mixture of meadow bromegrass (cv. Paddock; 6 kg ha⁻¹) and alfalfa (cv. Spredor II; 3 kg ha⁻¹) to produce alfalfa-dominated pastures. Broadleaf weeds were controlled with 1094 g 2,4-DB (a.i.) ha⁻¹ in the establishment year. In subsequent years, no chemical weed control was necessary as weed-free pastures were established. Pasture establishment costs were similar between all treatments. After seeding, two of the meadow bromegrass pastures and two of the alfalfa-meadow bromegrass pastures were fertilized with N, P, K and S (Table 1) to increase availability of these plant nutrients to levels recommended by Manitoba Agriculture and Food (Manitoba Agriculture and Food 2003), while the remaining four pastures were left unfertilized. The AF and GF pastures were fertilized once each year in early spring on the basis of results from soil tests collected the previous fall.

Grazing started in 1995. On each pasture, four cow-calf pairs were used to collect animal performance data and additional cow-calf pairs were added or subtracted one to two times per week as was necessary to maintain equal residual herbage after grazing in all pastures. This ensured the same length of grazing season for all treatments and that all animals were rotated between paddocks at the same time. Each 3.7-ha pasture was equally divided into five paddocks using portable electric fencing and all cow-calf pairs were rotationally stocked. Cattle were rotated between paddocks slowly when plant growth was slow (as in 1995, 1996 and 1996) and quickly when plant growth was rapid (as in 1998). Primiparous Simmental-Angus cross-bred cows (463 ± 30.6 kg) with calves were grazed in 1995, multiparous composite breed cows (566 ± 54.5 kg and 521 ± 56.2 kg) with calves were grazed in 1996 and 1997 and primiparous composite breed cows (464 ± 46.7 kg) and calves were grazed in 1998.

Pasture biomass (t DM ha⁻¹) was assessed directly before and after grazing each paddock by hand-clipping eight randomly selected 0.25-m² quadrats per paddock at ground level and drying the clipped herbage in a 50°C forced-air oven for 48 h. Pasture production was estimated from herbage dry matter disappearance while each paddock was grazed. A weakness of this method is that it may not account for pasture growth occurring while cattle grazed the paddock. These values were summed up for each paddock before calculating pasture yields on a per hectare basis. Pasture productivity was also estimated indirectly by estimating carrying capacity (cow grazing days per hectare, CGD ha⁻¹).

Pasture quality was assessed using four of the dried samples collected from each paddock. Samples were collected when cattle entered and exited the paddock and were hand-separated into the different forage species (alfalfa and meadow bromegrass) and re-weighed to determine pasture botanical composition. Since small amounts of quackgrass [*Elytrigia repens* (L.) Nevski] were present in the grass samples and could not be easily separated from the meadow bromegrass they were included together in the meadow bromegrass component. The remaining four samples collected when cattle entered the paddock were composited, ground to pass through a 1-mm steel sieve using a Wiley mill and stored in air-tight containers until submitted for forage quality analysis.

Table 1. Fertilizer nutrients applied (kg ha⁻¹) to meadow brome grass (GF) and alfalfa-meadow brome grass (AF) pastures (1994–1998) to increase nutrient supply to recommended levels^z

	Meadow brome grass				Alfalfa-meadow brome grass			
	N	P ₂ O ₅	K ₂ O	S	N	P ₂ O ₅	K ₂ O	S
1994	0	0	50	0	11	50	77	0
1995	95	4	0	30	29	20	0	30
1996	110	22	0	0	9	43	0	0
1997	110	10	0	0	5	22	0	0
1998	68	22	21	0	44	31	16	10

^zManitoba Agriculture and Food (2003).

Laboratory Analysis

Pasture samples were analyzed for acid detergent fibre [ADF; Association of Official Analytical Chemists (AOAC) 1990; method no. 973.18], and neutral detergent fibre (NDF; Van Soest et al. 1991) using the Tecator Fibertec System M 1020 Hot Extractor (Herndon, VA, USA), as well as crude protein (CP) via Kjeldahl digestion (AOAC 1990; method no. 984.13) to determine estimate the N content of the sample, which was then multiplied by 6.25 to estimate approximate the amount of CP content of in the forage sample. Results of all laboratory analyses were expressed on a dry matter basis (DM; AOAC 1990; method no. 934.01).

Statistical Methods

Annual pasture yield, carrying capacity, quality (CP, NDF and ADF) and botanical composition data were all analyzed by using the general linear models procedure (GLM, SAS Institute, Inc. 1990) and means that differed were identified using PDIF (GLM, SAS Institute, Inc. 1990).

The design used was a split-split-plot design with pasture treatments as the main plots in a randomized complete block arrangement, years were in the sub-plots and rotations were in the sub-sub-plots. Pasture quality parameters were analyzed for the first three years of data collection (1995 to 1997) and pasture yield and carrying capacity were analyzed for all four years of data collection (1995 to 1998).

Cost/Benefit Analysis

A cost/benefit analysis of the GF, AF and AU treatments was conducted by determining the additional carrying capacity relative to the GU treatment and determining the additional costs invested to obtain the additional carrying capacity. This method enabled the cost of each additional cow-day of grazing to be determined. The cost per additional cow-day of grazing was compared to typical pasture rental costs on the Canadian prairies to assess cost effectiveness.

RESULTS AND DISCUSSION

Growing Conditions

Total grazing season precipitation was 206 mm, 263 mm, 219 mm and 465 mm in 1995, 1996, 1997 and 1998, respectively (Table 2). This compares to a 92-yr average growing season precipitation of 312 mm. Average growing season temperatures were 16.1, 15.1, 16.1 and 15.0°C in 1995, 1996, 1997 and 1998, respectively (Table 2). This compares to a 92-yr average growing season temperature of 15°C.

Fertilization

Fertilization strategies differed between GF and AF treatments. The strategy on GF pastures was to provide 110 kg available N ha⁻¹ and balance for P, K and S as needed. The strategy on AF pastures was to balance for P, K and S as needed and rely on symbiotic (*Rhizobia* spp.) N fixation to provide sufficient N to maintain pasture production. AF pastures received small quantities of N as it was contained in the other fertilizer ingredients, monoammonium phosphate and ammonium sulphate.

From 1994 to 1998, the GF pastures received a total of 285 kg ha⁻¹ more N than the AF pastures (Table 1). In contrast, AF pastures received 108 kg ha⁻¹ more P, 22 kg ha⁻¹ more K₂O and 10 kg ha⁻¹ more S than the GF pastures (Table 1).

Pasture Productivity

A treatment × year interaction existed for pasture production. This was caused by fertilized pastures responding more strongly to available precipitation. Four-year average pasture production was 3.88, 3.12, 3.95 and 1.94 ± 0.26 t DM ha⁻¹ for AF, AU, GF and GU pastures, respectively (Table 3). Four-year average pasture production data indicated that both GF and AF yielded more ($P < 0.05$) than GU pastures but not more than AU pastures. Averaged over the 4 yr, fertilizing meadow brome grass increased pasture production by 2.1 t DM ha⁻¹ and including alfalfa in meadow-brome grass-based pasture mixes increased production by 1.2 t DM ha⁻¹ compared to GU pastures. A combination of including alfalfa in the pasture mix plus fertilization increased pasture production by 1.9 t DM ha⁻¹. These results are similar to those reported by Nuttall et al. (1980) who found that when alfalfa-brome grass pastures were fertilized with 90 kg N ha⁻¹ and 20 kg P ha⁻¹, herbage yield increased by 74%. In the current study, DM production of AF pastures did not differ significantly ($P > 0.05$) from AU pastures. The unfertilized grass (GU) treatment produced 49 and 50% of GF and AF pastures, respectively, and 62% of the pastures containing alfalfa in mixture with meadow brome grass (AU). These observations are similar to those of Smith et al. (1992) who observed that when alfalfa was sown with tall fescue (*Festuca arundinacea* Schreb.) it produced the same level of forage production as a fertilized tall fescue mono-culture.

Carrying Capacity

Forage production alone does not indicate how useful a pasture is for cow-calf production. Carrying capacity measured

Table 2. Growing season precipitation and temperature data (1995–1998), Brandon, Manitoba

Month	1995	1996	1997	1998	92-yr average
	<i>Precipitation (mm)</i>				
May	64.0	66.0	14.4	85.9	49.0
June	72.0	53.0	53.0	163.0	79.3
July	20.0	59.0	98.0	68.0	73.0
August	19.0	25.0	45.0	122.0	64.5
September	31.0	60.0	9.0	26.0	46.1
Total	206.0	263.0	219.4	464.9	311.9
	<i>Temperature (°C)</i>				
May	10.8	8.6	9.5	11.9	10.8
June	18.9	17.6	18.9	14.8	15.9
July	19.3	18.3	19.7	19.1	19.0
August	19.5	18.7	18.2	19.9	17.6
September	12.2	12.4	14.3	13.8	11.9
Average	16.1	15.1	16.1	15.9	15.0

Grazing seasons: 13 June 1995 – 24 August 1995, 15 June 1996 – 9 September 1996, 5 June 1997 – 27 August 1997, 28 May 1998 – 17 September 1998.

Table 3. Pasture yield (t DM ha⁻¹) of fertilized (F) and unfertilized (U) alfalfa-meadow bromegrass (A) and meadow bromegrass (G)-only pastures (1995–1998)

	Treatment				SEM
	AF	AU	GF	GU	
4-yr avg.	3.88a	3.12a,b	3.95a	1.94b	0.26
1995	3.24a	2.82a	3.40a	2.02a	0.35
1996	4.11a	3.31a,b	4.67a	2.24b	0.33
1997	2.82a	2.76a	2.98a	1.72b	0.08
1998	5.35a	3.58a,b	4.76a	1.80b	0.47

a–d Means within rows not having a common letter differ ($P < 0.05$).

Table 4. Carrying capacity (CGD ha⁻¹) of fertilized (F) and unfertilized (U) alfalfa-meadow bromegrass (A) and meadow bromegrass (G)-only pastures (1995–1998)

	Treatment				SEM
	AF	AU	GF	GU	
4-yr avg.	200.4a	163.9b	208.7a	127.6c	3.3
1995	136.6	130.0	146.6	107.7	8.1
1996	186.0ab	149.7b	229.2a	149.9b	12.7
1997	172.0	158.1	190.0	122.3	15.6
1998	323.1a	232.4b	282.8ab	141.5c	16.4

a–c Means within rows not having a common letter differ ($P < 0.05$).

as cow grazing days per hectare (CGD ha⁻¹) takes into account utilization of the pasture, since trampling and refusal of less-palatable forage may occur. A pasture treatment × year interaction existed for carrying capacity. This reflects the variation in growing conditions, animal type and date that cattle were placed on pasture. Thus, the results are presented separately for each treatment × year combination. Fertilized pastures (AF and GF) responded more strongly to available precipitation than unfertilized grass (GU) pastures. Overall, the ranking of 4-yr average carrying capacity indicated that GF = AF > AU > GU ($P < 0.05$) (Table 4). The GF (208.7 CGD ha⁻¹) and AF (200.4 CGD ha⁻¹) pasture treatments were the most productive followed by AU (163.9 CGD ha⁻¹), and GU (127.6 CGD ha⁻¹) was the least pro-

ductive. The most productive year was 1998, when rainfall was greater than the long-term average (Table 2). Generally, differences in carrying capacity were evident between treatments when sufficient precipitation was available. The widest range in pasture carrying capacity was observed for AF (136.3 to 323.1 CGD ha⁻¹), which suggests flexible harvest options (e.g., a combination of haying and grazing) must be used to achieve optimum utilization. By comparison, GF had a narrower carrying capacity range of 146.6 to 282.8 CGD ha⁻¹.

Botanical Composition

The pastures used in this experiment were dominated by alfalfa and meadow bromegrass. Small amounts of quackgrass were also present, but this was included in the grass component when hand-sorting to determine botanical composition. There were no annual weeds present in these pastures due to good establishment and dry growing conditions.

Alfalfa percentage declined from 75.4 and 84.1% in 1995 to 32.5 and 40.3% in 1998 for AF and AU pastures, respectively (Fig. 1). The decline was more rapid for the AF pastures; AU pastures took four grazing seasons to decline to levels observed for AF pastures in the second grazing season. The AU pastures contained 17.6% more alfalfa than the AF pastures ($P < 0.05$) in 1996. Similar results were found in R1 of 1997 ($P < 0.05$) and 1998 ($P < 0.05$) with AU containing on average 14.2% more alfalfa than the AF pastures. The treatment response in R1 may have been a reflection of the spring fertilizer application which may have encouraged bromegrass growth and more aggressive competition.

Generally, the alfalfa content (%) was greater in the unfertilized pastures than the fertilized pastures. Fertilizing legume-grass pastures with N often results in decreasing legume populations, because of greater grass competition (Dougherty and Rhykerd 1985; Sheard 1974). Alfalfa persistence has been observed to decrease when grasses are included in the pasture mix (Smith et al. 1992). However, with the selection and development of improved grazing tolerant and more vigorous alfalfa cultivars, the persistence of alfalfa under different environments may be improved.

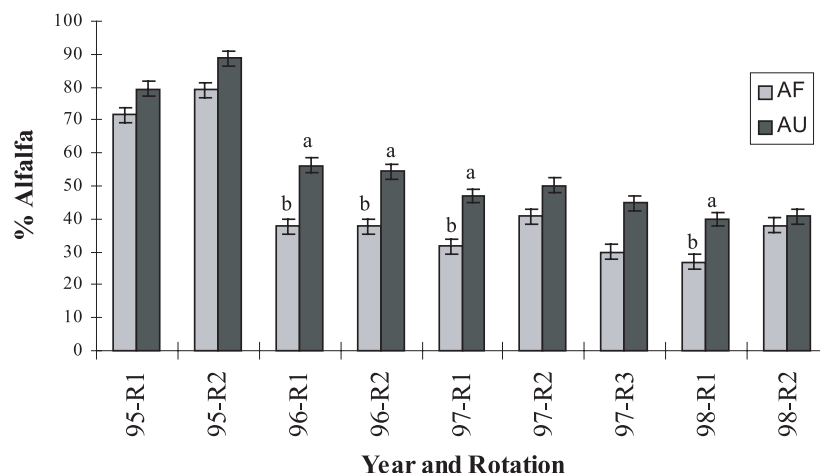


Fig. 1. Alfalfa content (%) in fertilized (AF) and unfertilized (AU) alfalfa-meadow brome grass pastures (1995–1998). *a, b* Denotes significant differences ($P < 0.05$).

Forage Quality

Forage quality is affected by pasture botanical composition, plant maturity, seasonal variations in temperature, light intensity, day length and grazing management (Coors et al. 1986). In this study, pasture treatment had variable effects on herbage CP, NDF and ADF concentrations. This reflected the variation in treatment response to growing conditions between years and rotations. Thus, the results are presented separately for each treatment \times year \times rotation combination (Tables 5, 6 and 7).

Crude Protein

Alfalfa-grass pastures often had higher CP content than grass-only pastures but the pasture treatment ranking did vary from year to year and between rotations (Table 5). Fertilization increased ($P < 0.05$) the CP content of grass-only pastures by an average of 4.1% units in R1 and by 3.3% units in R2. When the alfalfa-grass pastures were fertilized, the CP content increased ($P < 0.05$) by 0.8% units in R1, but were not affected in R2. The reason for the difference can be explained by the different fertilization strategies in grass-only and grass-legume pastures. GF pastures received heavy N fertilization to stimulate grass production while AF pastures (containing N-fixing alfalfa) were fertilized to balance important plant nutrients such as P, K and S and received limited amounts of N. The small amounts of N applied in the legume fertilization strategy were present in the other fertilizer ingredients, monoammonium phosphate and ammonium sulphate, which are the most common sources of P and S used in western Canada.

Herbage CP concentrations were greater ($P < 0.05$) in R1 for AF pastures compared to AU pastures in all years, except 1996. GU pastures always had the lowest ($P < 0.01$) herbage CP content, ranging from a low of 7.2% in R1 of 1996 to a high of 11.8 in R3 of 1997.

In 1995 and 1997, no treatment effects were apparent for CP content of pasture regrowth (R2), probably because most

Table 5. Crude protein (% DM) content of alfalfa-meadow brome grass (A) and meadow brome grass (G) pastures in fertilized (F) and unfertilized (U) conditions (1995–1997)

	Rotation	<i>n</i>	Treatment				SEM
			AF	AU	GF	GU	
3-yr avg.	1	120	14.1 _a	13.3 _b	12.4 _c	8.3 _d	0.26
	2	48	14.3 _a	14.1 _a	13.0 _b	9.7 _c	0.28
1995	1	40	15.8 _a	13.8 _b	10.6 _c	8.3 _d	0.28
	2	16	12.0	11.7	10.6	10.1	0.62
1996	1	40	11.4 _a	11.5 _a	10.6 _a	7.2 _b	0.38
	2	16	14.1 _a	13.2 _b	12.9 _b	7.7 _c	0.22
1997	1	40	15.1 _a	14.5 _a	16.1 _a	9.3 _b	0.84
	2	40	14.4	14.6	13.3	10.5	0.88
	3	16	17.5	15.7	16.0	11.8	1.11

a–d Means within rows not having a common letter differ ($P < 0.05$).

of the applied fertilizer nutrients were taken up by the plant in R1. It is also possible that applied N may have been lost through volatilization (Russelle 1992) resulting in lack of forage yield and quality differences in R2. Since 1995 and 1997 were dry years, there was little benefit of fertilization on pasture quality during these years.

One of the major issues identified in this study was low CP content on GU pastures due to N deficiency. On the basis of the 3 yr of data, GU would not be able to support optimum production. A 635-kg beef cow's requirement for CP 5 mo after calving, with milk production of 4.9 kg d⁻¹, is at least 8.3% CP (National Research Council 1996), and when this cow-calf pair is first put on pasture (2 mo after calving, producing 9 kg milk d⁻¹) it requires approximately 10.3% CP (National Research Council 1996). The problem of low CP could be alleviated by the use of either fertilization and/or the inclusion of legumes such as alfalfa in the pasture mix. Other research has shown that N fertilization can increase the CP concentration of dryland pasture (Nuttall et al. 1980; Nyren et al. 1983; McCaughey and Simons 1998).

Table 6. Neutral detergent fibre (% DM) of alfalfa-meadow bromegrass (A) and meadow bromegrass (G) pastures in fertilized (F) and unfertilized (U) conditions (1995–1997)

	Rotation	n	Treatment				SEM
			AF	AU	GF	GU	
3-yr avg.	1	120	53.0c	51.2d	61.7b	63.3a	0.40
	2	48	56.4c	53.6d	62.9b	66.5a	0.70
1995	1	40	50.5b	49.4b	63.7a	63.8a	0.38
	2	16	59.2b	56.2c	65.8a	65.2a	0.62
1996	1	40	60.2b	57.5b	65.1a	65.7a	0.91
	2	16	60.1b	58.5b	66.5a	73.0a	0.90
1997	1	40	48.1c	46.6c	56.2b	60.4a	0.47
	2	40	51.3c	49.3c	58.3b	61.9a	0.94
	3	16	60.8	62.2	64.9	67.0	1.45

a–d Means within rows not having a common letter differ ($P < 0.05$).

Table 7. Acid detergent fibre (% DM) content of alfalfa-meadow bromegrass (A) and meadow bromegrass (G) pastures in fertilized (F) and unfertilized (U) conditions (1995–1997)

	Rotation	n	Treatment				SEM
			AF	AU	GF	GU	
3-yr avg.	1	120	34.9c	34.8c	36.8b	39.0a	0.31
	2	48	39.7b	39.2b	39.8b	41.2a	0.30
1995	1	40	36.9b	37.1b	40.7a	41.0a	0.30
	2	16	45.2	43.5	42.8	42.9	0.52
1996	1	40	39.3	38.3	39	39.6	0.58
	2	16	41.4b	43.0b	42.6b	47.1a	0.74
1997	1	40	28.4b	29.0b	30.7b	35.9a	0.80
	2	40	33.5c	32.8c	35.5b	36.6a	0.25
	3	16	36.3bc	38.9ab	34.6c	40.0a	0.72

a–c Means within rows not having a common letter differ ($P < 0.05$).

Neutral Detergent Fibre

Neutral detergent fibre measures the amount of cellulose, hemi-cellulose, lignin and insoluble ash in a plant tissue sample and provides an indication of the potential voluntary intake of the animal (Fahey and Berger 1988). Cattle consuming herbage with lower NDF content generally have higher voluntary intake and improved performance. The 3-yr average for forage NDF concentration (Table 6) was similar for both R1 and R2. Treatments ranking in descending order from the highest level of NDF to the lowest was GU > GF > AF > AU ($P < 0.05$).

The lowest NDF levels were recorded in 1997, and the highest NDF values were seen in 1996. This observation may be reflective of the amount of precipitation received in July and August. In 1997, the pastures received 39 and 20 mm more rainfall than the same months in 1996. As well, the 1996 grazing season started and finished later than the 1997 grazing season and, therefore, the 1996 forage may have been more physiologically mature before grazing. The AF treatment had the largest range in forage NDF concentration, with a 6.8% range from the highest to the lowest year averages and AU had the most stable NDF levels with a 5.3% range. Alfalfa-grass pastures had on average 9.2% less NDF ($P < 0.01$) than the grass-only pastures. Including alfalfa in the pasture mix consistently reduced the NDF content of the forage, which is important to maximize voluntary intake by grazing animals.

Fertilization of the alfalfa-grass pastures resulted in NDF concentrations either increasing or staying the same. Increasing NDF in response to fertilization may have been due to changes in botanical composition, as the level of alfalfa in the alfalfa-grass stands decreased to a greater extent with fertilization (Fig. 1). In contrast to the alfalfa-grass pastures (AU), when the meadow bromegrass-only pastures were fertilized (GF), the level of NDF stayed the same or decreased ($P < 0.05$). When precipitation is adequate for good growth, N fertilization may help to maintain grass pastures in a less-mature, vegetative state with lower NDF concentrations than the unfertilized grass pastures.

Acid Detergent Fibre

Acid detergent fibre provides an estimate of relative digestibility of the forage ingested by the animal (Fahey and Berger 1988). Cattle consuming herbage with lower ADF content generally have higher digestibility and improved performance. The average ranking of ADF concentration for the experimental pastures, from highest to lowest was: GU > GF > AF = AU ($P < 0.01$) in R1, and changed only slightly (GU > GF = AF = AU) in R2 (Table 7). Fertilization did not affect the ADF concentration in the alfalfa-grass pastures but often resulted in reduced ADF concentrations in grass-only pastures. Incorporation of a legume such as alfalfa improved the quality of grass pastures more so than fertilization.

The lack of rainfall in 1995 caused alfalfa plants to drop leaves and the meadow bromegrass plants to turn brown (dormancy); this resulted in high ADF levels in 1995 (Table 6). The greatest range in ADF levels was seen in the AF pasture samples, with a range of 8.3%. The most stable ADF concentrations were observed in the GU samples, with a difference of 5.9%. The GU samples, however, had the highest level of ADF. Unfertilized alfalfa-grass pastures tended to be of better quality and were less variable over the course of the study.

Cost Benefit Analysis

To justify fertilizing or adding legumes to pastures, the costs have to be more than offset by the increase in carrying capacity. On the Canadian prairies, government-owned community pastures typically charge approximately \$0.48 per cow and calf per day (Saskatchewan Agriculture and Food 2000). Since all pastures in this study had similar establishment costs, the cost effectiveness of each pasture treatment can be evaluated by the extra cost to generate an additional cow-day of grazing relative to the unfertilized grass treatment (GU). Averaged over the 4 yr of the study, GF pastures produced 81.8 CGD ha⁻¹ more than GU pastures at a cost of \$1.22 per extra CGD (Table 8). AF pastures produced 74.0 CGD ha⁻¹ more than GU pastures, at a cost of \$1.04 per extra CGD.

It was only under conditions when precipitation was not limiting (i.e., 1998), that either fertilization treatment approached cost effectiveness. In 1998, GF and AF pastures produced 141.3 and 90.9 additional CGD ha⁻¹ at a cost of \$0.49 and \$0.37 per CGD, respectively. Therefore, renting additional pasture may be a less-risky strategy than growing

Table 8. Additional carrying capacity (CGD ha⁻¹) and cost per additional CGD (\$ CGD⁻¹) when comparing AF, AU and GF treatments to GU (1995–1998)

	GF-GU	AU-GU	AF-GU
	<i>Additional CGD ha⁻¹</i>		
1995	38.9	22.3	28.6
1996	79.3	-0.2	36.1
1997	67.7	35.8	49.7
1998	141.3	90.9	181.6
Average	81.8	37.2	74.0
Standard deviation	43.1	38.8	72.3
	<i>Cost of additional CGD (\$)</i>		
1995	2.11	0	1.97
1996	1.1	0	1.24
1997	1.16	0	0.57
1998	0.49	0	0.37
Average	1.22	0	1.04
Standard deviation	0.67	0	0.73

Fertilizer prices based on average market values (3-yr market survey of Manitoba fertilizer suppliers) for each nutrient; \$0.56 kg⁻¹ N, \$0.69 kg⁻¹ P, \$0.31 kg⁻¹ K and \$0.54 kg⁻¹ S; plus the cost of custom broadcasting granular fertilizer (\$10.38 ha⁻¹) (Manitoba Agriculture and Food 2000).

more pasture through the use of fertilization. However, renting pasture may entail other costs unique to each farm or ranch, which must be considered (e.g., trucking, travel) in the decision-making process. Fertilizing grass-based pastures to increase carrying capacity will only be cost-effective strategies in years of adequate precipitation. In contrast, on the Canadian prairies, adding alfalfa to the pasture mix at establishment is likely to be the most cost-effective strategy as it generally increases pasture productivity without additional costs.

CONCLUSIONS

Yield, quality and persistence of pastures were affected by alfalfa content and by fertilization. However, response to these treatments varied depending on year and grazing rotation. On average, incorporating alfalfa (AU) into meadow bromegrass pastures improved carrying capacity by 28% and met the requirements of lactating beef cows at no additional cost. Fertilizing meadow bromegrass pastures (GF) improved the carrying capacity of grass pasture by 64% and met the nutrient requirements of lactating beef cows. Incorporating a legume with fertilization (AF) improved carrying capacity of pasture by 57% and met the nutritional requirements of lactating beef cows. However, AF and GF treatments entailed significant financial risk as they were only cost-effective strategies when precipitation was not limiting. The AU treatment did not entail financial risk and was the only treatment which was cost effective.

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