Supplementation of yearling steers grazing Northern Great Plains rangelands

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Abstract

Growing yearling steers on summer rangelands as part of a cow-calf-yearling operation would allow producers to maximize forage utilization, and selling yearling steers when forage was in short supply would minimize potential genetic losses in the cow herd. A series of summer supplementation and intake studies were conducted from 1988–1992 to determine if weight gains of grazing yearling steers could be increased by supplemental energy (ground barley), phosphorus (P), or crude protein. Studies were conducted at 2 locations on pastures of approximately 51 ha each, which contained quite different mixtures of forage species. Forage P, crude protein and IVDOM levels were monitored throughout the grazing season. Supplementation results varied among years and between locations. There were significant ($P < 0.14$) location by treatment interactions in 1989 and 1990 because steers at the WEST location tended to respond more to supplementation than steers at the EAST location, but EAST location steers had the highest rates of gain. Providing supplements at gradually increasing rates produced results comparable to supplementing at a constant rate all summer. Supplemental crude protein showed no significant benefit, but crude protein levels in pasture forage were generally above steer requirements. Weight gains averaged over all 5 years were greater ($P < 0.05$) for steers supplemented with barley or barley and P, compared to unsupplemented control steers. The response to supplementation should be beneficial most years, but results may vary with the quantity and quality of available forage.

Key Words: Dry matter intake, forage crude protein, forage phosphorus, ground barley

Grazing yearling steers on Northern Great Plains native rangelands could improve the economic viability of a ranching operation. During dry years, steers could easily be sold without jeopardizing the investment in a high quality cow herd. When forage production was abundant, steers could be used to harvest the extra forage without increasing cow numbers. Enhancing the weight gains of grazing steers through appropriate supplementation may make this option even more viable. Chemical composi-

Resumen

El desarrollar novillos en pastizales de verano como parte del sistema vaca-becerro-novillo podría permitir a los productores maximizar la utilización de forraje y vender los novillos cuando el forraje es escaso y minimizar las pérdidas genéticas potenciales en el hato de vacas. De 1988 a 1992 se condujo una serie de estudios de consumo y suplementación de verano para determinar si las ganancias de peso de novillos en apacentamiento podrían ser incrementadas por la suplementación energética (cebada molida), de fósforo (P) o de proteína cruda (PC). Los estudios se condujeron en 2 localidades en potreros de aproximadamente 51 ha cada uno, los cuales contenían mezclas de especies forrajeras muy diferentes. El contenido de fósforo, proteína cruda del forraje y su digestibilidad *in vitro* de la materia orgánica se monitorearon a través de la estación de apacentamiento. Los resultados de la suplementación variaron entre años y entre localidades. En 1989 y 1990, hubo interacciones significativas ($P < 0.14$) entre tratamiento y localidad, esto debido a que los novillos de la localidad OESTE tendieron a responder mejor a la suplementación que los novillos de la localidad ESTE, pero los novillos de la localidad ESTE tuvieron mayores tasas de ganancia de peso. El proveer el suplemento a tasas graduales de incremento produjeron resultados comparables que suplementar a una tasa constante durante todo el verano. La proteína cruda suplementaria no mostró beneficios significativos, pero los niveles de proteína cruda en el forraje del potrero generalmente fueron superiores a los requerimientos de los novillos. Las ganancias de peso, promediadas en los 5 años, fueron mayores ($P < 0.05$) para los novillos suplementados con cebada o con cebada y fósforo que las ganancias obtenidas por los novillos sin suplemento (control). La respuesta a la suplementación debe ser benéfica en la mayoría de los años, pero los resultados pueden variar con la cantidad y calidad del forraje disponible.

tion data for Northern Great Plains native forages reported by Karn (1992) suggest that phosphorus (P), crude protein, and energy are probably the nutrients which most limit animal productivity, especially during the latter part of the grazing season.

Although the recommended (NRC 1996) range of P for yearling steers is 0.15–0.24%, depending on steer weight and rate of gain, Call et al. (1978) reported that P supplementation was not beneficial to replacement heifers receiving a basal diet containing 0.14% P (as fed basis). However, Echevarria et al. (1987) reported that steers grazing grasses containing 0.16 to 0.19% P had improved weight gains when supplemented with dicalcium phosphate. Winter (1988) reported an immediate weight gain response in P supplemented steers grazing grasses containing 0.1 to 0.15% P during the wet but not the dry season.

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Table 1. Precipitation and mean monthly ambient air temperatures between April and September for 1988, 1989, 1990, 1991, and 1992, and the 80-year average.

	1988		1989		1990		1991		1992		80-year average	
	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.
	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)
Apr.	6.7	2.5	6.6	54.1	6.5	3.3	8.0	47.5	4.9	7.9	5.3	39.1
May	16.0	33.8	13.5	48.8	12.0	55.1	13.9	67.3	14.9	37.3	12.5	57.4
June	24.3	23.1	17.3	19.6	18.6	132.8	19.6	97.8	17.1	110.2	17.8	89.2
July	22.7	38.6	24.0	31.0	21.0	25.6	21.8	21.1	17.0	77.0	21.2	56.9
Aug.	20.8	82.0	20.9	32.8	21.9	48.5	22.9	22.3	17.6	36.6	20.4	50.0
Sep.	13.3	15.7	14.3	27.2	16.4	41.1	14.9	59.4	13.3	26.7	14.0	39.6

Denham (1975) found that supplementing steers grazing annual rye with 0.9 kg of corn daily over a 63-day period increased daily gains by 0.33 kg. Vadiveloo and Holmes (1979) reported that when herbage supply was limiting, weight gains of grazing steers were significantly increased by supplemental energy but not by protein, however, when herbage was adequate supplementation was not beneficial. Reyneke (1976) reported that strategic supplementation of grazing steers produced significant results 2 out of 3 years, with protein concentrate producing the greatest response and maize meal producing the least. Lusby et al. (1981) also reported that in the late summer and fall, steer weight gains were efficiently increased by supplemental protein but not by energy. The inconsistency of previous results, plus a lack of research on supplements for grazing steers in the Northern Great Plains, suggested a need for further research. Thus, the objective of the current research was to determine the effect of crude protein and energy supplementation, at either constant or variable rates, and P supplementation at a constant rate, on the performance of yearling steers summer grazing on native rangelands.

Materials and Methods

Study Site

Two pastures located near Mandan, N.D., were used in these studies and will be referred to as EAST and WEST. Each pasture contained approximately 51 ha and was primarily native rangeland, but the topography and species represented in each pasture was quite different. The WEST pasture was relatively flat and contained primarily western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), needleandthread (*Stipa comata* Trin. and Rupr.), green needlegrass (*S. viridula* Trin.), blue grama (*Bouteloua gracilis* (H.B.K.) Griffiths), prairie junegrass [*Koeleria cristata* (Lam.) Beauv.], and upland sedges (*Carex* spp.). The EAST pasture was more rolling and

contained a greater diversity of species, including the same species as the WEST pasture plus lead plant (*Amorpha canescens* Pursh), western snowberry (*Symphoricarpos occidentalis* Hook), buffalo berry [*Sherpherdia argentea* (Pursh) Nutt.], and the introduced cool-season grass species crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schultes] and smooth broomegrass (*Bromus inermis* Leyss).

Daily precipitation and ambient minimum and maximum air temperatures were recorded at a weather station located about 3.2 km north of the study site. Monthly precipitation totals and mean monthly temperatures (minimum and maximum) were calculated and compared to historic values (Table 1).

Supplementation

A series of supplementation trials were conducted with yearling steers (*Bos taurus*) grazing during the summer on the previously described pastures. Supplementation trials were conducted at the WEST pasture in 1988 and 1989, while both supplementation and intake trials were conducted at the EAST pasture. In 1990, 1991, and 1992 replicated studies were conducted at both

locations. Trials were conducted from 26 May to 4 October 1988 (131 days); 30 May to 6 October 1989 (129 days); 5 June to 12 October 1990 (129 days); 31 May to 11 October 1991 (133 days); and 28 May to 8 October 1992 (133 days). Straight bred Hereford steers were used in all years, but in 1988, Hereford-Simmental crossbred steers also were used to compare the effect of breed type on supplementation response. Initial and final steer weights, as well as weights taken at 21-day intervals, were obtained following an overnight stand without feed or water.

1988

Supplementation treatments in 1988 were no supplement (control), ground barley, and ground barley plus P. There were 6 steers per treatment and 2 breed types for a total of 36 steers at the WEST location and 5 Hereford steers per treatment for a total of 15 steers at the EAST location. Supplement composition and amounts fed daily (as-fed basis), 6 days per week, are shown in Table 2.

1989

The control, barley, and barley + P treatments were also used in 1989, but there

Table 2. Barley (B), barley-phosphorus (BP), barley-soybean meal (BS), and barley-soybean meal-phosphorus (BSP), supplement ingredients, and the grams (as-fed basis) fed per steer per day during the summers of 1988, 1989, 1990, 1991, and 1992.¹

Year/ Month	B	BP		BS		BSP		
	Barley	Barley	MSP ³	Barley	SBM ²	Barley	SBM	MSP
	----- (g) -----							
1988 ³	908	908	23	--	--	--	--	--
1989 ³	908	908	23	--	--	--	--	--
1990 ³	908	908	23	454	454	454	454	23
1991–1992 ⁴								
Jun.	454	454	23	--	--	363	91	23
Jul.	681	681	23	--	--	454	227	23
Aug.	908	908	23	--	--	454	454	23
Sep.	1135	1135	23	--	--	681	454	23
Oct.	1498	1498	23	--	--	817	681	23
Mean	908	908	23	--	--	539	369	23

¹Steers were fed 6 days per week.

²MSP=monosodium phosphate; SBM=soybean meal.

³Steers supplemented at a constant rate all summer.

⁴In 1991 and 1992, steers were supplemented at a variable rate; there were 24 feeding days at the June, July, August, and September rates respectively, and 18 feeding days at the October rate.

Table 3. Phosphorus, crude protein and metabolizable energy provided daily, 6 days per week in supplements fed to yearling steers grazing native rangelands in 1988, 1989, 1990, 1991, and 1992.^{1,2}

Period of Use		Supplements								
1988-1990	1991-1992	B			BP			BSP		
		P	CP	ME	P	CP	ME	P	CP	ME
		(g)	(g)	(mcals)	(g)	(g)	(mcals)	(g)	(g)	(mcals)
	Jun.	1.6	58	1.2	6.0	58	1.2	7.5	88	1.2
	Jul.	2.4	87	1.8	8.4	87	1.8	9.2	163	1.8
Jun.-Oct.	Aug.	3.3	116	2.4	9.7	116	2.4	11.5	265	2.4
	Sep.	4.1	145	3.1	9.7	145	3.1	11.4	300	3.1
	Oct.	5.4	192	4.0	10.8	192	4.0	13.0	418	4.0

¹B = ground barley; BP = ground barley and monosodium phosphate; BSP = ground barley, monosodium phosphate and soybean meal.

²The barley-soybean meal supplement used in 1990 had the same crude protein and metabolizable energy content with 6 grams less phosphorus than the August BSP supplement.

were 7 steers per treatment for a total of 21 steers at the WEST location and 6 steers per treatment for a total of 18 steers at the EAST location.

1990

In 1990, in addition to the control, barley, and barley + P treatments, supplements containing a 50-50 mixture of barley and soybean meal and a 50-50 mixture of barley and soybean meal plus P were also used. Supplements were isocaloric. There were 5 steers per treatment per location for a total of 50 steers.

1991 and 1992

In 1991 and 1992, only the control, barley, barley + P, and barley + soybean + P treatments were used, and there were 7 steers per treatment per location for a total of 56 steers used each year. Supplements in 1991 and 1992 were fed at gradually increasing rates from June through October in contrast to 1988, 1989, and 1990 when supplements were fed at a constant rate throughout the summer (Table 2). Supplement levels were increased to coincide with the usual decline in forage quality. Levels of P, crude protein, and metabolizable energy supplied by supplements are shown in Table 3.

Supplementation Procedure for all Years

In all treatments where P was supplemented, monosodium phosphate was used as the P source and it was fed at a rate of 6 g P steer⁻¹ day⁻¹. Steers at each location were maintained together at all times except when corralled each morning between 0600 and 0800 hours, 6 days per week, separated into treatment groups and bunk fed their respective supplements by group. Non-supplemented steers were also corralled while supplemented steers were being fed. Trace mineralized salt contain-

ing 96-98.5% salt, 0.35% zinc, 0.34% iron, 0.20% manganese, 0.033% copper, 0.007% iodine, and 0.005% cobalt (Akzo Salt, Inc., Clarks Summit, Penn.) was available at all times.

Intake

Five intake trials were conducted at the EAST location each summer during 1988 and 1989, and 2 intake trials were conducted at each location during the summers of 1991 and 1992. Intake trials were initiated on 23 June, 14 July, 4 and 25 August and 15 September 1988; and 22 June, 13 July, 3 and 24 August and 14 September 1989. In 1991, trials were initiated on 26 June (early summer) and 28 August (late summer), and in 1992, trials were initiated on 15 July (early summer) and 9 September (late summer). Dry matter intake was estimated for unsupplemented (control) steers, steers fed ground barley, and steers fed ground barley + P in 1988 and 1989 and for control and barley + soybean + P treatment steers in 1991 and 1992. All steers at the EAST location were used in the 1988 and 1989 intake trials, and all steers on the control and barley + soybean + P treatments at both locations were used in 1991 and 1992 trials.

Fecal output was estimated using chromium as an external indicator. In 1988 and 1989, gelatin capsules containing chromic oxide were administered daily. In 1991 and 1992, chromium was delivered with an intra-ruminal continuous release device¹ (Adams et al. 1991) administered at the beginning of each trial. Five daily fecal collections were made following a 10-day adjustment period to insure that chromium had reached a consistent concentration in the digestive tract. During the first 2 trials in 1988, steers were dosed with 10 g

chromic oxide per steer daily, which was midway between levels used by Rittenhouse et al. (1970) and Adams et al. (1986). From the third trial on and for all of the 1989 trials, chromic oxide was given at the rate of 8 g per steer daily (Rittenhouse et al. 1970). The continuous release device used in 1991 had mean release rates of either 1.57 or 1.74 g chromic oxide day⁻¹ and the continuous release device used in 1992 had mean release rates of 1.48 g chromic oxide day⁻¹ according to the manufacturer. Two unsupplemented steers in 1988 and 1989 and 3 unsupplemented steers in 1992 were fitted with fecal collection bags and dosed with chromic oxide during each trial in 1988 and 1989 or given a continuous release device at the beginning of each trial in 1992 to measure total fecal output for chromium recovery calculations. Daily fecal collections during each trial were composited on an equal wet volume basis across days for each steer, so that a single sample per steer per trial was saved for analysis.

Indigestible neutral detergent fiber (INDF) was determined on extrusa, supplement, and fecal samples as suggested by Ellis et al. (1984) and was used instead of lignin to calculate forage intake according to procedures outlined by Rittenhouse et al. (1970). Because supplements and forages are likely to have different digestibilities, the amount of fecal dry matter originating from supplements must be partitioned from the total fecal dry matter before forage intake can be calculated. Since the amount of supplement dry matter is known, the amount of an internal indicator such as lignin or indigestible NDF, which is presumed to be indigestible can be determined for supplements and feces. Then the amount of indicator originating from the supplement can be subtracted from the total amount of indicator in the feces. The remaining quantity of the indicator is presumed to originate from ingested forage. Forage intake can then be determined by dividing the weight of indicator in the feces originating from the forage by the concentration of the indicator in the forage. Once forage dry matter intake is determined, total dry matter intake is calculated by combining forage and supplement intake values.

Sampling Procedures

Forage samples were collected each year at both locations with 3 mature esophageally fistulated steers at approximately 3 week intervals throughout the grazing season. Fistulated steers were penned off feed overnight before each sampling date to ensure that they would

¹Captec chrome manufactured by Captec PTY, LTD., Laverton, Victoria, Australia.

Table 4. Mean ($\pm$ SD) monthly phosphorus and crude protein concentrations in Northern Great Plains native pastures being grazed by yearling steers receiving energy, phosphorus and crude protein supplements in 1988, 1989, 1990, 1991, and 1992.^{1,2,3}

		Phosphorus					Crude protein				
Year	Location	Jun.	Jul.	Aug.	Sep.	Location mean	Jun.	Jul.	Aug.	Sep.	Location mean
-----(% of D.M.)-----											
1988	E	0.235±0.018	0.204±0.011	0.277±0.046	0.179±0.022	0.213±0.041	12.5±0.6	11.3±0.9	16.4±1.9	10.7±3.2	12.2±2.8
	W	0.174±0.023	0.178±0.020	0.166±0.018	0.144±0.012	0.167±0.021	8.6±0.7	9.1±0.5	11.1±0.6	8.2±0.1	9.4±1.4
1989	E	0.229±0.004	0.183±0.009	0.140±0.024	0.176±0.008	0.180±0.029	13.7±0.5	9.9±0.5	8.7±1.2	11.3±0.1	10.9±1.8
	W	0.195±0.023	0.133±0.007	0.151±0.009	0.234±0.003	0.178±0.038	11.4±1.8	11.6±0.5	9.0±0.8	12.1±0.7	10.8±1.7
1990	E	0.238±0.014	0.262±0.029	0.190±0.008	0.194±0.019	0.224±0.038	13.5±0.4	13.1±2.5	8.5±0.6	10.6±0.9	11.6±2.4
	W	0.243±0.004	0.202±0.035	0.172±0.004	0.166±0.010	0.192±0.035	14.2±0.5	16.2±4.4	9.3±0.1	10.0±1.0	12.7±3.9
1991	E	0.220±0.018	0.170±0.019	0.144±0.015	0.138±0.020	0.168±0.037	11.2±1.5	8.8±0.3	5.9±0.4	7.2±1.5	8.3±2.2
	W	0.209±0.029	0.175±0.017	0.135±0.009	0.129±0.020	0.162±0.038	13.8±1.6	9.3±0.4	6.0±0.3	6.2±0.9	8.8±3.3
1992	E	0.166±0.011	0.189±0.018	0.140±0.016	0.122±0.001	0.159±0.029	12.5±0.8	14.4±1.1	10.8±1.4	9.9±0.2	12.2±2.0
	W	0.122±0.004	0.138±0.011	0.112±0.006	0.091±0.013	0.119±0.021	13.3±0.6	12.3±2.0	9.0±0.8	7.5±0.7	10.7±0.3

¹Samples were collected with unsupplemented esophageal fistula steers in 1988-1991 and by hand clipping in 1992.

²The EAST (E) location pasture was used for the intake trials in 1988 and 1989 and as a replicate pasture in 1990, 1991, and 1992.

³Monthly values are means of 3 to 6 sample collections.

graze the following morning. Grazing selectivity did not appear to be affected by this method. Individual animal collections were mixed, subsampled, freeze dried and analyzed for nitrogen (N), in vitro digestible organic matter (IVDOM) and INDF. Extrusa subsamples for P analysis were squeezed to remove saliva (Hoehne et al. 1967) and oven dried at 50° C. In 1992, because no squeezed extrusa samples were collected, samples were hand clipped to simulate grazing (Karn and Hofmann 1990) and analyzed for N and P. Hand clipped samples were freeze dried before grinding. All forage samples were ground to pass a 1 mm screen before chemical analyses.

Chemical Analyses

Nitrogen and P in forage were determined with a Quikchem 8000 continuous flow autoanalyzer (Lachat Instruments, Milwaukee, Wisc. 53218). Fecal samples from the intake trials were prepared for chromium analysis according to Williams et al. (1962), and chromium was determined with a Perkin Elmer P II inductive coupled plasma optical emission spectrophotometer (Perkin Elmer, Norwalk, Conn.). In vitro digestible organic matter was determined by the Tilley and Terry (1963) procedure as modified by Moore and Mott (1974). Indigestible neutral detergent fiber was determined by following a 6-day in vitro fermentation (Ellis et al. 1984) with neutral detergent fiber analysis of the fermentation residue (Goering and Van Soest 1970).

Statistical Analyses

Steer weight gain data were analyzed over locations by year using a randomized design, with locations considered as replicates and treatment groups considered

the experimental unit. Treatment and location were tested with the treatment x location interaction term. Although crossbred and Hereford steers responded similarly to supplements, only Hereford steer data were included in the analysis over both locations in 1988 so that data would be more nearly balanced. Treatment means for individual years were separated by the Student-Newman-Keuls' test. In a second analysis, treatments in common over the 5 years were analyzed as a mixed model according to a treatment by location factorial in a randomized block design. Least squares means were separated by a Tukeys test. Constant versus increasing supplementation levels were considered as nested within treatments (Milliken and Johnson 1984).

Intake data in 1988, 1989, 1991, and 1992 were analyzed as a completely randomized design, with the steer within treatment term used to test treatment in the 1988 and 1989 trials, and the steer within treatment by location term used to test treatment, location, and treatment x location in 1991 and 1992 trials. Least squares means were calculated for intake data using SAS (1985) GLM procedures in 1991 and 1992. Treatments were considered different at the 5% probability level unless otherwise stated.

Results and Discussion

According to the NRC (1996), the crude protein requirement of growing steers, of the weight used in these studies, ranges between 8 and 12% of the diet dry matter depending on steer weight and daily gains. Crude protein at both locations was generally within this range throughout the summer, except for 1991 (Table 4) which prob-

ably explains the lack of a significant response to supplemental protein in 1990 and 1992. Forage P levels during August and September at both locations were generally at or below the NRC (1996) recommended range of 0.15–0.24% P for yearling steers. Forage growth and hence forage quality, especially for cool-season grasses, is very closely related to seasonal precipitation patterns. In 1988, August precipitation (Table 1) was above normal which facilitated forage regrowth and resulted in unusually high August forage crude protein, P and IVDOM levels, especially at the EAST location (Tables 4 and 5).

Steer weight gain data were analyzed by year as well as over all years because there were apparent differences in treatment responses among years and between locations which reflected differences in topography and forage types between locations.

1988

In 1988 crossbred and straight-bred Herefords at the WEST location responded similarly to barley and barley + P treatments (data not shown), but only Hereford steer data were analyzed with weight gain data from the EAST location (Table 6) so that data would be more nearly balanced. There were no significant treatment differences; however, there was a location effect with steers at the EAST location having higher daily gains than steers at the WEST location (1.07 vs. 0.72 kg; $P < 0.05$). This was thought to be due to forage quality differences between pastures since P, crude protein, and IVDOM were all higher in forage from the EAST pasture (Tables 4 and 5).

1989

In 1989, daily gains (Table 6) were higher ($P < 0.15$) for steers receiving the

Table 5. Mean ($\pm$ SD) monthly IVDOM of extrusa samples from Northern Great Plains native pastures being grazed by yearling steers receiving energy, phosphorus and crude protein supplements in 1988, 1989, 1990, 1991, and 1992.^{1,2}

Year	Location	Jun.	Jul.	Aug.	Sep.	Loc. Mean
		-----(-%)-----				
1988	E	70.4 $\pm$ 1.0	63.3 $\pm$ 2.0	67.0 $\pm$ 1.9	61.8 $\pm$ 0.4	64.6 $\pm$ 3.5
	W	59.2 $\pm$ 1.8	58.0 $\pm$ 1.5	59.9 $\pm$ 3.0	58.4 $\pm$ 1.1	59.1 $\pm$ 2.1
1989	E	74.3 $\pm$ 0.5	67.4 $\pm$ 2.1	63.8 $\pm$ 1.0	60.7 $\pm$ 1.2	65.7 $\pm$ 5.0
	W	70.5 $\pm$ 4.1	65.1 $\pm$ 4.1	62.8 $\pm$ 0.8	56.4 $\pm$ 1.6	64.1 $\pm$ 6.4
1990	E	69.5 $\pm$ 0.8	65.8 $\pm$ 3.7	61.8 $\pm$ 1.1	57.2 $\pm$ 3.1	62.9 $\pm$ 5.4
	W	63.6 $\pm$ 1.4	65.6 $\pm$ 3.7	63.6 $\pm$ 1.4	59.8 $\pm$ 1.7	63.0 $\pm$ 3.4
1991	E	67.4 $\pm$ 4.8	64.2 $\pm$ 1.4	61.5 $\pm$ 3.5	58.5 $\pm$ 1.8	62.9 $\pm$ 4.4
	W	69.0 $\pm$ 3.2	60.4 $\pm$ 2.1	63.4 $\pm$ 2.6	59.9 $\pm$ 1.8	63.2 $\pm$ 4.3
1992	E	68.4 $\pm$ 0.8	64.4 $\pm$ 1.1	60.7 $\pm$ 1.9	57.8 $\pm$ 2.2	62.7 $\pm$ 4.0
	W	65.9 $\pm$ 0.9	62.5 $\pm$ 1.9	57.1 $\pm$ 2.2	57.3 $\pm$ 0.6	60.4 $\pm$ 3.9

¹The EAST (E) location pasture was used for intake trials in 1988 and 1989 and as a replicate pasture in 1990–1992.

²Monthly values are means of 3 to 6 sample collections.

barley + P supplement compared to the control treatment (1.10 vs 0.88 kg). There was also a significant ($P < 0.14$) location by treatment interaction. Daily gains of steers at the EAST location were again higher than at the WEST location (1.10 vs 0.91 kg; $P < 0.07$).

1990

There were no significant treatment differences in 1990 ($P > 0.20$; Table 6); however, there was a significant treatment by location interaction ($P < 0.05$). Steers at the WEST location tended to benefit more from the barley + P supplement [(barley + P) - control = 0.26 kg] than steers at the EAST location [(barley + P) - control = 0.06 kg]. Steers at the EAST location continued to gain more than WEST location steers, but the difference was not as great as in previous years (1.10 vs 0.99 kg; $P < 0.08$).

1991 and 1992

Because the barley + soybean treatment used in 1990 had shown little benefit, it was eliminated so that the number of steers per treatment could be increased from 5 to 7. Barley significantly ($P < 0.05$)

improved weight gains compared to control steers in both years whereas the barley + P treatment increased weight gains compared to barley alone in 1992 but not in 1991 (Table 6). These results show the consistent benefit of feeding barley and the inconsistent benefit of feeding phosphorus. The barley + soybean + P treatment was not different from the barley treatment in 1991 or the barley + P treatment in 1992, suggesting that supplemental protein was not beneficial either year. Steers at the EAST location had higher gains than WEST location steers both years, but the difference was greatest in 1992 (1.15 vs 0.98 kg; $P < 0.05$).

1988–1992

When treatments common to all 5 years were analyzed together, steers supplemented with barley had higher ($P < 0.05$) gains than control steers, and steers receiving the barley + P treatment had higher gains than steers receiving only barley, indicating that both barley and phosphorus were beneficial.

Data for 1988–1990 were compared with 1991–1992 data to determine whether

supplementation results were affected by feeding at a constant rate compared to a gradually increased rate. Weight gains were not affected ($P > 0.20$) by feeding method. However, feeding at a gradually increasing level would be more desirable because steers would more readily consume a small amount of feed in the early summer and increasing supplement levels would more nearly coincide with decreasing forage quality later in the summer.

In these studies the most consistent response was from barley (energy supplement), which agrees with results reported by Denham (1975) and Vadiveloo and Holmes (1979), but disagrees with Lusby et al. (1981) who reported a beneficial effect from protein but not from energy. Supplemental P produced inconsistent results among years but over all 5 years it significantly increased ADG compared to barley alone. Winks et al. (1977) in Australia also reported erratic results with P supplementation; in the wet season, P supplementation increased weight gains, but in the dry season it did not.

Steers at the rolling EAST location on the control, barley, and barley + P treatments had higher weight gains each year compared to steers at the flat WEST location. The consistent weight gain difference between locations may have been due to generally higher quality diets (Tables 4 and 5) at the EAST location. This may also help to explain why steers at the EAST location did not respond as well to supplements. Forage availability was not considered to be a limiting factor at either location during these studies.

Intake

During the summer of 1988, dry matter intake in early July was significantly lower than for other periods when expressed as kg/day, but intake was not significantly different among periods when expressed as a percent of body weight (Table 7). In 1989, dry matter intake as a percent of body weight and in kg/day generally declined throughout the season. Dry matter intakes expressed as a percent of body weight for control, barley, and barley + P supplement treatments were 2.7, 2.9 and 3.0%, respectively, in 1988 and 2.7, 2.6 and 2.8%, respectively, in 1989. However, treatments were not significantly different ($P > 0.05$) either year and there was no treatment by period interaction.

Intake trials were conducted in 1991 and 1992 at both the EAST and WEST locations to determine if the higher ADG of

Table 6. Average daily gains of yearling steers grazing native rangelands in the Northern Great Plains and supplemented with energy, phosphorus, and/or crude protein in 1988, 1989, 1990, 1991, and 1992.

Year	Steers/ Treatment	Treatments					SE
		C ¹	B ¹	BS ¹	BP ¹	BSP ¹	
		----- (kg) -----					
1988	11	0.80 ^a	0.90 ^a	--	0.93 ^a	--	0.05
1989	13	0.88 ^b	1.00 ^{ab}	--	1.10 ^a	--	0.05
1990	10	0.95 ^a	0.98 ^a	1.08 ^a	1.11 ^a	1.10 ^a	0.06
1991 ²	14	0.73 ^c	0.94 ^{ab}	--	0.89 ^b	0.98 ^a	0.01
1992 ²	14	0.88 ^c	1.05 ^b	--	1.17 ^a	1.15 ^a	0.02
		Combined analysis of treatments common to all years ^{2,3}					
	62	0.85 ^c	0.98 ^b	--	1.04 ^a	--	0.02

¹C=Control, (no supplement); B=ground barley; BS=ground barley and soybean meal; BP=ground barley and monosodium phosphate; and BSP=ground barley, soybean meal and monosodium phosphate.

²In 1989, treatments with different letters differed significantly at ($P < 0.15$). In 1991, 1992, and over all 5 years, treatments with different letters differed significantly at ($P < 0.05$).

³Least squares means.

Table 7. Daily dry matter intakes by period averaged across supplemental treatments in 1988 and 1989.^{1,2}

Trial	Period	1988		1989	
		Dry Matter		Dry Matter	
		(% B.W.)	(kg day ⁻¹)	(% B.W.)	(kg day ⁻¹)
1	Early Jul.	2.7a	9.6b	3.2a	12.4a
2	Late Jul.	3.0a	11.4a	2.8b	11.0ab
3	Mid Aug.	3.0a	11.9a	2.6b	11.1ab
4	Early Sep.	3.0a	12.6a	2.6b	11.6ab
5	Late Sep.	2.8a	12.4a	2.3c	10.6b
	SE	0.10	0.44	0.08	0.45

¹Means are averages of 15 values in 1988 and 18 values in 1989.

Table 8. Dry matter intakes for control (C) and supplemented (BSP) steers for early and late summer in 1991 and 1992.^{1,2,3}

	Dry Matter							
Period	C	BSP	Period mean	SE	C	BSP	Period mean	SE
	-----(% of B.W.)-----				----- (kg day ⁻¹)-----			
	1991							
Early Summer	2.2	2.2	2.2a	0.08	8.5	8.1	8.3a	0.33
Late Summer	1.8	2.2	2.0a	0.08	7.6	9.6	8.6a	0.33
Treatment Mean	2.0a	2.2a			8.0a	8.9a		
SE	0.09	0.09			0.37	0.37		
	1992							
Early Summer	2.3	2.5	2.4a	0.11	8.8	10.0	9.4a	0.49
Late Summer	2.3	2.6	2.5a	0.12	10.0	12.2	11.1b	0.51
Treatment Mean	2.3a	2.6b			9.4a	11.1b		
SE	0.09	0.09			0.54	0.53		

¹Dry matter intake was not significantly different between locations either year.

²Within a year, least squares treatment means with different letters differ (P<0.07).

³Within a year, least squares period means with different letters differ (P<0.05).

steers at the EAST location could be due to higher dry matter intakes. Trials conducted in early and late summer of each year indicated that dry matter intake did not differ (P > 0.05) between locations (data not shown). In 1991 dry matter intake was not different between early and late summer trials (Table 8). However, in 1992 dry matter intake in kilograms per steer per day was higher in late summer. Dry matter intake tended to be numerically higher for supplemented steers in the 1991 late summer trial and was significantly higher (P < 0.07) for supplemented steers over both trials in 1992 (Table 8).

Conclusions

Average daily gains and the inconsistent response to supplementation between years and locations suggests that the nutrient content and dry matter intake of grazed forage in these studies were quite high. Ground barley was usually beneficial, whereas P was beneficial in some years and locations, but crude protein showed little benefit. Over all 5 years, ground barley and ground barley plus P increased ADG by 0.13 and 0.19 kg, respectively,

above unsupplemented steers. In most years, feeding a supplement containing a combination of ground barley and P should be beneficial, but the response to supplements will vary according to the quantity and quality of available forage. Feeding gradually increasing levels of supplement during the summer would probably be a more desirable supplementation approach because steers would more readily consume small amounts of supplement early in the summer and larger amounts of supplement in late summer. This supplementation pattern would also help to compensate for expected declines in forage nutritive quality.

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