Effects of Weaning Date and Prepartum Protein Supplementation on Cow Performance and Calf Growth

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Abstract

Two experiments evaluated effects of weaning date on cow body condition score (BCS) and calf growth. In Experiment 1, 134 March-calving cows were used in a four-year experiment. Calves were weaned 18 August or 7 November and cows were fed 0 or 0.45 kg protein supplement (42% crude protein) three days per week from 1 December to 28 February while grazing upland range in a 2 by 2 factorial arrangement of treatments. In Experiment 2, spring calving cows (year 1, $n = 97$; year 2, $n = 104$) were assigned randomly to one of eight weaning dates at 2-week intervals from 19 August to 25 November. In Experiment 1, weaning in August increased cow BCS precalving ($P < 0.001$) and prebreeding ($P < 0.001$), but not pregnancy rates ($P = 0.56$). Cows fed supplemental protein had greater BCS precalving ($P < 0.001$) and prebreeding ($P = 0.001$) than nonsupplemented cows, but pregnancy rates were similar ($P = 0.27$). Calves born to cows fed supplemental protein prepartum had greater weaning weight than calves born to nonsupplemented cows regardless of whether weaning occurred in August ($P = 0.001$) or November ($P < 0.001$). Effects of weaning date on feedlot performance interacted with supplementation treatment. Calves born to cows fed supplement that were weaned in November generated the greatest net returns. In Experiment 2, BCS decreased linearly ($P < 0.001$) as date of weaning was delayed from August to November. Nursing calf gain increased cubically ($P < 0.0004$) and weaned calf gain from August to November increased quadratically ($P < 0.002$). Protein supplementation did not affect cow pregnancy rate, but calves born to cows fed protein supplement had greater pre- and postweaning gains. Cow BCS decreased as weaning date was moved later in the year but cow pregnancy rate was not affected by weaning date.

Resumen

Dos experimentos evaluaron los efectos de la época de destete sobre la condición corporal de la vaca (BCS) y el crecimiento del becerro. En el experimento 1, 134 vacas que parieron en marzo se usaron en un experimento de cuatro años. Los becerros se destetaron el 18 de agosto o el 7 de noviembre y las vacas fueron alimentadas con 0 o 0.45 kg de suplemento proteico (42% PC) tres días a la semana del 1 de diciembre al 28 de febrero mientras apacentaban en un pastizal de tierras altas. Los tratamientos tuvieron un arreglo factorial 2×2. En el experimento 2, vacas que parieron en primavera (año 1, $n = 97$; año, 2 $n = 104$) fueron asignadas aleatoriamente a una de ocho fechas de destete, con dos semanas de separación entre ellas, del 19 de agosto al 25 de noviembre. En el experimento 1, el destete en agosto incrementó la BCS de las vacas antes del parto ($P < 0.001$) y antes del empadre ($P < 0.001$), pero no aumentó las tasas de preñez ($P = 0.56$). Las vacas suplementadas con proteína tuvieron una mayor BCS antes del parto ($P < 0.001$) y del empadre ($P < 0.001$) que las no suplementadas, pero las tasas de preñez de ambos grupos fueron similares ($P = 0.27$). Los becerros nacidos de las vacas suplementadas con proteína antes del parto tuvieron un mayor peso al destete que los nacidos de vacas no suplementadas, independientemente de si el destete ocurrió en agosto ($P = 0.001$) o noviembre ($P = 0.001$). Los efectos de la fecha de destete en las ganancias de peso en el corral interactuaron con el tratamiento de suplementación. Los becerros nacidos de las vacas suplementadas que fueron destetados en noviembre generaron los mayores retornos netos. En el experimento 2, la BCS disminuyó linealmente ($P = 0.001$) conforme la fecha de destete se retrazó de agosto a noviembre. La ganancia de los becerros amamantando se incrementaron cúbicamente ($P < 0.0004$) y la ganancia de agosto a noviembre de los becerros destetados se incrementó cuadráticamente ($P < 0.002$). La suplementación proteica no afectó la tasa de preñez, pero los becerros nacidos de vacas suplementadas tuvieron mayores ganancias de peso antes y después del destete. La BCS disminuyó conforme la fecha de destete se retrazó, pero la tasa de preñez no fue afectada por la fecha de destete.

Key Words: beef cows, systems, production, management

INTRODUCTION

Beef cattle are a common means by which rangeland managers generate income. Therefore, adopting management practices that increase profitability of beef production is critical to the sustainability of rangeland management. Reducing feed costs while maintaining reproductive efficiency is key to profitability

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in extensive, rangeland-based beef production settings. One way to reduce feed costs is to extend the grazing season through the winter (Adams et al. 1994), but in the Nebraska Sandhills, native range is deficient in degradable intake protein during fall and winter, resulting in cow body weight (BW) and body condition score (BCS) loss (Hollingsworth-Jenkins et al. 1996; Villalobos et al. 1997). Adequate precalving BCS is traditionally thought to be necessary for achieving acceptable pregnancy rates (Richards et al. 1986; Selk et al. 1988; Morrison et al. 1999). In spring-calving production systems, maintaining BCS through the winter is often the least expensive method of achieving adequate precalving BCS (Adams et al. 1994). One method of preventing BW and BCS loss when the grazing season is extended through the winter is to feed supplemental protein; however, feeding supplemental protein can be cost prohibitive (DelCurto et al. 2000). An alternative to feeding supplement as a means of improving cow BCS precalving is early weaning. There is a tradeoff between calf weight and cow BCS on the day of weaning. The longer the calf remains with the cow, the heavier the calf will be, but calf weight comes at the expense of cow BCS (Short et al. 1996). In addition to potential for improved cow BCS precalving, a second advantage to early weaning can be reduced production costs. Peterson et al. (1987) showed total feed costs were 20% less for early-weaned (110 days) compared to normal-weaned (222 days) fall-born calves because of lower feed consumption for nonlactating vs. lactating cows.

We hypothesized precalving BCS could be increased both by early weaning and by feeding supplemental protein, which would result in increased pregnancy rates. We further hypothesized that late-weaned calves born to cows fed supplement would be more profitable during the feedlot finishing phase of production. However, the impact of choice of weaning date on precalving BCS and interactions between weaning date and winter protein supplement on range has not been established for the spring-calving cow, calf, or finished steer. Therefore, the objective of this research was to determine the impact of management of cows grazing dormant rangeland on economic efficiency of the production system. Specifically, our objective was to evaluate long-term effects of weaning date and protein supplementation of the dam and their potential interaction on cow reproduction, calf growth through the feedlot, and the economic impact of these management practices in spring-calving, beef production systems in an extensive rangeland environment.

MATERIALS AND METHODS

Study Site

Both experiments were conducted at the Gudmundsen Sandhills Laboratory located 5 miles north of Whitman, Nebraska (lat 42°05′N, long 101°26′W, elevation 1 073 m). One segment of Experiment 1 was conducted in feedlot facilities in North Platte, Nebraska. A detailed description of the study site is given by Adams et al. (1998). The study was conducted on sands range sites (deep sands ecological site) with soils classified as Valentine fine sands (mixed, mesic Typic Ustipsamments). Study pastures were in an area that had been used exclusively for dormant-season (October to March) grazing the previous 8 years and were in good to excellent range condition. Major grass species found in the study pastures include little bluestem (*Schizachyrium scoparium* [Michx.] Nash), prairie sandreed (*Calamovilfa longifolia* [Hook.] Scribn.), sand bluestem (*Andropogon gerardii* Vitman var. *paucipilus* [Nash] Fern.), switchgrass (*Panicum virgatum* L.), sand lovegrass (*Eragrostis trichodes* [Nutt.] Wood), scribner panicum (*Dichanthelium oligosanthes* [J. A. Schultes] Gould var. *scribnerianum* [Nash] Gould), and grasslike plants (*Carex* spp. and *Cyperus* spp.) with sun sedge (*Carex heliophila* Mack.) the most common of these. Common forbs included western ragweed (*Ambrosia psilostachya* DC.), cutleaf ironplant (*Haplopappus spinulosus* [Pursh] DC.), and prairie clover (*Dalea purpurea* Vent.), and shrubs included leadplant (*Amorpha canescens* Pursh) and small soapweed (*Yucca glauca* Nutt.).

Common grass species found in subirrigated meadows are smooth brome (*Bromus inermus* Leyss.), redtop bent (*Agrostis gigantean* Roth), timothy (*Phleum pratense* L.), slender wheatgrass (*Elymus trachycaulus* [Link] Gould ex Shinn.), quackgrass (*Elytrigia repens* [L.] Nevski.), Kentucky bluegrass (*Poa pratensis* L.), prairie cordgrass (*Spartina pectinata* Bosc ex Link), reed grasses (*Calamagrostis* spp.), and grasslike plants (*Carex* spp. and *Cyperus* spp.), rushes (*Scirpus* spp.), and spikerushes (*Eleocharis* spp.). Plant nomenclature follows Stubbendieck et al. (1997).

Annual herbage production on similar, adjacent pastures averaged 1 260 kg $\cdot$ ha^{-1} during the study period (Volesky et al. 2005). Precipitation and temperature during the study are given in Table 1.

Experiment 1

Animals, Treatments, and Procedures. In a 4-year experiment, 136 MARC II (one-fourth Angus, one-fourth Gelbvieh, one-fourth Hereford, and one-fourth Simmental), March-calving cows were blocked by age and assigned randomly to one of four treatment combinations. Treatments were arranged as a 2 by 2 factorial with calves weaned 18 August or 7 November each year as one factor and cows fed the daily equivalent of 0 or 0.45 kg protein supplement from 1 December to 28 February each year as the second factor. Cows remained in their treatment group during the experiment unless culled for reproductive failure, calf death, or health problems experienced by either the cow or calf. Replacement cows were not added to the experiment. Herd health practices followed a standard protocol as described by Stalker et al. (2006). Cow BW and BCS (1 = emaciated to 9 = obese; Wagner et al. 1988) were measured 18 August, 7 November, at the beginning (1 December) and end (1 March) of the supplementation period, and prebreeding (6 June) each year. BCS was recorded as the average value assigned independently by two experienced technicians who were blind to treatment assignments. Cow pregnancy status was determined by rectal palpation each year in September. Calf BW was measured at birth, weaning (either 18 August or 7 November), and upon entry and exit at the feedlot. Average calving date was 30 March and weaning date was either 18 August or 7 November, depending on treatment.

The experiment began in August of year 1. On 18 August, calves assigned to the 18 August weaning date treatment were removed from their dams. Cow–calf pairs assigned to the 7

Table 1. Average monthly temperatures and yearly precipitation at Whitman, Nebraska.

	January	February	March	April	May	June	July	August	September	October	November	December	Annual ave.
Precipitation, mm													
Year 1	2.5	3.3	4.4	31.0	4.7	75.0	67.9	54.0	47.0	53.7	8.4	04.2	398.3
Year 2	0.0	0.0	18.4	19.7	9.1	91.0	53.0	40.9	17.0	99.0	13.0	0.0	443.0
Year 3	2.7	0.0	0.0	84.0	6.5	99.0	13.0	17.0	40.4	1.0	12.6	0.0	334.6
Year 4	11.7	14.5	25.9	52.3	12.0	52.6	49.7	14.2	32.8	65.8	15.5	0.0	455.1
20-yr ave.	6.3	4.4	12.0	41.3	7.7	86.3	71.3	49.4	43.1	30.4	15.0	3.1	439.7
Mean temperature, °C													
Year 1	−5.9	−1.7	3.1	3.7	11.3	18.7	21.8	20.4	16.8	9.1	1.0	−1.5	8.1
Year 2	−2.4	1.6	−0.3	7.9	14.7	16.0	23.4	22.1	19.6	7.9	3.7	−2.6	9.3
Year 3	−2.3	2.3	3.1	6.3	12.5	18.1	22.7	21.2	14.7	10.1	7.7	0.8	9.8
Year 4	−2.3	1.0	4.0	7.4	14.6	17.6	22.7	22.9	16.1	9.2	−3.4	−7.0	8.6
20-yr ave.	−3.6	−1.5	2.0	7.1	13.1	18.4	21.9	21.0	15.3	8.0	1.0	−3.6	8.3

November weaning date treatment and dry cows from the 18 August weaning date treatment grazed upland range as a single herd from 18 August until 7 November. On 7 November calves assigned to the 7 November weaning date treatment were weaned and all cows grazed subirrigated meadow regrowth from 7 November until 1 December. At the start of winter supplementation period (1 December) cows were distributed into one of eight upland pastures (32 ± 2 ha) where they grazed dormant upland range until 28 February. Cows assigned to the protein supplementation treatment received 1.06 kg of a 42% crude protein (CP) supplement three times per week. The supplement contained 50.0% sunflower meal, 47.9% cottonseed meal, and 2.1% urea. On a pasture basis, supplement was fed Monday, Wednesday, and Friday, 1 December through 28 February. Following the winter grazing period, cows calved in a dry lot and were fed hay 1 March through 14 May. Cow–calf pairs grazed subirrigated meadow 15 May through 5 June and upland range 6 June to 17 August. A sufficient number of bulls to achieve at least a 1:20 bull:cow ratio were introduced to the cow herd on 1 June and removed 1 August. This exact management protocol was repeated each year during the 4-year study.

In years 2 and 3, feedlot performance of steer calves was determined. Steer calves were fed hay for 10 days after weaning in a dry lot and then transported to a feedlot in North Platte, Nebraska (167 km) for finishing. Steers in the 18 August weaning treatment entered the feedlot on 27 August and steers in the 7 November weaning treatment entered the feedlot on 17 November. Steers from each winter supplementation treatment pasture were penned together and fed as replicates ($n = 4$ pens · treatment^{-1} · yr^{-1}) in the feedlot. The starting diet contained 35% alfalfa and steers were adapted over 14 days to a finishing diet that contained 48% dry rolled corn, 40% wet corn gluten feed, 7% alfalfa, and 5% supplement (dry matter [DM] basis) by replacing alfalfa with corn. Steers were harvested when it was visually estimated the average 12th rib fat thickness was 1.3 cm. Steers in the 17 August weaning treatment were harvested on 8 May and steers in the 7 November weaning treatment were harvested on 17 June, each year. Carcass data were obtained via the Cattlemen's Carcass Data Service, West Texas A&M University, Canyon, Texas. Hot carcass weight was obtained at harvest. Following a 24-hour chill, marbling score, fat thickness at the 12th rib, longissimus muscle area, yield grade, quality grade, and percentage of kidney, pelvic, and heart fat were determined.

Because of differences in back fat thickness at harvest, days on feed, carcass weight, and marbling score were adjusted to equal fat end points so valid comparisons could made among treatments (Tedeschi et al. 2004). Back fat thickness of each animal upon entry into the feed lot was calculated using the equation of Bruns et al. (2004), subtracted from fat thickness at harvest and divided by days on feed to determine rate of fat accretion. Using the calculated fat accretion rate, the number of days on feed required for each animal to achieve a back fat thickness of 1.3 cm was determined. The weight of the carcass of each animal when back fat thickness was 1.3 cm was calculated by first multiplying the BW of each animal upon entry into the feedlot by a 55% dressing percentage (initial carcass weight), which was subtracted from the actual carcass weight of the animal at harvest and divided by the number of days on feed to determine the daily carcass gain of each animal. Calculated rate of daily carcass gain was multiplied by the calculated number of days on feed required to reach 1.3 cm of back fat to which initial carcass weight was added back, yielding adjusted carcass weight. Marbling rate was determined using a regression equation derived by combining the equations of May et al. (1992) and Bruns et al. (2004) as described by Griffin (2006). The Proc Reg function of SAS (SAS Institute, Inc. 1999) was used to determine if the intercepts for these two regression equations were different. The intercepts were not different ($P = 0.14$); therefore, we averaged the two intercepts to determine initial marbling score at feedlot entry (324; marbling score, 400 = slight^0, 500 = small^0). Initial marbling score was subtracted from the final marbling score and divided by days fed to determine the marbling rate. Calculated marbling rate was multiplied by the calculated number of days on feed required to reach 1.3 cm of back fat, to which initial marbling score was added yielding adjusted marbling score.

Diet Quality. Diet quality (Table 2) of winter range and subirrigated meadow was estimated from masticate samples obtained from esophageally fistulated cows external to the experiment. Surgeries had been performed on all cows at least two years prior to the beginning of the experiment and at least two animals were used for each diet collection. Cows were

Table 2. Quality of upland range and subirrigated meadow diets collected in the Nebraska Sandhills near Whitman, Nebraska (Experiment 1).[1]

Item	Upland range				Subirrigated meadow	
	December	March	June	July	May	June
NDF,[2] % DM	71.1	75.5	49.6	50.9	51.6	61.5
ADF, % DM	50.5	48.9	29.0	31.8	31.0	36.5
Ash, % DM	10.1	11.3	8.9	9.3	10.5	12.1
CP, % DM	7.5	7.7	15.2	12.9	18.0	14.3
IVOMD, % DM	54.9	53.0	73.8	54.1	71.7	68.7

[1]Diets collected using esophageally fistulated cows.
[2]NDF = neutral detergent fiber, DM = dry matter, ADF = acid detergent fiber, CP = crude protein, IVOMD = in vitro organic matter disappearance.

withheld from feed for 12 hours, then fitted with screen bottom bags after removal of the esophageal plug. Cows were allowed to graze for about 30 minutes in an ungrazed upland pasture or meadow immediately adjacent to those used in the experiment. Masticate samples were stored frozen at -20°C, freeze dried, and analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), CP, and ash using standard methods (AOAC 1990). In vitro organic matter disappearance (IVOMD) was determined using a modified two-stage Tilley and Terry (1963) procedure with addition of 1 g $\cdot$ L^{-1} urea to the buffer solution (Weiss 1994).

Economic Analysis. An economic analysis was conducted for Experiment 1 using input costs differing between treatments. Protein supplement was valued at \$0.22 $\cdot$ kg^{-1}, which included a \$0.011 $\cdot$ kg^{-1} feeding cost. Fall grazing costs were derived from estimates by Johnson et al. (2001) who reported the average grazing cost in Nebraska was \$25 for a 454-kg cow with calf at side for one month during the summer. For the time period between the August and November weaning dates, a grazing cost of \$16.67 per animal unit (AU) month was used to reflect lower value of fall vs. summer pasture. Cows in the August weaning treatment were equivalent to 1.2 AU and cow/calf pairs in the November weaning treatment were 1.7 AU. All costs during the cow–calf phase except supplement and fall grazing were equivalent between treatments and therefore were not included in the analysis.

Economic analysis of the feedlot phase included associated costs that differed between treatments. Feedstuffs were valued using 10-year average prices (Mark et al. 2005). Yardage was charged at \$0.30 $\cdot$ steer^{-1} $\cdot$ day^{-1}. Interest was included at 7% for calf value at weaning, one-half of feed, and costs associated with trucking to the feedlot.

Calf, finished steer, and cull cow market values were 5-year average prices and included seasonal price differences at the associated marketing time (Mark et al. 2005). Utility prices were used for cows weaned in August and cutter prices for cows weaned in November because of differences in BCS. Finished steers were valued based on weight because marbling score was similar for all treatments. Base value for the replacement of a cow was assumed to be \$600 $\cdot$ head^{-1} (Mark et al. 2005). Income from the sale of culls was treated as the sale of a capital item. Net revenue at weaning includes the difference between the cull and the base (replacement cost) values of the cows. Replacement rate was one minus the weaning rate for each treatment. Differences in weaning rates between treatments were accounted for in the gain or loss in sale of cull cows and gross revenue at weaning.

Statistical Analysis. Experiment 1 was analyzed using the MIXED procedures of SAS (SAS Institute, Inc. 1999) as a 2 by 2 factorial arrangement of treatments in a completely randomized design. Winter grazing pasture or feedlot pen was used as the experimental unit. The model included effects of prepartum treatment (supplement vs. no supplement) and weaning treatment (18 August vs. 7 November) and their interaction as fixed effects and year was included in the random statement. Where treatment interaction occurred, simple effects are reported, otherwise main effects are given.

Experiment 2

In a 2-year experiment, MARC II, spring calving cows (year 1, $n = 97$; year 2, $= 104$) were stratified by milk production within age and assigned randomly to one of eight weaning dates (12–13 cows per date). The first weaning date was 19 August and weaning continued at 2-week intervals through 25 November. Cow–calf pairs grazed upland range from June through weaning. After weaning, cows were returned to the upland range pasture while weaned calves were fed hay in a dry lot for 5 days then grazed subirrigated meadow regrowth.

Cow BW and BCS were measured at the first (19 August) and last (25 November) weaning date. Body weight of all calves was measured at the first (19 August) and last (25 November) weaning date, and calves weaned at intermediate dates were weighed on the day they were weaned.

Statistical Analysis. Data for Experiment 2 were analyzed using the MIXED procedures of SAS using year as a random variable. Weaning date was included in the model as a fixed effect and year and year by weaning date interaction were included as random variables. Single degree of freedom orthogonal polynomials were used to determine linear, quadratic, and cubic treatment effects. All possible higher order polynomials were tested but were not statistically significant ($P > 0.10$).

RESULTS

Experiment 1

Cow Variables. At the beginning of the experiment cow BCS and BW were equivalent among all treatments ($P = 0.15$ to $P = 0.60$; Table 3). Weaning 18 August allowed nonlactating cows to essentially maintain BCS during the interval from 18 August to 7 November, whereas lactating cows lost BCS during the same period. Body weight change followed a similar

Table 3. Body condition score (BCS), body weight (BW), pregnancy rate, calf weight, and percentage of calves weaned of cows whose calves were weaned 18 August or 7 November and fed protein supplement (S) or no protein supplement (NS) during gestation (Experiment 1).

Item	August wean		November wean		SE[1]	*P* value[2]		
	NS	S	NS	S		Wean	Sup.	W × S
Cow BCS								
Start (18 August yr 1)	5.2	5.3	5.2	5.3	0.08	0.60	0.46	0.68
1 December	5.7	5.7	4.9	5.0	0.03	< 0.001	0.17	0.02
1 March	4.8	5.3	4.0	4.7	0.06	< 0.001	< 0.001	0.05
6 June	5.2	5.3	4.8	5.1	0.05	< 0.001	0.001	0.21
18 August	5.3	5.4	5.1	5.3	0.03	0.001	0.004	0.61
7 November	5.5	5.6	4.7	4.8	0.03	< 0.001	0.01	0.38
Cow BCS change								
1 December to 1 March	−0.9	−0.4	−0.9	−0.3	0.07	0.98	< 0.001	0.45
18 August to 7 November	0.2	0.2	−0.4	−0.5	0.04	< 0.001	0.32	0.56
Cow BW, kg								
Start	512	519	508	506	5	0.15	0.57	0.35
1 December	572	582	525	533	4	< 0.001	0.04	0.81
1 March	517	552	477	519	5	< 0.001	< 0.001	0.50
6 June	513	532	485	502	3	< 0.001	< 0.001	0.80
18 August	538	551	520	527	2	< 0.001	< 0.001	0.32
7 November	556	561	497	506	3	< 0.001	0.01	0.50
Cow BW change, kg								
1 December to 1 March	−55	−31	−48	−15	7	0.11	0.001	0.51
18 August to 7 November	18	11	−23	−21	2	< 0.001	0.28	0.07
Pregnancy rate, %	97.2	95.8	96.5	95.0	1.3	0.56	0.27	0.97
Calving day of yr	89	90	90	87	1	0.43	0.58	0.05
Calf BW, kg								
Birth	39.0	40.1	37.9	39.5	0.4	0.05	0.004	0.58
18 August	174.2	180.5	169.2	180.5	2.2	0.27	0.001	0.27
Wean	174.2	180.5	225.5	239.6	2.3	< 0.001	< 0.001	0.10
Calves weaned, %	96.6	94.8	99.1	96.3	1.6	0.27	0.22	0.78

[1]Pooled standard error of treatment means, $n = 16$ pastures per treatment.
[2]Wean = Weaning treatment main effect, Sup. = Supplementation treatment main effect, W × S = weaning by supplementation treatment interaction.

pattern. Cows whose calves were weaned 18 August had greater BW and BCS than cows whose calves were weaned 7 November at every measurement, although weaning date by supplement treatment interaction occurred for BCS in December and March. Cows whose calves were weaned in November had less BCS and responded more to supplement than cows whose calves were weaned in August. Despite differences in BW and BCS, pregnancy rate was not influenced ($P = 0.56$) by weaning date.

Regardless of weaning date treatment, feeding supplemental protein from 1 December through 28 February decreased ($P < 0.001$ to $P = 0.001$) BCS and BW loss during the winter and caused cows to have greater BW and BCS precalving (March) and prebreeding (June). As with the weaning date treatment, feeding supplemental protein to increase prebreeding BCS did not influence pregnancy rate ($P = 0.27$). There was no difference among treatments in cow health or longevity in the study.

Calf Variables. Average calving date was March 30 and was not affected ($P = 0.43$ to $P = 0.58$) by treatments (Table 3). Both weaning date and winter supplementation affected ($P = 0.004$ to $P = 0.05$) calf birth weight but the magnitude of difference among treatments were small. Weaning date by supplement treatment interaction occurred for calf BW at weaning. For calves weaned August 18, those born to cows fed supplement weighed 6 kg more at weaning than calves born to nonsupplemented cows. However, for calves weaned November 7, those born to cows fed supplement weighed 14 kg more at weaning than calves born to nonsupplemented cows. Percentage of calves weaned was not affected ($P = 0.22$ to $P = 0.27$) by either treatment nor was calf health.

Feedlot Performance. Steers weaned 18 August were in the feedlot 42 days longer than steers weaned 7 November (Table 4). August-weaned steers were harvested in mid-May vs. mid-June for the November-weaned steers. A weaning date by protein supplement interaction occurred for BW upon entry to the feedlot ($P = 0.04$), average daily gain (ADG; $P = 0.06$), and final BW ($P = 0.05$). In all three instances, the interaction was caused by greater weight or weight gain differences between steers born to supplemented cows vs. steers born to

Table 4. Feedlot performance of steer calves weaned in August or November born to dams fed protein supplement (S) or no protein supplement (NS) during gestation (Experiment 1).

Item	August wean NS	August wean S	November wean NS	November wean S	SE[1]	P value[2] Wean	P value[2] Sup.	P value[2] W × S
Finishing period								
Days on feed	254	254	212	212				
In wt., kg	193	200	226	243	2	< 0.001	0.001	0.05
Out wt., kg	569	579	546	594	8	0.66	0.003	0.03
DMI,[3] kg	10.9	11.8	11.4	12.3	0.2	0.03	0.002	0.85
ADG,[4] $kg \cdot d^{-1}$	1.55	1.55	1.64	1.81	0.04	0.006	0.06	0.05
Gain:feed, kg:kg	0.143	0.131	0.144	0.147	0.004	0.08	0.36	0.09
Carcass data								
HCW,[5] kg	354	361	339	369	5	0.56	0.04	0.05
Marbling[6]	562	568	535	554	20	0.32	0.54	0.74
LM,[7] cm^2	87.6	85.0	86.7	90.3	1.8	0.24	0.78	0.11
Empty BF[8]	29.3	29.8	28.5	28.6	0.3	0.006	0.25	0.47
Yield grade	2.8	3.0	2.6	2.6	0.1	0.003	0.54	0.36
Fat,[9] cm	1.28	1.31	1.20	1.11	0.06	0.04	0.68	0.32
Adjusted data								
Adj. DOF[10]	257	246	221	262	16	0.66	0.30	0.19
Adj. HCW,[11] kg	362	362	369	448	19	0.03	0.06	0.06
Adj. Marb.,[12] kg	564	568	557	628	25	0.31	0.16	0.20

[1]Pooled standard error of treatment means, $n = 8$ pens per treatment.
[2]Wean = Weaning treatment main effect, Sup. = Supplementation treatment main effect, W × S = weaning by supplementation treatment interaction.
[3]DMI = dry matter intake.
[4]ADG = average daily gain.
[5]HCW = hot carcass weight.
[6]Marbling score: 400 = slight^{00}, 500 = small^{00}.
[7]LM = longissimus muscle area.
[8]BF = body fat.
[9]Backfat thickness measured at the 12th rib.
[10]DOF = days on feed adjusted to a constant back fat thickness (1.3 cm) across all treatments using the equation of Bruns et al. (2004).
[11]Hot carcass weight adjusted to a constant back fat thickness (1.3 cm) across all treatments using the equation of Bruns et al. (2004).
[12]Marb. = marbling score adjusted to a constant back fat thickness (1.3 cm) across all treatments using the equation of Griffin (2006): 400 = slight^{00}, 500 = small^{00}.

nonsupplemented cows within the November weaning treatment compared to the August weaning treatment.

Carcass Data. A weaning date by protein supplement interaction ($P = 0.07$) occurred for hot carcass weight with a difference of 30 kg between the November-weaned steers from supplemented cows and nonsupplemented cows and only 7 kg difference between August-weaned steers from supplemented cows and nonsupplemented cows (Table 4). Twelfth rib fat ($P = 0.01$) and yield grade ($P = 0.006$) were greater for August-weaned steers compared to November-weaned steers. Twelfth rib fat thickness ($P = 0.57$) and yield grade ($P = 0.38$) were not different between protein supplement treatments. No differences ($P = 0.17$ to $P = 0.74$) occurred for longissimus muscle area for weaning date or protein supplement and averaged 87.4 cm^2 for all steers. Marbling score was not different between weaning date ($P = 0.23$) or supplementation ($P = 0.44$) treatments. When hot carcass weight, marbling score, and days on feed were adjusted to a constant back fat thickness, the same statistical relationships among treatments occurred as for the unadjusted data. Adjusting the data to a constant back fat thickness increased the differences in hot carcass weight of steers weaned in November compared to August and steers born to cows fed supplement compared to steers born to cows not fed supplement.

Economic Analysis. Costs and returns are reported in Table 5 for preweaning and postweaning phases of production. At weaning, calves from the November weaning treatment returned $\$12.03 \cdot cow^{-1}$ more net revenue than August-weaned calves (averaged between supplement and nonsupplement treatments). Calves born to nonsupplemented cows had net revenues at weaning that were $\$7.72 \cdot cow^{-1}$ greater than calves born to supplemented cows (averaged between August and November weaning treatments) when calves are sold at weaning. Therefore, in production systems where calves are sold at weaning, feeding supplement and weaning later in the year would be more profitable if resources and management were similar to this study.

Feedlot feed costs averaged $\$54.18 \cdot steer^{-1}$ more and yardage cost was $\$15.20 \cdot steer^{-1}$ more for August-weaned calves compared to November-weaned calves because August-weaned calves were in the feedlot 42 days longer and consumed more total feed compared to November-weaned calves. Market price of August-weaned calves at harvest was $\$2.00 \cdot 45\ kg^{-1}$ greater than November-weaned calves because of seasonal price differences at the time of marketing. Calves weaned in

Table 5. Costs, market values, and net revenue ($ · animal^{-1}) of cows weaned 18 August or 7 November and fed protein supplement (S) or no protein supplement (NS) during winter grazing (Experiment 1).[1]

	August		November	
Item	NS	S	NS	S
Cow–calf phase				
Returns				
Weaned calf value	420.95	429.92	451.06	467.72
Gain (loss) in sale of culls	(3.89)	(4.16)	(2.08)	(8.54)
Costs				
Fall grazing[2]	52.82	53.93	73.17	74.86
Supplement		15.77		15.77
Net revenue at weaning	364.24	356.06	375.81	368.55
Feedlot phase				
Observed animal performance				
Returns				
Finished steer	858.48	875.46	807.16	878.59
Costs				
Calf purchase cost	448.62	470.51	451.06	474.08
Feed	300.98	325.63	249.36	268.88
Yardage	73.80	73.80	58.60	58.60
Trucking	2.13	2.19	2.51	2.69
Net revenue at finishing	32.95	3.33	45.63	74.34
Adjusted to constant back fat thickness				
Returns				
Finished steer	877.88	877.89	878.59	1 066.69
Costs				
Calf purchase cost	448.62	470.51	451.06	474.08
Feed	304.53	315.37	259.95	332.30
Yardage	74.67	71.48	61.09	72.42
Trucking	2.19	2.20	2.73	3.27
Net revenue at finishing	47.87	18.33	103.76	184.62

[1]Net revenue is the sum of all income and/or losses minus associated costs on a per cow basis.
[2]Accounts for difference in forage intake of non-lactating cow vs. lactating cow and calf.

November born to supplemented cows returned \$71.01 · cow^{-1} more net revenue through the feedlot than August-weaned calves from supplemented cows (Table 5).

Based on observed animal performance (unadjusted data), feeding supplement returned \$28.71 per finished steer more than not feeding supplement when calves were weaned in November, but resulted in a \$29.62 per finished steer decrease in net returns when weaning occurred in August. When hot carcass weight and days on feed were adjusted to a constant back fat thickness feeding supplement returned \$80.87 per finished steer more than not feeding supplement when calves were weaned in November, but resulted in a \$29.55 per finished steer decrease in net returns when weaning occurred in August.

Experiment 2

No year-by-treatment interactions ($P > 0.10$; Table 6) occurred for any measured variable; therefore, data from both years were pooled. Cow BCS, cow BW, and calf BW were similar ($P > 0.10$) among all treatments on 19 August. A linear decrease in cow BW ($P < 0.001$) and BCS ($P < 0.001$) occurred as date of weaning was delayed. Cows weaned prior to 14 October gained BCS during the treatment period (19 August to 25 November), but cows weaned after 14 October lost BCS during the same interval.

Calves averaged 139 days of age at the first weaning date (19 August). Nursing calves gained weight cubically ($P = 0.004$; Table 6) as weaning date progressed from 19 August to 25 November. Calf BW on 25 November increased quadratically ($P = 0.05$) with the lowest body weight occurring for calves weaned on 19 August (196 kg) and the highest for calves weaned on 11 November (237 kg). Calf ADG from 19 August to 25 November also increased quadratically ($P = 0.002$). Calf weight reached a plateau for dates after 14 October.

DISCUSSION

Experiment 1

Cow Variables. Adequate BCS at calving is generally accepted as the most important determinant of subsequent pregnancy

Table 6. Cow body weight (BW) and body condition score (BCS) change and calf BW and daily BW gain when weaning occurred at 2-week intervals from mid-August to mid-November (Experiment 2).

	Weaning date									P value[2]		
Item	19 August	2 September	16 September	30 September	14 October	28 October	11 November	25 November	SE[1]	L	Q	C
Cow												
BW change, kg	27	17	19	1	2	−8	1	−17	4	< 0.001	0.51	0.50
BCS change	0.36	0.23	0.19	0.13	0.03	−0.05	−0.13	−0.37	0.09	< 0.001	0.31	0.37
Calf												
End BW, kg	196	209	215	222	229	221	237	230	5	< 0.001	0.05	0.70
Start to wean ADG,[3] $kg \cdot d^{-1}$	—	1.60	1.16	1.04	0.90	0.79	0.64	—	0.03	< 0.001	< 0.001	0.004
Start to end ADG, $kg \cdot d^{-1}$	0.39	0.48	0.54	0.59	0.62	0.63	0.68	0.68	0.02	< 0.001	0.002	0.43

[1]Pooled standard error of treatment means.
[2]Observed significance level for orthogonal contrasts; L = linear, Q = quadratic, C = cubic.
[3]ADG = average daily gain.

rate (Richards et al. 1986; De Rouen et al. 1994) and the practice of managing cows to calve in BCS of 5 is commonly recommended (Richards et al. 1986; Morrison et al. 1999). In our experiment, weaning in August was an effective means of achieving a precalving BCS of 5. Increased nutrient requirements associated with lactation caused cows in the November weaning treatment to lose BCS from 18 August to 7 November but cows in the August weaning treatment gained BCS and BW during this period. The BW and BCS gained by cows in the August weaning treatment in year 1 from 18 August to 7 November carried over into subsequent production phases and years. Feeding supplement was also an effective means of achieving a precalving BCS of 5.

Given the substantial difference in precalving (1 March) BCS of cows in the August weaning treatment that were fed supplement compared to cows in the November weaning treatment that were not fed supplement (5.3 vs. 4.0), differences in pregnancy rates would be a logical expectation. Lack of difference in pregnancy rates observed in this study might be a result of allowing cows to graze subirrigated meadow before the start of the breeding season (15 May to 5 June). In May, subirrigated meadow forage is highly digestible (Lardy et al. 2004) and would have provided cows in this study with a plane of nutrition that exceeded their requirements. Increased postpartum nutritional plane can shorten postpartum interval and increase pregnancy rate, particularly if cows are thin at calving (Spitzer et al. 1995; Wettemann et al. 2003).

An alternative explanation for lack of difference in pregnancy rate could be that the importance of mature cows achieving a BCS of 5 at calving has been overemphasized. Stalker et al. (2006) compared pregnancy rates of cows that grazed subirrigated meadow for one month immediately prior to the start of the breeding season (prebreeding BCS of 5.2) with those of cows fed grass hay (prebreeding BCS of 4.9) during the same time frame and did not observe an increase in pregnancy rate, regardless of whether or not cows were fed protein supplement prepartum. The present study and the study by Stalker et al. (2006) represent 7 years of data comparing the effects of feeding supplement vs. not feeding supplement to cows grazing dormant upland range in the Nebraska Sandhills. A combined analysis of results from these two studies reveals a 0.6 (5.1 vs. 4.5; $P < 0.001$) unit improvement in precalving BCS of supplement-fed cows but no difference in pregnancy rates (94.5% vs. 94.0%; $P = 0.80$). Taken together, results of this study and those of Stalker et al. (2006) suggest allowing mature cows to calve with BCS slightly less than 5 can result in acceptable reproductive performance under conditions encountered in applied production settings.

Calf Variables. Increased calf birth weight as a result of increased nutritional plane during gestation has been established for some time (Bellows and Short 1978). Weight of calves at weaning interacted between treatments. This interaction is a result of age of the calf at weaning. Calves born to supplemented cows had more rapid growth rates and the older November-weaned calves had more time to widen the weaning weight difference. Increased weaning weight of calves born to cows fed greater prepartum nutrient plane has been reported previously. Houghton et al. (1990) showed calves born to cows with high energy intake prepartum compared to cows with low energy intake maintained a weight advantage to 205 days postpartum. Similar to the results of this study, Stalker et al. (2006) reported increased weaning weight of calves born to cows fed supplement while grazing dormant range, compared to calves born to nonsupplemented cows. However, not all studies report differences in weaning weight when cows are fed differing prepartum diets. Freetly et al. (2000) showed calves from cows that lost BCS during the second and third trimester were not different in BW at 205 days of age compared to calves from cows who maintained BCS.

Greater weaning weight of calves born to cows fed supplement might be a result of increased milk production. Perry et al. (1991) observed increased calf weaning weight as a consequence of elevated prepartum nutritional plane and attributed the increase to milk production. Alternatively, differences in calf weight between supplementation treatments might not necessarily be a result of a growth stimulatory effect of the supplement but might have resulted from inhibitory effects on the developing fetus as a consequence of not supplementing the cow. Feeding supplement to March-calving cows grazing dormant winter range might be necessary to ensure the calf will reach its growth potential and is not necessarily a method of increasing growth potential.

Increased weaning weight in November-weaned calves is likely strictly a result of age of the calf because there was no effect of weaning date treatment on calf weight in August ($P = 0.27$).

Feedlot Performance. More pronounced finished BW differences between steers in the supplement treatment compared to steers in the no supplement treatment within the November weaning date could be related to prepartum body energy reserves of the cow. The fetus can be buffered from deleterious effects of gestational under-nutrition by mobilization of maternal nutrient reserves (Martin et al. 1997). Weaning in August could have allowed the cow to accumulate sufficient energy reserves which could be mobilized during late gestation to compensate for dietary deficiency in nonsupplemented cows, whereas delaying weaning until November might have depleted maternal nutrient reserves, thus eliminating them as a resource to support fetal growth. This conclusion is supported by the results of Stalker et al. (2006), who managed cows to achieve precalving BCS similar to cows in the August weaning treatment in the present study and did not observe differences in final weight of finished steers born to supplemented or nonsupplemented cows. If mobilization of maternal tissues to support fetal growth is the reason for differences in offspring weight, then not supplementing inhibited calves from realizing their full growth potential and calf weight differences are not a result of a stimulatory effect of supplementation.

The ADG of August-weaned steers in the feedlot compared to November-weaned steers is inconsistent with other research that has shown early-weaned calves have about 0.7 kg greater ADG than calves weaned later in the fall (Myers et al. 1999; Story et al. 2000).

Carcass Data. Carcass weight differences are consistent with live animal performance differences. Myers et al. (1999) and Fluharty et al. (2000) reported weaning age did not affect hot carcass weight but Story et al. (2000) observed increased hot carcass weight as weaning age increased.

Days on feed are the most important determinate of back fat thickness and likely accounts for differences observed in this study. Fluharty et al. (2000) found yield grade was not dependent upon age at weaning, but Story et al. (2000) observed a difference in yield grade between earlier-weaned and later-weaned calves. Lack of difference in longissimus muscle area is consistent with other research (Myers et al. 1999; Fluharty et al. 2000; Stalker et al. 2006). Myers et al. (1999) reported early-weaned steers had greater marbling score than normal-weaned steers. Story et al. (2000) observed increased percentage of carcasses grading USDA Choice or greater in early-weaned steers, but when adjusted to the same fat depth, no differences occurred.

Economic Analysis. The costs of fall grazing, protein supplementation, and gain or loss from cull cow sales were considered in the economic analysis. Supplemented cows had greater costs compared to nonsupplemented cows because of costs associated with purchasing and feeding supplement. Because not supplementing cows in the November weaning treatment resulted in lighter finished weight, the loss in net returns after the feedlot phase justifies the additional costs associated with feeding supplement.

Cow costs were less for the August weaning treatment because of reduced forage intake by the cow. This difference in cost is similar to research by Peterson et al. (1987). The August weaning treatment resulted in decreased cow costs at the ranch, but when the August-weaned calves entered the feedlot, higher costs associated with feed and yardage were incurred.

Even though market prices were higher for the August-weaned calves, gross revenue from calves was higher for November-weaned calves because of heavier sale weights. Research by Story et al. (2000) supports this observation. Our results show costs can be shifted from one enterprise (production phase) to another, depending on age at weaning and feed costs in the different enterprises. Marketing early-weaned calves creates potential to increase income by reducing fall grazing costs but retention of calves on the ranch improves profits in the feedlot by reducing yardage and feed costs. Relying on the cow for maintaining performance of calf gain while reducing winter feed inputs by extending the grazing season shows potential for increased profit (Adams et al. 1994).

Weaning in August increased income from cull cows because marketing occurred during seasonal increased market prices. A second factor increasing income for sale of cull cows in August was greater BW and BCS compared to culls from the November weaning treatment, which translated into increased quality grade. However, increased income generated by sale of cull cows in August was offset by lighter weaning weight of earlier-weaned calves.

Experiment 2

Results of Experiment 2 agree with results of Experiment 1 and with Myers et al. (1999) and Story et al. (2000), who reported decreased BCS and cow BW as weaning date was moved later in the fall. Loss in BCS as weaning date was moved later into the fall occurred because forage nutrient quality was not sufficient to meet requirements for lactation. Quality of cattle diets grazing upland Sandhills range decreased in digestibility and CP from August through November (Lardy et al. 2004). Results of this study suggest weaning on or before 14 October would allow the cow to regain BCS while grazing native range before the winter grazing months in the Nebraska Sandhills.

Weight gain of calves in the 11 November and 25 November weaning date treatments might have been affected by weather and/or fill effects at weaning time. Calves weaned later in the fall had greater gains; however, the amount of gain diminished as weaning dates advanced from October through November. Lamb et al. (1997) showed calves nursing 2-year-old cows on Sandhills range had similar gains to weaned calves grazing meadow regrowth. In this study, calves did not gain as much BW as calves nursing mature cows. Difference in weaning weight between weaned and nursing calves is potentially explained by the greater milk production expected for mature vs. 2-year-old cows.

MANAGEMENT IMPLICATIONS

Feeding protein supplement to cows grazing dormant forage and early weaning of the calf allows the cow to achieve greater body condition at calving, but not feeding supplement and late weaning will not necessarily translate into decreased reproductive performance of the mature cow. Marketing of early-weaned calves occurs during seasonally elevated market prices but can result in fewer net returns than traditional weaning because of lighter calf weight at weaning and harvest. Ownership of the calf during the feedlot phase might be necessary to realize the greatest increase in net returns as a result of feeding supplemental protein to cows grazing dormant range. Decisions for weaning date and winter protein supplementation of the cow must be based on available resources and marketing strategy. Producers must know how costs associated with production interact with marketing time of calves and finished cattle.

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