Management strategies to improve cow-calf productivity on meadow bromegrass pastures

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Kopp, J. C., Wittenberg, K. M. and McCaughey, W. P. 2004. **Management strategies to improve cow-calf productivity on meadow bromegrass pastures**. Can. J. Anim. Sci. **84**: 529–535. A 4-yr experiment was conducted to determine the effects of fertilization, incorporation of a legume and use of the Rumensin®-controlled release capsules (CRC) on productivity of cow-calf pairs grazing meadow bromegrass (*Bromus biebersteinii* Roem & Schult.). Four pasture treatments (T), alfalfa-grass fertilized (AF), alfalfa-grass unfertilized (AU), grass-only fertilized (GF) and grass-only unfertilized (GU), each replicated twice were compared. The eight 3.7-ha pastures were split into five equally sized paddocks and rotationally stocked with first-calf cows in 1995 and 1998, and with mature cows in 1996 and 1997. Half of the cows on each pasture received a Rumensin® CRC 1 wk prior to the start of the pasture season. Cow DMI was not influenced by fertilization or incorporation of a legume. However, cows treated with monensin consumed less (2.3% BW) compared to the control cows (2.5% BW, $P < 0.05$). Incorporation of alfalfa and fertilization improved pasture quality and resulted in higher CP and lower NDF content in forage selected by the animals. Monensin improved ($P < 0.05$) cow average daily gain (ADG, kg d^{-1}) when grazing unfertilized grass and alfalfa-grass pastures, but did not influence gains of cows on fertilized pastures. Fertilizer application, legume incorporation and monensin administration did not affect milk yield or milk composition. Despite differences in diet quality, calf ADG for AU, AF, and GF were similar. However, calf ADG was lower for GU pastures ($P < 0.05$), probably as a result of the high fibre and low protein content of this pasture treatment. Both incorporation of alfalfa and fertilization increased total calf gain (kg ha^{-1}); the greatest improvement was associated with fertilization. There were, however, economic advantages to legume incorporation, as the cost of the additional gain for GF and AF pastures averaged \$1.08 and \$0.79 kg^{-1} ha^{-1}, and no extra costs were incurred for AU.

Key words: Beef cows, calves, milk yield, pasture productivity, alfalfa, meadow bromegrass

Kopp, J. C., Wittenberg, K. M. et McCaughey, W. P. 2004. **Stratégies en vue d'accroître le rendement des vaches et des veaux dans les pâturages de brome des prés**. Can. J. Anim. Sci. **84**: 529–535. Les auteurs ont entrepris une expérience de quatre ans en vue de préciser les effets de la fertilisation, de l'incorporation d'une légumineuse et de l'usage de capsules de Rumensin® à libération lente sur la productivité de couples constitués d'un veau et de sa mère mis à l'herbe dans des pâturages de brome des prés (*Bromus biebersteinii* Roem & Schult.). Pour cela, ils ont comparé quatre traitements étudiés en double : la graminée et de la luzerne avec fertilisation (AF), la graminée et de la luzerne sans fertilisation (AU), la graminée avec fertilisation (GF) et la graminée sans fertilisation (GU). Les huit pâturages de 3,7 hectares ont été scindés en cinq enclos de superficie identique et on y a mis à l'herbe, en rotation, des vaches primipares (1995 et 1998) ou des vaches matures (1996 et 1997). La moitié des sujets de chaque enclos a reçu des capsules de Rumensin® à libération lente une semaine avant que débute la paissance. La fertilisation et l'incorporation d'une légumineuse n'affectent pas l'ingestion de matière sèche par la vache. Toutefois, les animaux recevant du monensin mangent moins (2,3 % du poids corporel) que les vaches témoins (2,5 % du poids corporel, $P < 0,05$). L'incorporation de luzerne et la fertilisation améliorent la qualité du pâturage tout en augmentant la concentration de protéines brutes et en réduisant celle de fibres au détergent neutre dans les fourrages que consomment les animaux. Le monensin accroît ($P < 0,05$) le gain quotidien moyen (GQM, kg par jour) de la vache quand elle broute des graminées dans les pâturages non bonifiés ou les mélanges de graminée-luzerne, mais il n'agit pas sur le gain de poids des animaux dans les pâturages bonifiés. L'application d'engrais, l'incorporation de légumineuses et l'administration de monensin n'affectent ni la production ni la composition du lait. Bien que la qualité de l'aliment varie, les veaux AU, AF et GF avaient un GQM analogue. Le GQM était cependant plus faible ($P < 0,05$) pour les veaux mis à l'herbe dans les pâturages GU, sans doute à cause de la teneur élevée en fibres et de la faible concentration de protéines attribuables à ce traitement. L'incorporation de luzerne et la fertilisation augmentent le gain global des veaux (kg par hectare), la plus forte amélioration résultant de la fertilisation. L'incorporation de légumineuses présente cependant des avantages économiques, car le coût du gain supplémentaire pour les pâturages GF et AF s'établit en moyenne à 1,08 \$ et à 0,79 \$ par kilo et par hectare, sans frais additionnels pour les pâturages AU.

Mots clés: Vaches à viande, veaux, rendement laitier, productivité des pâturages, luzerne, brome des prés

Alfalfa (*Medicago sativa* L.) provides high forage yields and exceptional forage quality that translates into high rates of live-weight gain (Douglas 1986). Meadow bromegrass (*Bromus biebersteinii* Roem & Schult.) has good forage quality, is well adapted to grazing, and is an excellent grass species to sow with alfalfa (Pearen and Baron 1996; Holt and Jefferson 1999). Very little research has been conducted on the benefits of including legumes such as alfalfa in pasture mixtures for cow-calf production. Two common

Abbreviations: **AF**, alfalfa-grass fertilized; **AU**, alfalfa-grass unfertilized; **GF**, grass-only fertilized; **GU**, grass-only unfertilized; **T**, pasture treatment; **Y**, year; **M**, monensin; **S**, sex of calf; **SUN**, serum urea nitrogen; **R1**, rotation one; **R2**, rotation two; **PUN**, plasma urea nitrogen; **CRC**, controlled release capsule

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recommendations for grass pasture improvement include fertilization at soil-test recommended rates or inclusion of a legume species such as alfalfa at the time of seeding. There are few data available to assess the impact of these recommendations for pastures seeded to improved grass species such as meadow bromegrass on weight gain and lactation performance of beef cows and resulting calf gains under the semi-arid conditions typical of the Canadian prairies.

Based on data with dairy cattle, monensin has the potential to increase milk production by 0.41 to 0.75 L d^{-1} (Hayes et al. 1996; Beckett et al. 1998). Monensin also can have an effect on milk composition. In a study by Ramanzin et al. (1997), monensin-treated dairy cows had lower percentages of milk fat and protein compared to the untreated cows, but the daily production of fat and protein per cow was increased. There is a lack of data relative to the effects of monensin on suckled beef cows and their calves.

The objective of this study was to determine the effects of pasture treatments such as fertilization, incorporation of a legume, combination of fertilization and incorporation of a legume, and animal treatments such as administration of monensin using a controlled release capsule (CRC), on cow and calf weight gain, and on voluntary intake, milk production, milk composition and serum urea nitrogen (SUN) levels of lactating beef cows.

MATERIALS AND METHODS

Description

A 4-yr grazing trial was conducted east of Brandon, Manitoba, Canada (49°52′N; 99°59′W; 363 m above sea level). 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 was replicated twice. 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. Details relative to pasture establishment and fertilization rates are provided in Kopp et al. (2003). Each pasture was equally divided into five paddocks by an electric fence and all cow-calf pairs were rotationally grazed.

On each pasture, four "tester" cow-calf pairs were used to collect animal performance data and additional "put and take" cow-calf pairs were added or subtracted one or two times per week, as was necessary, to maintain equal residual herbage. The cattle were moved when approximately 1000 kg forage DM ha^{-1} remained. This ensured the same length of grazing season for all treatments and that all animals were rotated between paddocks at the same time. The assessment of pasture biomass and quality is described and reported in Kopp et al. (2003).

Breed and age of the cowherd were different in each of the 4 yr (Table 1). Of the four "tester" cows used to collect production data in each pasture, two cows had steer calves and two cows had heifer calves, with the exception of 1998 when there were three heifer calves and one steer calf per pasture. Half of the "tester" cows in each pasture received a Rumensin®-controlled release capsule (CRC) (active ingredient crystalline monensin sodium; manufactured and provided by PROVEL®, Division Eli Lilly Canada Inc.) in 1995, 1996 and 1997; Rumensin® CRC was not used in 1998. All cow-calf pairs had ad libitum access to water, salt and 2:1 (Ca:P) granular mineral on the meadow bromegrass pastures and 1:1 granular mineral on the alfalfa-meadow bromegrass pastures. Experimental animals were cared for according to the *Guide to the Care and Use of Experimental Animals* (Canadian Council on Animal Care 1993).

Data Collection

Shrunk body weights of all the "tester" cow-calf pairs were taken on 2 consecutive days (12-h fast), at the beginning and end of the grazing season. Cow and calf average daily gains (ADG, kg d^{-1}) and total calf gain per hectare [kg ha^{-1} = calf ADG (kg d^{-1}) × average cow grazing days (CDG) ha^{-1}] were determined.

Two data collection periods per year were conducted in 1995, 1996, and 1997, first when cattle entered (I) and exited (O) paddock 3 in rotation 1 (R1) and again when cattle entered and exited paddock 1 or 2 in rotation 2 (R2). Four oesophageal fistulated steers were used to monitor the quality of grazed forage (1995 to 1997). Between oesophageal collection times, these steers were maintained on pastures similar to the treatment pastures. During collections, the oesophageal fistulated steers were fitted with canvas collection bags and one steer was used to collect samples from each pasture treatment. The steers were fasted overnight and allowed to graze for 20 to 40 min, with the consumed forage collected at the end of the grazing bout. Extrusa samples were squeezed through muslin cloth, the saliva samples were collected and subsequently analysed to correct for organic matter losses (Cohen 1979). Squeezed plant material was dried in a forced-air oven at 50°C for at least 48 h and ground using a Wiley mill fitted with a 1-mm screen. The dried samples were analysed for Kjeldahl nitrogen [Association of Official Analytical Chemists (AOAC) 1990, method no. 984.13], acid detergent fibre (ADF; 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, Virginia, U.S.A). In vitro organic matter digestibility (IVOMD) was determined by using a modification (Troelson and Hanel 1966) of the method of Tilley and Terry (1963) using bovine instead of ovine inoculum. Voluntary intake of the tester cows was determined using chromium sesquioxide (Cr_2O_3) controlled-release capsules (CRC, Captechrome, Nufarm Ltd., New Zealand) to estimate fecal output (Barlow et al. 1988).

The "tester" cows were milked prior to being put out to pasture to determine a pre-test milk yield and composition. This information was used as a covariate for the analysis of milk data collected during the grazing season. Calves were separated from cows immediately prior to the first milking at 0630. To aid milk let down, 3 mL of oxytocin was injected intramuscularly (on the advice of a veterinarian). Cows were milked using a portable milking machine, which was removed when milk flow from each quarter ceased. Calves

Table 1. Cow breed, age, initial weights, milking dates, initial and final calf age and weights for the 4-yr pasture study

	1995	1996	1997	1998
Cow breed	Simmental × Angus	Composite breed^{z}	Composite breed^{z}	Composite breed^{z}
Cow age	First calf	Mature	Mature	First calf
Initial cow weight (kg ± SD)	463 ± 30.6	566 ± 54.5	521 ± 56.2	464 ± 46.7
Pre-trial milking	Jun. 08	Jun. 12	May 22	NA
Rotation 1 milking	Jul. 13	Jul. 22	Jun. 23	NA
Rotation 2 milking	Aug. 11	Sep. 04	Jul. 24	NA
Calf age on test (days ± SD)	121 ± 12	75 ± 6	67 ± 7	57 ± 13
Calf age off test (days ± SD)	193 ± 12	161 ± 6	150 ± 7	169 ± 3
Initial calf weight (kg ± SD)	138 ± 13.8	114 ± 9.2	96 ± 10.9	86 ± 14.5
Final calf weight (kg ± SD)	218 ± 16.7	198 ± 14.9	188 ± 16.7	186 ± 22.2

^{z}The composite breed consists of 7/16 British (Angus, Hereford, Shorthorn), 1/4 Charolais, 1/4 Simmental, 1/16 Limousin).

remained separated from their dams until after a second milking scheduled 12 h later. Milk weight was recorded and daily milk yield was calculated and corrected to 4% milk fat. Milk was sampled for analysis of protein, fat, and solids non-fat (SNF) by an accredited lab (#125) ISO Guide 25 (Milk-O-Scan 303AB, Foss Electric, Hillerød, Denmark). Milk somatic cell counts (SCC) were performed on a Fossomatic 300 Cell Counter (Foss Electric, Hillerød, Denmark).

Blood samples were taken from the cow's tail vein during the 0630 milking of each collection period. Blood samples were centrifuged, and serum was decanted and frozen until analysed for serum urea nitrogen. Serum urea nitrogen values were determined using a colorimetric diacetyl monoxine procedure (Urea Nitrogen, Procedure No. 535, Sigma Diagnostics, St. Louis, MO).

Statistical Methods

The quality of the consumed forage (CP, NDF, and ADF) for the initial 3 yr was analysed as a split plot design. The main plot included pasture treatment and pasture replication. The sub-plot represented measurements taken in two rotations (R1 and R2) upon entering (I) and exiting (O) the paddocks. Cow DMI, ADG, and SUN and calf productivity were analysed in the same manner as the consumed forage data, with sex of calf (S) and monensin (M) incorporated into the sub-plot. As animal type and growing conditions varied from year to year, year effects and interactions of year with the above variables were included in the model; however, they were considered random effects. All other effects were considered fixed.

The effect of monensin was included in the analysis for 1995 to 1997; however, in 1997 cows assigned to the monensin treatments were not balanced for sex of calf (12 cows with male calves were treated with monensin and only four cows with female calves were treated with monensin). Milk production and composition data were analysed in the same manner as the cow parameters; however, the pre-trial milk yield and composition values were used as covariates. In 1998, the cows were not treated with monensin, thus effect of monensin was removed from the subplot effects for that year.

The general linear models procedure (GLM, SAS Institute, Inc.1990) was used for all analyses and means that differed were identified using PDIFF (SAS Institute, Inc.1990).

RESULTS AND DISCUSSION

Post-grazing residual forage DM averaged 811.6, 820.0, 864.4, and 730.5 ± 111.9 kg DM ha^{-1} (means ± SEM) for AF, AU, GF, and GU, respectively. Therefore, the "put and take" stocking system did establish similar forage availability across all pasture treatments for the duration of each grazing season. As such, yield differences between treatments would result in differences for cow-calf pair grazing days and pasture forage quality differences would be reflected as differences in animal productivity.

Diet Quality

Kopp et al. (2003) provided the standing forage biomass and quality data. This section discusses the quality of pasture forage actually selected and consumed by the grazing animal. Forage selected by cattle grazing AF, AU, and GF pastures was, on average, 3.0 ± 0.3 percentage units higher in CP than that consumed by cows grazing GU pastures ($P <$ 0.001; Table 2). Although standing forage CP content was improved with fertilization (Kopp et al. 2003), fertilizing the alfalfa-grass pastures did not increase CP levels of the consumed forage relative to unfertilized alfalfa-grass pastures. Pasture regrowth, representing the forage material available to animals in the second rotation (R2), was significantly higher quality than the initial growth (R1) for all pasture treatments (See table 5, Kopp et al. 2003), consequently, cows had greater opportunity to select for high forage CP levels in R2. The difference in CP levels for consumed forage from the time animals entered paddocks to the time they were removed from paddocks averaged 6.1 vs. 2.1 ± 0.2 percentage units for R2 as compared to R1 (data not presented). The rotation by I/O interaction reflected the limited opportunity for selection at the time animals exited as compared to entering paddocks, selection being greatest for cattle entering paddocks in rotation 2.

A total of 41 of the 96 samples collected in the first three grazing seasons were below 8% CP. Of these 41 samples, 15 were collected from the GU pastures and averaged 5.0% CP, DM basis. Dietary CP levels below 8% for an extended period of time can adversely affect beef cow milk production (National Research Council 1996).

Serum urea N (SUN) and milk urea N levels of dairy cows are used as indicators of the efficiency of protein and energy utilization (Roseler et al. 1993). Therefore, the levels of SUN were examined in the grazing beef cows to deter-

Table 2. Three-year average (1995–1997) quality (% DM) and in vitro organic matter digestibility (IVOMD, % DM) of forage consumed by oesophageal fistulated animals for the alfalfa-meadow bromegrass (A) and meadow bromegrass (G) pastures in fertilized (AF, GF) and unfertilized (AU, GU) conditions

	Treatment (T) (*n* = 24)					Rotation (R) (*n* = 48)			In/out of paddock (I/O)(*n* = 48)					
	AF	AU	GF	GU	SEM	R1	R2	SEM	In	Out	SEM	T × R	T × I/O	R × I/O
CP	11.1*a*	10.1*ab*	9.4*b*	7.2*c*	0.28	8.4*b*	10.5*a*	0.31	11.5*a*	7.4*b*	0.31	NS	NS	***
NDF	59.6*b*	59.3*b*	67.8*a*	66.5*a*	0.81	64.8*a*	61.8*b*	0.78	58.1*b*	68.5*a*	0.78	NS	***	**
ADF	39.8*b*	41.8*ab*	41.2*ab*	43.0*a*	0.60	42.8*a*	40.1*b*	0.42	37.5*b*	45.4*a*	0.70	NS	*	*
IVOMD	61.4	61.1	59.1	58.1	0.99[z]	63.6*a*	56.3*b*	0.81[z]	62.5*a*	57.4*b*	0.81[z]	NS	NS	*

[z] Average of standard errors.

*, **, *** $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively; NS, not significant.

a–c Means within rows for a parameter (T, R or I/O) not having a common letter differ ($P < 0.05$).

mine their nitrogen status under the different pasture treatments. Serum urea N levels for cows grazing AF, AU, GF, and GU pastures were 6.3, 6.2, 4.8, and 2.5 ± 0.12 mmol L^{-1}, respectively. Boyd (1984) suggested 2.8 mmol L^{-1} to be the lower end of the normal SUN range for cattle. Approximately 67% of serum samples for cows grazing the GU pastures were below 2.8 mmol L^{-1}. Incidence of low SUN was 2.1, 0, and 16.7% for AF, AU, and GF pastures, respectively. Sletmoen-Olsen et al. (2000) observed that Hereford-Angus cross cows consuming low-quality prairie grass hay (5.8% CP) with 1.3 kg DM d^{-1} supplementation of a low, medium or high level of undegradable intake protein had plasma urea nitrogen (PUN) concentrations proportional to N intake and concluded PUN could be used as an indicator of protein intake. Furthermore, they demonstrated that dietary protein levels and PUN concentration were related to body weight change. Lactating cows not offered supplemental protein had PUN levels averaging 3 mmol L^{-1} and had the greatest weight loss over the lactation period. A positive linear relationship between cow ADG and SUN level [cow ADG = 0.21(SUN) – 0.58, $R^2 = 0.36$, $P < 0.01$] was observed for cows grazing unfertilized grass pastures over 3 yr. Serum urea nitrogen level explained 18% of the variation in cow ADG when pasture treatments were combined [cow ADG = 0.06(SUN) – 0.31, $R^2 = 0.22$, $P < 0.001$]. Although the relationship between SUN and ADG is poor when animals have access to excess dietary protein, the measurement of SUN may be a useful tool for monitoring the protein status of beef cows while grazing low quality forages.

Fertilizing meadow bromegrass pastures did not decrease the NDF content of forage consumed by cows; however, introduction of a legume species resulted in significant improvements (Table 2). In all cases, this benefit due to inclusion of legumes in the pastures species mixture was lost as pasture forage availability declined (treatment by I/O interaction). High forage levels of NDF in the grass pastures could limit the DM intake by the grazing animal (Fahey and Berger 1988). Consumed forage had a wide range in NDF content (31.6–79.2%, DM basis) and measured forage NDF levels frequently exceeded levels known to decrease intake, however no relationship could be established between cow DMI and consumed forage NDF for this study. It is possible that other factors, such as herbage moisture content or declining forage availability from the time animals enter to the time they exit a paddock, are more important determinants of herbage intake by free-ranging cattle.

Acid detergent fibre levels of consumed forage followed the same pattern as that observed for NDF, the time within a paddock being the criteria that had the greatest effect on concentrations. In vitro forage OM digestibility was not affected by pasture treatment, but there was a rotation by I/O interaction. Contrary to the forage NDF and ADF, IVOMD of consumed forage was highest for animals entering paddocks in R1 (67.6%) as compared to 57.4% for animals entering paddocks in R2. The IVOMD decreased 10% from the time cattle entered to the time they exited paddocks in R1, with little decline observed when grazing regrowth in R2. In vitro organic matter digestibility was not strongly related to consumed forage ADF content.

The quality of the consumed forage in each pasture treatment was similar to the quality of the clipped herbage samples (Fig. 1). However, the advantages of fertilization that were evident from hand-clipped samples were reduced when consumed forage was used as a criterion.

Dry Matter Intake

Fertilization and incorporation of a legume did not have an effect on DMI when compared to the unfertilized grass pastures ($P > 0.05$; Table 3). Monensin administration as CRC, however, did decrease DMI, % BW ($P < 0.05$). Cows that were treated with monensin consumed 0.2 percentage units less of their body weight in forage DM compared to the control cows. A number of studies involving the feeding of harvested forages to cows have shown monensin can reduce DMI by as much as 10.2% during gestation and early lactation (Turner et al. 1980; Walker et al. 1980; Clanton et al. 1981).

Cow Productivity

The cows used in this study were representative of beef cows commonly used in Manitoba (Table 1). From 1996 to 1998, a composite beef breed developed at the Agriculture Agri-Food Canada Research Centre in Brandon, Manitoba, was used in the grazing experiment. The cows were average to superior in terms of productivity versus a Hereford-Angus control for weight of calf weaned per mating opportunity (Fredeen et al. 1988).

Cow ADG was influenced by the interaction of pasture type and monensin administration ($P < 0.05$; Fig. 2).

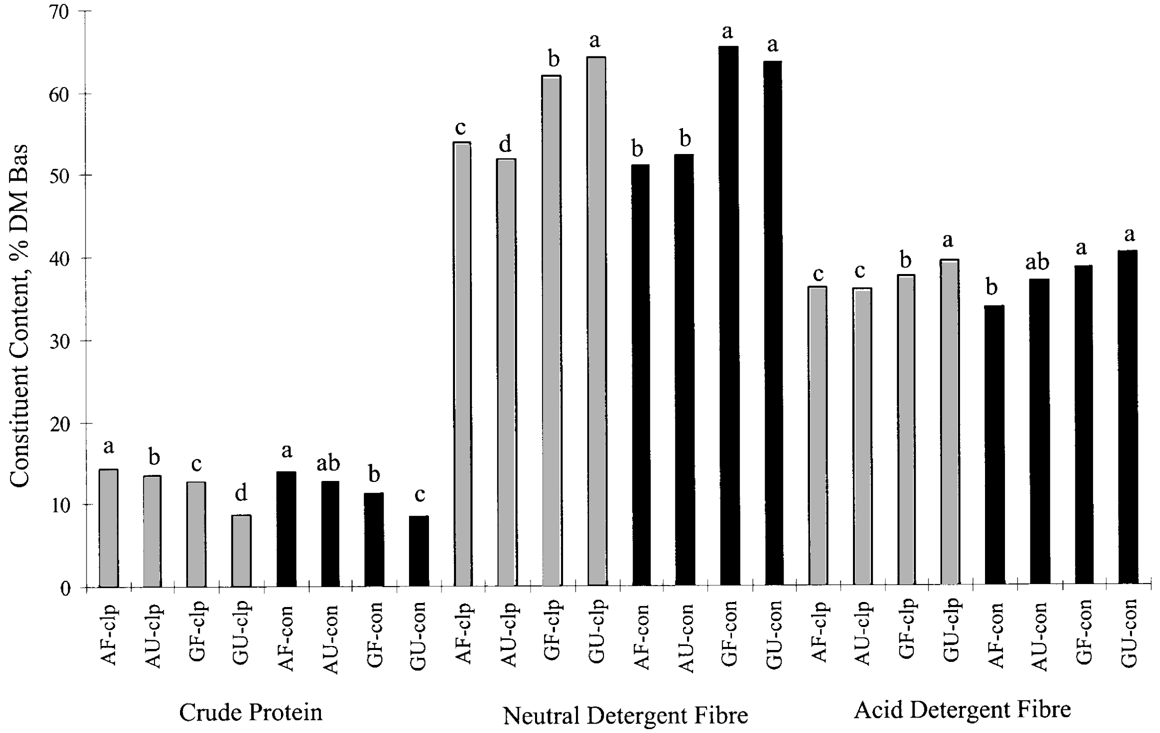

Fig. 1. Forage quality of clipped (Clp, ▨) and consumed (Con, ■) forage for the alfalfa-meadow bromegrass (A) and meadow bromegrass (G) pastures in fertilized (AF, GF) and unfertilized (AU, GU) conditions (CP-clp SE = 0.22, CP-con SE = 0.51, NDF-clp SE = 0.28, NDF-con SE = 1.38, ADF-clp SE = 0.28, ADF-con SE = 0.99). Bars with different letters within each quality parameter and collection method reflect treatment differences, $P < 0.05$.

Table 3. Effect of pasture treatment (T), monensin controlled release capsule (M) and sex of calf (S) on cow productivity during the grazing season

	Treatment (n = 24)					Monensin (n = 48)			Sex of calf (n = 48)					
	AF	AU	GF	GU	SEM	Yes	No	SEM	Male	Female	SEM	T × M	T × S	M × S
1995–1997														
DMI (% BW)	2.3	2.4	2.3	2.5	0.11^{z}	2.3*b*	2.5*a*	0.10^{z}	2.5	2.3	0.09^{z}	NS	NS	NS
DMI (kg d^{-1})	12.8	13.0	13.5	13.8	0.73^{z}	12.7	13.8	0.62^{z}	13.6	12.9	0.62^{z}	NS	NS	NS
ADG (g d^{-1})	–4	–20	103	–73	57.5	2.0	1.0	34.6	19	–17	34.6	*	NS	NS
Milk														
Yield^{y} (kg)	5.8	5.8	5.9	5.8	0.30^{z}	6.0	5.6	0.29^{z}	5.7	5.9	0.29^{z}	NS	NS	NS
Fat (%)	3.1	3.0	3.3	3.1	0.11^{z}	3.1	3.1	0.09^{z}	3.2	3.1	0.09^{z}	NS	NS	NS
Protein (%)	3.7	3.8	3.8	3.8	0.08^{z}	3.7	3.8	0.06^{z}	3.8	3.7	0.06^{z}	NS	NS	NS
SNF^{x} (%)	9.2	9.3	9.2	9.0	0.07^{z}	9.2	9.2	0.05^{z}	9.2	9.1	0.05^{z}	NS	NS	NS
SCC^{w} log	5.5	5.4	5.4	5.4	0.14^{z}	5.4	5.4	0.08^{z}	5.4	5.4	0.08^{z}	NS	NS	NS
1998														
ADG^{v} (g d^{-1})	343	338	216	276	56.3	NA	NA	NA	341	246	42.8^{z}	NA	NS	NA

[z] Average of standard errors.

[y] 4% fat corrected milk yield.

[x] SNF = solids non-fat.

[w] SCC = somatic cell counts.

[v] Cow 1998 ADG: Treatment n = 8, Sex: females n = 24, males n = 8. NA = not applicable, the factor was not part of the analysis.

a–b Means within rows for a parameter (T, M or S) not having a common letter differ ($P < 0.05$), NS = not significantly different.

Monensin improved cow gain by 115 and 132 g d^{-1} for AU and GU pastures and reduced ADG on AF pastures ($P < 0.05$). It is unclear why monensin decreased cow ADG on the AF pastures. It should be noted that the average weight changes were small for all treatments. In a review by Sprott et al. (1988), cows that were fed low-quality forage diets had improved feed efficiency when supplemented with monensin. The fertilization and legume incorporation strategies did not have an effect on cow milk yield or composition ($P > 0.05$). There were no pasture treatment effects on 1998 cow productivity measurements ($P > 0.05$).

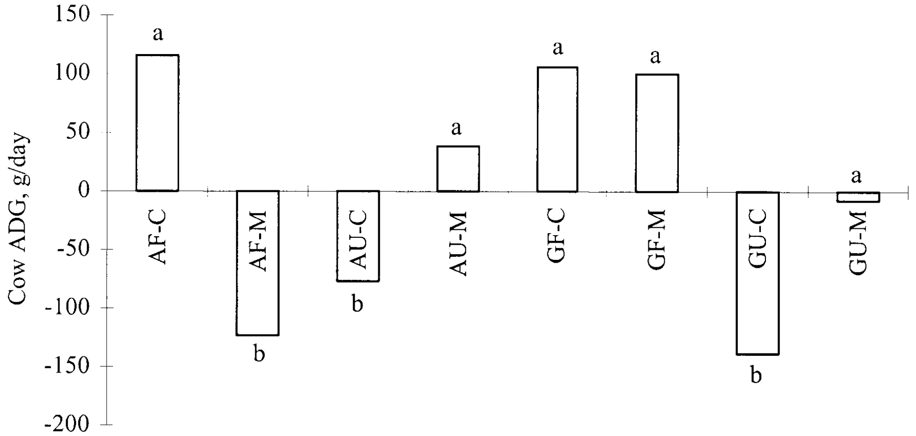

Fig. 2. The effect of monensin on cow ADG (g d^{-1}, SE = 65.8) when grazing alfalfa-meadow bromegrass (A) and meadow bromegrass (G) pastures in fertilized (AF, GF) and unfertilized (AU, GU) condition.

Table 4. Effect of pasture treatment (T), monensin controlled release capsule (M) and sex of calf (S) on calf productivity during the grazing season

	Treatment (*n* = 24)					Monensin (*n* = 48)			Sex of calf (*n* = 48)			*P* values		
	AF	AU	GF	GU	SEM	Yes	No	SEM	Male	Female	SEM	T × M	T × S	M × S
							1995–1997							
ADG (g d^{-1})	1100*a*	1087*a*	1099*ab*	1034*b*	16.6^y	1086	1074	17.0	1111*a*	1049*b*	17.0	NS	NS	NS
Gain (kg ha^{-1})	179.2*b*	158.0*c*	204.8*a*	129.1*d*	5.78^y	168.0	167.6	2.89	172.7*a*	162.9*b*	2.89	NS	NS	NS
							1998							
ADG^z (g d^{-1})	863	902	859	901	52.2	NA^x	NA	NA	887	876	28.7^y	NA	*	NA
Gain^z (kg ha^{-1})	279.0*a*	210.1*c*	242.7*b*	127.0*d*	21.30	NA	NA	NA	211.5	217.9	7.1^y	NA	*	NA

^{z}Calf 1998 ADG and gain per hectare: Treatment *n* = 8, Sex: females *n* = 24, males *n* = 8.
^{y}Average of standard errors.
^{x}NA = not applicable, the factor was not part of the analysis.
*, **, *** $P < 0.05$, $P < 0.01$ and $P < 0.001$; NS, not significant.
a–d Means within rows for a parameter (T, M or S) not having a common letter differ ($P < 0.05$).

Calf Productivity

Calves on the alfalfa-grass pastures gained 59.5 g d^{-1} more than the calves on the GU pastures (Table 4, $P < 0.05$). Fertilization of grass pastures did not result in improved calf ADG. Sex of calf also had an effect on ADG ($P < 0.01$), male calves gained on average 62 g d^{-1} more than female calves. Monensin administration to dams did not have any affect on suckling calf productivity ($P > 0.05$).

Pasture treatment affected calf gain ha^{-1} from 1995 to 1997 ($P < 0.001$, Table 4) with the treatment rank from highest to lowest being, GF > AF > AU > GU. The GF pastures produced 44 kg calf weight gain ha^{-1} more than GU pastures. These results are reflective of the high forage production on the GF pastures (Kopp et al. 2003).

Cost Benefit Assessment of Fertilization

When grazing alfalfa, producers are concerned about the risk of frothy bloat. None of the 180 head grazing alfalfa-grass pastures had to be treated for bloat over the course of this study.

The cost-effectiveness of each pasture strategy can be evaluated by the extra cost to generate an additional kg calf gain ha^{-1} relative to the unfertilized grass treatment (GU). Averaged over the 4 yr of this study, fertilization of grass pastures (GF) produced an additional 87.2 ± 34.9 kg calf gain ha^{-1} yr^{-1} (Table 5). The AF and AU pastures had an additional 77.2 ± 54.4 and 43.2 ± 27.1 kg calf gain ha^{-1} yr^{-1} compared to GU pastures, respectively. The benefits of fertilization were most apparent when precipitation was not limiting (i.e., 1998). Pasture treatments in this study had similar establishment costs. Given this, the cost for the additional gain on the AU pasture is zero. The cost of the additional gain for GF and AF pastures averaged \$1.08 and \$0.79 kg^{-1} ha^{-1}, respectively, with high variability from year to year. The question of whether it is cost effective to fertilize grass-based pastures or to use a combination of fertilization and incorporation of a legume, revolves around the value of the calves. If the average value for weaned calves is \$0.79 kg^{-1} ha^{-1} or more then AF is profitable, and if the calves are valued at more than \$1.08 kg^{-1} ha^{-1}, then GF is profitable. The greatest increase in animal productivity comes from fertilizing the grass-based pastures; however, adding alfalfa to a pasture mix at establishment is likely to be the most cost effective strategy for increased calf gains without additional costs.

CONCLUSION

Despite differences in diet quality, cow productivity measured as weight gain, milk yield and milk composition when

Table 5. Additional calf gain and fertilizer cost per kg calf gain, comparing AF, AU and GF to GU over four grazing seasons

	GF-GU	AU-GU	AF-GU
Additional calf gain (kg ha^{-1} yr^{-1})			
1995	43.1	39.3	44.8
1996	82.7	15.3	44.1
1997	95.5	37.7	61.9
1998	127.4	80.3	157.9
Average	87.2	43.2	77.2
Standard deviation	34.9	27.1	54.4
Fertilizer cost per calf gain ($ kg^{-1} calf gain ha^{-1})			
1995	1.91	–	1.26
1996	1.05	–	1.02
1997	0.82	–	0.46
1998	0.55	–	0.42
Average	1.08	–	0.79
Standard deviation	0.59	–	0.42

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).

grazing AU, AF and GF pastures was similar. Lactating beef cows assigned to unfertilized grass or alfalfa-grass pastures lost body weight, this trend was prevented with monensin administration. Incorporation of a legume in grass pastures was the only management strategy that increased calf ADG relative to unfertilized grass pastures. However, the dramatic improvement in forage biomass associated with fertilization of grass pastures resulted in the greatest increase in total calf weight gain per hectare. From an agronomic point of view, fertilizing meadow bromegrass pastures would be the most productive strategy, in terms of total calf gain ha^{-1}. From an economic point of view, incorporating a legume in meadow bromegrass pastures improves calf productivity without incurring financial risks associated with uncertain calf prices and weather conditions.

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