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Early weaning in Northern Great Plains beef cattle production systems: I. Performance and reproductive response in range beef cows ☆

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ABSTRACT

A study was conducted to determine if early weaning spring born calves can be an alternative management strategy during drought and if early weaning facilitates rebreeding of young cows. Our objectives were to determine effects of early weaning at the start of breeding on cow body weight, body condition score, and reproductive performance with or without estrous synchronization and AI in two herds in the Northern Great Plains, USA. In Exp. 1 and 2, crossbred cows were stratified within cow age by postpartum interval, and calf sex, and were assigned within strata to one of two weaning treatments at the start of breeding when calves averaged 80-d of age: (1) early weaned (permanent calf removal); or (2) no weaning (calves suckled cows until normal weaning approximately 210-d of age). Cows in Exp. 1 were exposed to natural service whereas cows in Exp. 2 were exposed to estrous synchronization for AI using a CIDR for 7 d with GnRH at CIDR insertion and $PGF_{2\alpha}$ at CIDR removal followed by natural service. In Exp. 3, cows were stratified within breed by age, postpartum interval, calf sex, and AI sire and were assigned within strata to one of two weaning treatments at the start of breeding, as described for Exp. 1 and 2. Estrous cycles of all cows were synchronized for AI using one of two protocols including 14 d CIDR+$PGF_{2\alpha}$ 16 d following CIDR removal (primiparous cows) or a CIDR insert for 7 d with GnRH at CIDR insertion and $PGF_{2\alpha}$ at CIDR removal (multiparous cows). Cows in Exp. 2 and 3 were bred by AI approximately 12 h after observation of estrus or by timed AI at 80 h after $PGF_{2\alpha}$ concurrent administration of GnRH. Artificial insemination (Exp. 2), breeding season pregnancy rate, and day of conception was not influenced ($P>0.10$) by weaning treatment for Exp. 1 and 2. However, early weaned cows in Exp. 3 had 12.0% greater ($P=0.03$) AI pregnancy rates and conception occurred 3.78 d earlier ($P=0.03$) than normal weaned cows. At the time of normal weaning, cows that had their calves removed at early weaning were heavier and had greater body condition ($P<0.01$) than normal weaned cows in each experiment. We conclude that early-weaning beef cows at the start of the breeding season improved BW gain and BCS allowing those females to enter winter in greater BCS then NW cows, but improvements in reproductive performance were inconsistent.

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1. Introduction

Cow–calf producers may optimize beef cow performance by implementing early weaning of calves particularly during times when forage quantity and/or quality are insufficient to meet cow requirements (e.g., drought) or when there is concern about impacts of low body condition on subsequent reproductive success (especially young cows). Lactation stress during periods of drought can exhaust nutritional stores in beef cows resulting in BW loss and decreased reproductive performance.

Suckling delays the onset of estrus in beef cows (Short et al., 1972), and early weaning before the breeding season has shortened the postpartum anestrous period and increased pregnancy rates (Laster et al., 1973; Lusby et al., 1981). Primiparous heifers have benefited from higher planes of nutrition when compared to multiparous cows during the anestrous period (Hansen et al., 1982), which would also suggest a benefit to early weaning. Lactating cows consume more forage than gestating cows (Galindo-Gonzalez et al., 2007; Marston and Lusby, 1995) and research has shown for each kg increase in milk yield a 0.33–0.37 kg (R^2=0.52 and 0.64, respectively) increase in daily forage dry matter intake (DMI) throughout lactation (Johnson et al., 2003). Thus indicating the removal of the demands of lactation early in the postpartum period should allow for the repartitioning of dietary nutrient towards maternal tissue and allow cows to be in greater body condition going into month where dietary forage is less nutrient dense (Waterman et al., 2007). Furthermore, the removal of lactational demands reduces intake demands and may conserve pasture resources that are valuable especially during extended drought conditions. Young cows (2 and 3-yr-olds) that are still partitioning nutrients for growth should benefit the most from early weaning strategies.

Reproductive protocols that induce estrous cycles are available for beef producers today that were not available 30 years ago. The objectives of this study were to determine effects of early weaning at the start of the breeding season compared to normal weaning at 7 months of age (Exp. 1) and the value of early weaning in association with applied reproductive strategies (Exp. 2 and 3) on reproductive performance, cow age, body weight (BW) gain, and body condition score (BCS) of beef cow herds in the Northern Great Plains, USA.

2. Material and methods

2.1. Study sites

The study was conducted at two locations in the Northern Great Plains, USA. For Exp. 1 and 2 the research was conducted at the USDA-ARS, Fort Keogh Livestock and Range Research Laboratory (LARRL), located approximately 1.6 km west of Miles City, MT 59301 (46°22′N 105°5′W), USA, at an average elevation of 730 m. Average annual precipitation is 340 mm with the majority occurring from April through September from convectional thunderstorms (Fig. 1). Predominant grass genera at this location included wheatgrass (*Pascopyron*), needlegrass (*Hesperostipa*), and grama (*Bouteloua*) within a mixed-grass dominated rangeland (Küchler, 1964). The average annual forage standing crop at the study site is 870 ± 14 kg/ha (Grings et al., 2005). Average daily temperatures range from −5 °C in January to 24 °C in July with daily maximum temperatures occasionally exceeding 37 °C during summer and daily minimums occasionally dropping below −40 °C during winter (WRCC, 2006).

For Exp. 3 the research occurred in Central Montana, approximately 5 km northeast of Judith Gap, MT 59453 (46°41′N 109°45′W), USA, at an average elevation of 1270 m. Annual precipitation for this region is 383 mm with the majority of that moisture accumulating from April through October (Fig. 1). Predominant forages in pastures at this location included wheatgrass (*Pascopyron*) and needlegrass (*Hesperostipa*) with slighter amounts of alfalfa (*Medicago*), grama (*Bouteloua*), junegrass (*Koeleria*), and bluegrass (*Poa*). Average daily temperatures, at this site, range from −3 °C in February to 21 °C in July with daily maximum temperatures occasionally exceeding 37 °C during summer and daily minimum temperatures occasionally dropping below −40 °C during winter (WRCC, 2006).

2.2. Animals, measurements and management

The LARRL Institutional Animal Care and Use Committee approved all animal handling and experimental procedures utilized in the present studies. Three similar experiments were conducted; two at LARRL and a third in a commercial production situation, Judith Gap. Each experiment had approximately twice as many early weaned (EW; weaned at approximately 80-d of age) cows as normal weaned (Control) cows to balance calf weaning treatments. While normal weaned calves remained on their dam until time of normal weaning (approximately 7 months of age) early weaned calves (approximately 2.5 months of age) received one of the following diets: (1) 17.5% CP (69% RDP and 7.53 MJ/kg NEm) or (2) 17.5% CP (57% RDP and 7.69 MJ/kg NEm) from time of early to normal weaning.

In Exp. 1, crossbred cows (predominantly Angus × Hereford) at the LARRL location (2005) calved over a 87 d period from March 1, 2005 to May 27, 2005 (primiparous cows March 14, 2005 through May 6, 2005 with a mean of March 30, 2005 ± 1.2 d; multiparous cows March 1, 2005 through May 27, 2005 with a mean of April 25, 2005 ± 0.9 d) and were stratified within cow age by calf sex and age then randomly assigned within strata to one of two weaning treatments at the start of breeding. Cows (n=338) had calves removed at the start of breeding (n=220; 78.1 ± 0.96 d postpartum) or at normal weaning (n=118; at approximately 210.5 ± 0.96 d postpartum). Cows were bred by natural service (bull:cow ratio of 1:23) without synchronization for a 58-d breeding season on July 5, 2005. Breeding pastures (n=2) contained both early weaned cows and normal weaned cows (cows with calves still nursing) and cows were assigned to a breeding pasture that contained either Angus or Polled Hereford bulls to maximize heterosis. Each breeding pasture contained a similar number of early and normal weaned

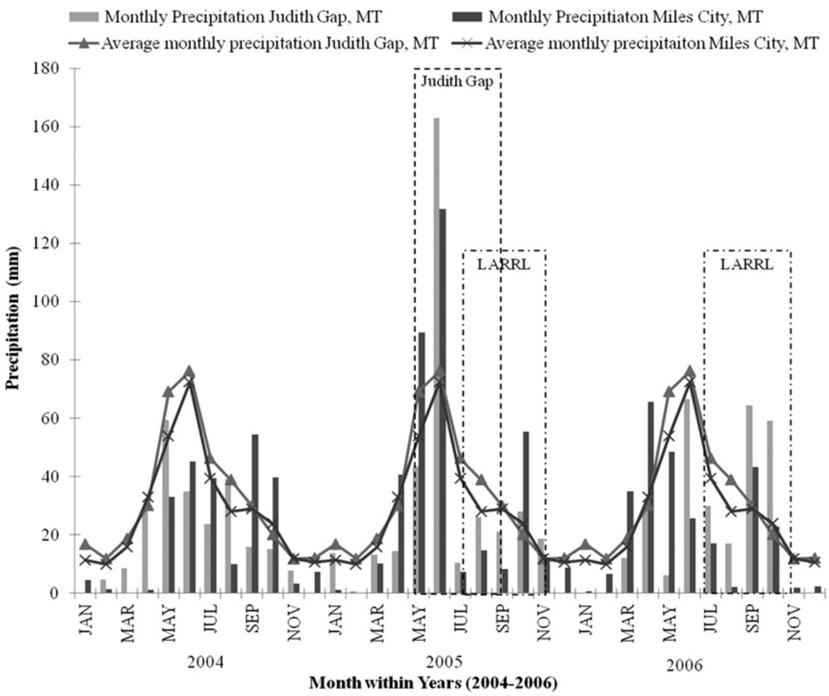

Fig. 1. Monthly precipitation between 2004 and 2006 within years (bars) and 57- and 70-year average (line) for Judith Gap and Miles City, MT, respectively. Dashed boxes indicate when each experiment took place [Judith Gap (May 9–September 19, 2005); Miles City (July 5–November 15, 2005); Miles City (July 10–November 20, 2006)]. Information obtained from Western Regional Climate Center (WRCC, 2006). These studies were conducted from May 2005 to November 2006.

cows. Pregnancy was diagnosed on day 58 and 133 after onset of breeding and date of conception estimated by transrectal ultrasonography using a 5 MHz linear probe (Aloka, Wallingford, CT 06492, USA). Cow BW was measured and recorded at time of early and normal weaning along with BCS (1 = emaciated to 9 = extremely obese) which was assigned by 2 experienced technicians as described by Herd and Sprott (1986) and Wagner et al. (1988). Cow BW and BCS changes were calculated for the 133-d period (July 5 through November 15, 2005) between early and normal weaning and again prior to start of calving on March 4, 2006 (mean calving date April 25, 2006 $\pm$ 0.65 d).

In Exp. 2, the same cow herd was used in 2006 at LARRL and cows calved over a 80 d period from March 12, 2006 to May 31, 2006 (primiparous cows March 12, 2006 through May 31, 2006 with a mean of March 29, 2006 $\pm$ 1.2 d; multiparous cows April 3, 2006 through May 31, 2006 with a mean of April 25, 2006 $\pm$ 0.6 d). Cows were stratified within cow age by calf sex and age then randomly assigned within strata to one of the two weaning treatments as described in Exp. 1. Cows ($n = 322$) had calves removed at the start of breeding on July 10, 2006 ($n = 215$; 83.0 $\pm$ 0.85 d postpartum) for EW treatment or at normal weaning ($n = 107$; 208.4 $\pm$ 0.85 d postpartum). Estrous cycles of all cows were synchronized for AI using a controlled intravaginal drug releasing insert (CIDR; Pfizer Animal Health, New York NY, 10017, USA) for 7 d with GnRH (100 μg, i.m.; Fertagyl, Intervet Inc., Millsboro, DE 19966, USA) at CIDR insertion and $PGF_{2\alpha}$ (25 mg, i.m.; ProstaMate, Teva Animal Health, Saint Joseph, MO 64503, USA) at time of CIDR removal. Timing of early weaning coincided with the $PGF_{2\alpha}$ injection of the above protocol. Cows were observed for estrus continuously during daylight hours from $PGF_{2\alpha}$ injection until 72 h after $PGF_{2\alpha}$. Cows detected in estrus were inseminated approximately 12 h later. Cows not detected in estrus by 72 h after $PGF_{2\alpha}$ received timed AI with GnRH (100 μg, i.m.) at 80 h after $PGF_{2\alpha}$. To accurately measure cows bred by AI, herd bulls were placed with cows two weeks following AI and remained with cows until the end of a 50-d breeding season. Breeding pastures ($n = 2$) contained a similar number of early weaned (EW) and normal weaned (NW) cows. Cows were assigned to a breeding pasture that contained either Angus (bull:cow ratio of 1:23) or Polled Hereford (bull:cow ratio of 1:22.5) bulls to maximize heterosis. Pregnancy was diagnosed on day 59 and 115 after AI and date of conception estimated by transrectal ultrasonography as described above. Cow BW and BCS was collected as described above for the 133-d period (July 10 through November 20, 2006) between early and normal weaning and again on March 3, 2007 just prior to the start of calving (mean calving date April 30, 2007 $\pm$ 0.75 d).

In Exp. 3, at the Judith Gap location (2005), Angus ($n = 199$) and Angus $\times$ Simmental ($n = 158$) cows calved over an 81 d period from January 2, 2005 to March 24, 2005 (primiparous cows January 2, 2005 through March 14, 2005 with a mean of January 30, 2005 $\pm$ 0.8 d; multiparous cows January 2, 2005 through April 5, 2005 with a mean of February 26, 2005 $\pm$ 0.8 d). Cows were stratified within breed and age, then by calf sex, age, and AI sire before being randomly assigned within strata to one of the two weaning treatments as described in Exp. 1 and 2. Cows (n=357) had calves removed at the start of breeding (n=236; 77.3 ± 0.90 d postpartum) or at normal weaning (n=121; 211.8 ± 0.90 d postpartum). Cow BW was measured and recorded at time of early and normal weaning and BW change was evaluated over the 133-d period (May 9 through September 19, 2005). Estrous cycles of all cows were synchronized for AI using one of two protocols designed to maximize pregnancy rates to AI. Primiparous cows (n=90) received a CIDR insert for 14 d with $PGF_{2\alpha}$ (25 mg, i.m.) 16 d following CIDR removal and multiparous cows (n=267) received a CIDR insert for 7 d with GnRH (100 μg) at CIDR insertion and $PGF_{2\alpha}$ (25 mg, i.m.) at CIDR removal. Like Exp. 2, timing of early weaning coincided with the $PGF_{2\alpha}$ injection of the above protocols. Estrous synchronization protocols were offset in primiparous and multiparous cows so that the $PGF_{2\alpha}$ injection in both groups occurred on the same date. Cows were observed for estrus continuously during daylight hours from $PGF_{2\alpha}$ injection until 72 h after $PGF_{2\alpha}$. Cows detected in estrus were inseminated approximately 12 h later. Cows not detected in estrus by 72 h after $PGF_{2\alpha}$ were time AI'ed with GnRH (100 μg, i.m.) 80 h after $PGF_{2\alpha}$. Two weeks after AI, Angus bulls were placed with cows and remained with cows until the end of a 50-d breeding season. Primiparous cows (bull:cow ratio of 1:31.3) remained in a single breeding pasture for the duration of this study regardless of weaning treatment. Multiparous cows were pastured in two adjacent and similar breeding pastures according to weaning treatment (bull:cow ratio of 1:40 and 1:35.8 for early and normal weaned cows, respectively). Pregnancy was diagnosed on day 85 after $PGF_{2\alpha}$ injection and date of conception estimated by transrectal ultrasonography as described above. Cow BW was measured and recorded once at time of early and normal weaning and BW change was evaluated over the 133-d period (May 9 through September 19, 2005).

2.3. Forage characteristics

Rumen extrusa samples were analyzed (LARRL location only) to estimate and describe nutritional chemical composition of forages grazed by experimental cows. Diet extrusa samples were collected on July 26, and November 9, 2005 and on July 26, and November 13, 2006 representing the initial (EW) and ending (NW) nutritional characteristics of forage grazed (Table 1). Two ruminally cannulated cows were pasture grazed with experimental cows throughout the study. On day of extrusa sampling, ruminal contents from cannulated cows were evacuated and stored in 208-L plastic tubs, and ruminal walls were sponge dried to remove any residual moisture as described by Lesperance et al. (1960). After removal of ruminal contents, cows were released into experimental pastures and allowed to graze for 45–60 min. After grazing about, extrusa was recovered from the rumen and thoroughly mixed. An aliquot was saved for analysis and original ruminal contents were returned. Collected extrusa samples (1 from each cow) were frozen at −20 °C, lyophilized, ground to pass a 2-mm screen, and stored until analysis for dry matter (DM), organic matter (OM) by previously reported procedures (AOAC, 1990), and NDF (Goering and Van Soest, 1970). Sub-samples of ground extrusa were placed in glass square bottom jars with metal rod inserts and dried in a 60 °C oven for 12 h. Upon removal from a drying oven, jars were capped with lids and subsequently placed on a roller grinder for 24 h (Mortenson, 2003). Nitrogen was determined by combustion techniques using a C–N analyzer (CE Elantech, Inc., Lakewood, NJ08701, USA). Nitrogen values were multiplied by 6.25 to obtain CP, which was expressed on an OM basis.

To estimate diet digestibility, ground extrusa samples (5 g) were placed in duplicate Dacron bags (10 cm × 20 cm; pore size = 53 ± 10 μm; Ankom Technology Corp., Fairport, NY 14450, USA). These filled Dacron bags (4/cow) and a blank bag (1/cow) were placed into a 60 cm × 60 cm zippered laundry bag with an attached cord and then placed into the rumen at specific times to allow for 96, 48, 24, and 0 h of incubation. Amount of residue in the blank Dacron bag was subtracted from each sample bag collected at the same incubation time to correct for influx of particles during incubation. Upon removal from the rumen, at 0 h, all bags were subjected to an initial rinse by submerging bags 3 times in a 19-L bucket. The 19-L bucket was filled with cold water to stop fermentation (0-h bags were not inserted into the rumen but were subjected to the rinsing in the 19-L bucket). Bags

Table 1
Forage extrusa nutrient composition collected from ruminally-cannulated cows grazing alongside experimental cows in Exp. 1 (2005) and Exp. 2 (2006) on rangelands in the Northern Great Plains, USA.

Item	Extrusa collection	
	Early weaning (Breeding)	Normal weaning
Year 1 (2005)	MJ/kg OM	
DE	12.1	9.2
ME	10.0	7.9
	%	
DM	91.1	91.9
OM	86.2	86.0
CP[a]	9.1	7.3
NDF[a]	67.6	72.3
48 h OM digestibility	69.4	49.7
96 h OM digestibility	76.3	59.5
48 h NDF digestibility[a]	66.3	46.4
96 h NDF digestibility[a]	75.4	57.6
	%/h	
Rate of fiber digestion	4.8	4.9
Year 2 (2006)	MJ/kg OM	
DE	11.7	10.9
ME	9.6	8.8
	%	
DM	91.0	91.8
OM	89.6	86.7
CP[a]	8.5	7.9
NDF[a]	67.4	73.6
48 h OM digestibility	62.3	58.5
96 h OM digestibility	73.7	68.3
48 h NDF digestibility	66.7	57.9
96 h NDF digestibility	75.4	70.5
	%/h	
Rate of fiber digestion	4.7	4.8

[a] OM basis.

were stored in plastic zippered bags prior to being frozen at −20 °C until further analysis. Upon thawing, bags were individually rinsed in cold tap water until the effluent was clear, after which bags were frozen (−20 °C), lyophilized, and weighed. Residue remaining in the bag was analyzed for DM, OM, and NDF, and NDF disappearance was calculated. To estimate ME of diets consumed, 48 h in situ OM digestibility (ISOMD) was used to calculate ME. Conversion of ISOMD to DE was accomplished using the formula of Rittenhouse et al. (1971):

$$\mathrm{DE(Mcal/kg)} = 0.039(\%\mathrm{ISOMD}) - 0.10,$$

and DE was converted to ME using the relationship provided by NRC (2000):

$$\mathrm{ME(Mcal/kg)} = \mathrm{DE(Mcal/kg)} \times 0.82.$$

Final conversion was to express DE and ME on a MJ/kg basis

$$\mathrm{DE(MJ/kg)} = \mathrm{DE(Mcal/kg)} \times 4.184$$
$$\mathrm{ME(MJ/kg)} = \mathrm{ME(Mcal/kg)} \times 4.184$$

2.4. Statistical analysis

Experiments were analyzed separately. Pregnancy rate was evaluated using PROC LOGISTIC (SAS Inst. Inc., Cary, NC) procedures with a model that included weaning treatment, cow age and the interaction of weaning treatment and cow age. Cow BW and BCS data were analyzed using Proc MIXED with a model that included weaning treatment, cow age, and the interaction of weaning treatment and cow age. Days postpartum when appropriate were used as covariate. The Random statement was used and included breeding pasture when appropriate. In addition, three preplanned single degree of freedom orthogonal polynomials were used to evaluate the effect of cow age. Tukey–Kramer adjusted least squares means were computed and a significance level was set at $P \leq 0.05$.

A separate analysis was conducted evaluating responses observed to cows receiving weaning treatments for 2 consecutive years (Exp. 1 and 2) on measures obtained in Exp. 2. Data were analyzed the same as above except weaning treatment for both years were tested in the model. Data was unavailable for subsequent year analysis in Exp. 2 due to animals being reassigned to another experiment that manipulated estrous cycles and pregnancy.

3. Results

3.1. Experiment 1

Breeding season pregnancy rate and conception date (d into breeding season) were not influenced by weaning treatment ($P > 0.54$) or cow age ($P > 0.23$) at LARRL in 2005 when natural mating occurred without estrous synchronization (Table 2). At the time of normal weaning, cows that had their calves removed at early weaning were in greater body condition ($P < 0.01$), and weighed 15 kg more ($P < 0.01$) than cows that had their calves removed at normal weaning. Cow BW change ($P < 0.01$) and ADG ($P = 0.01$) throughout the 133-d period from early to normal weaning resulted in a weaning treatment × cow age interaction (Fig. 2). A decrease in BW and ADG for NW cows was measured as cow age increased whereas similar BW gains were measured for EW cows regardless of cow age. Cows receiving EW treatment gained 0.13 kg/d, whereas cows assigned the NW treatment lost between 0.36 and 0.51 kg/d during the 133-d treatment period between early and normal weaning. The change in BCS over the 133-d period resulted in a 1.0 unit increase ($P < 0.01$) for EW cows compared to NW cows. Cows with calves removed at time of early weaning produced calves that had 2 kg heavier birth weights ($P = 0.01$) the subsequent year than cows that had calves removed at normal weaning (Table 2). Calving interval was not influenced by weaning treatment ($P = 0.87$) but measured a quadratic ($P < 0.01$) response due to cow age.

Table 2
Least squares means ± SEM for reproductive and production performance for cows receiving weaning treatments over 133-d period in 2005 (Exp. 1).

	Treatment[b]				Cow age						
Item[a]	NW	EW	SEM	*P*-value	2	3	4	5⁺	SEM	*P*-value	Effect[c]
n =	118	220			97	70	104	67			
Reproduction											
Overall pregnancy (%)	92.4	94.1	–	0.54	93.8	90.0	97.1	91.0	–	0.23	–
Conception date, d	17.4	18.1	1.00	0.60	18.7	16.2	17.0	19.0	1.40	0.37	–
Calf birth weight SY (kg)	31.2	33.2	1.23	0.01	31.2	32.2	33.6	31.9	1.45	0.07	–
Calving interval (d)	371	371	1.68	0.87	393	362	367	360	2.52	< 0.01	L, Q
BW and condition											
Cow BW at EW (kg)	588	573	5.64	0.03	500	559	617	646	7.63	< 0.01	L, Q
Cow BW at NW (kg)	538	597	4.95	< 0.01	504	547	597	622	6.72	< 0.01	L
Cow BW at calving SY (kg)	562	603	8.15	< 0.01	531	572	609	617	9.46	< 0.01	L, Q
Cow BCS at EW	6.2	6.1	0.07	0.55	5.5	6.2	6.4	6.5	0.10	< 0.01	L, Q
Cow BCS at NW	5.3	6.3	0.12	< 0.01	5.3	5.9	6.0	6.0	0.15	< 0.01	L, Q
BCS change (NW–EW)	−1.0	0.1	0.07	< 0.01	−0.3	−0.4	−0.6	−0.6	0.09	0.03	L
Cow BCS at calving SY	4.6	5.4	0.14	< 0.01	4.5	5.1	5.3	5.1	0.17	< 0.01	L, Q

[a] Subsequent year (SY); Body weight (BW); Body condition score (BCS).
[b] Treatment = Early weaning (EW); Normal weaning (NW).
[c] Significant ($P \leq 0.05$) orthogonal polynomials for cow age; Linear (L) and Quadratic (Q).

In addition, BW and BCS were greater ($P<0.01$; Table 2) for EW treated cows just prior to subsequent year calving compared to cows that received the NW treatment. There was also a quadratic response ($P<0.01$) for both BW and BCS as cow age increased.

3.2. Experiment 2

Artificial insemination pregnancy rate, breeding season pregnancy rate, and day of conception were not different ($P>0.17$) by weaning treatment or cow age when estrous synchronization was used at the start of breeding (Table 3). At the time of normal weaning, cows with calves removed at early weaning weighed 44 kg more ($P<0.01$) than cows that had calves removed at normal weaning. In fact, cows with calves removed at time of normal weaning lost BW during the 133-d period between early and normal weaning, whereas cows with calves removed at early weaning gained BW during this same period. Cows that received the early weaning treatment gained 0.13 kg/d, whereas cows assigned to the normal weaning treatment lost 0.27 kg/d ($P<0.01$; Table 3) during the 133-d treatment period between early and normal weaning. At time of normal weaning, early weaned cows had a 1.3 unit greater BCS ($P<0.01$) than normal wean treated cows. Body weight and BCS change over the 133-d period favored EW cows ($P<0.01$). A quadratic response to BW change ($P<0.01$) over the 133-d indicated that 2-yr-olds maintained BW while 3-yr-olds gained BW and 4-yr-olds and older lost BW. Cows with calves removed at early weaning produced 2 kg heavier birth weights ($P=0.01$) the subsequent year than cows that had calves removed at normal weaning (Table 3). Calving interval was not influenced by weaning treatment ($P=0.89$) but measured a quadratic ($P<0.01$) response due to cow age. Body weight was greater ($P<0.01$) for EW treated cows just prior to calving compared to cows that received the NW treatment. There was weaning treatment × cow age interaction ($P=0.02$) for pre-calving BCS where all EW cows were in greater BCS than NW cows of similar age; however older cows that received the EW treatment had the greatest BCS (Fig. 3).

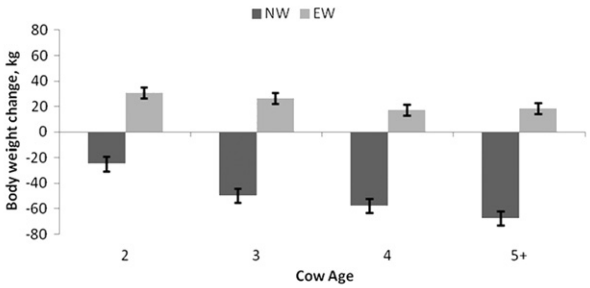

Fig. 2. Least squares means ± SEM for a weaning treatment × cow age interaction for body weight change ($P<0.01$) during a 133-d period between early (EW) and normal weaning (NW) in 2005 (Exp. 1).

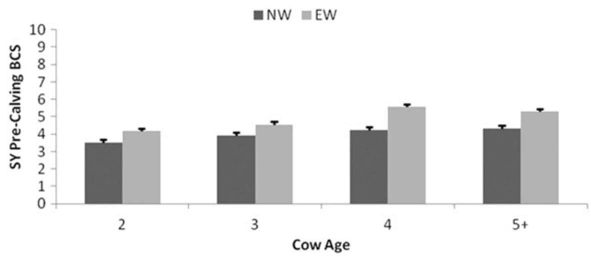

Fig. 3. Least squares means ± SEM for a weaning treatment × cow age interaction for subsequent year (SY) pre-calving body condition score (BCS; $P=0.02$) between early (EW) and normal weaning (NW) in 2006 (Exp. 2).

Table 3
Least squares means ± SEM for reproductive and production performance for cows receiving weaning treatments over 133-d period in 2006 (Exp. 2).

Item[a]	Treatment[b] NW	EW	SEM	P-value	Cow age 2	3	4	5+	SEM	P-value	Effect[c]
n=	107	215			88	72	47	115			
Reproduction											
AI pregnancy (%)	55.1	60.5	–	0.36	52.3	63.9	61.7	59.1	–	0.48	–
NW	–	–	–		40.0	56.5	81.3	55.3	–		–
EW	–	–	–		58.6	67.4	51.6	61.0	–		–
Overall pregnancy (%)	93.5	96.7	–	0.17	93.2	95.8	97.9	96.5	–	0.56	–
Conception date (d)	11.4	12.3	1.40	0.59	14.2	9.8	11.9	11.5	2.07	0.30	–
Calf birth weight SY (kg)	39.4	41.4	0.92	<0.01	40.1	39.9	40.0	41.6	1.32	0.12	–
Calving interval (d)	377	377	2.07	0.89	401	365	372	369	3.07	<0.01	L, Q
BW and condition											
Cow BW at EW (kg)	546	537	4.90	0.15	463	529	570	606	7.42	<0.01	L, Q
Cow BW at NW (kg)	512	556	4.64	<0.01	464	531	558	582	7.01	<0.01	L, Q
Cow BW change (kg)	−36.1	16.4	3.11	<0.01	−0.2	0.8	−14.6	−25.5	4.55	<0.01	L, Q
ADG (kg/d)	−0.27	0.13	0.02	<0.01	−0.01	0.01	−0.11	−0.19	0.04	<0.01	L, Q
Cow BW at calving SY (kg)	543	582	4.95	< 0.01	492	561	587	610	7.34	<0.01	L, Q
Cow BCS at EW	4.4	4.4	0.08	0.83	3.9	3.9	4.9	4.8	0.12	<0.01	L
Cow BCS at NW	4.1	5.4	0.07	<0.01	4.3	4.5	5.1	5.1	0.10	<0.01	L
BCS change (NW–EW)	−0.2	1.3	0.13	<0.01	0.5	0.9	0.4	0.5	0.18	0.01	–

[a] Subsequent year (SY); Body weight (BW); Body condition score (BCS).
[b] Treatment = Early weaning (EW); Normal weaning (NW).
[c] Significant ($P\leq0.05$) orthogonal polynomials for cow age; Linear (L) and Quadratic (Q).

Cows in Exp. 2 that had also received weaning treatment the previous year (Exp. 1) had similar AI pregnancy rates ($P=0.16$; Table 4). Furthermore, overall pregnancy rate, conception date, and calving interval were not influenced by weaning treatment combination (Exp. 1 and 2) or cow age. There was a tendency ($P=0.09$) for EW cows in Exp. 2 that also received the EW weaning treatment in Exp. 1 to have heavier calf birth weights the subsequent year (Table 4). Cow BW and BCS was greater ($P<0.01$) for cows that received the EW treatment in both Exp. 1 and 2. An interaction between weaning treatments × cow age for BW change ($P=0.04$) during the 133-d period indicated that younger cows respond more favorably to EW whereas older cows were more negatively influenced by having calves that remained suckling until time of normal weaning (Fig. 4).

3.3. Experiment 3

Cows receiving the early weaning treatment had 12.0% greater ($P=0.03$) AI pregnancy rate and conceived 3.8 d earlier ($P=0.03$) than cows receiving the normal weaning treatment (Table 5). Overall breeding season pregnancy rates tended to be greater ($P=0.07$) for early wean treated cows compared to normal wean treated cows. Subsequent year calf birth weights were similar ($P=0.96$) for weaning treatments and increased linearly ($P\leq 0.05$) as cow age increased. Body weight for EW cows was 37 kg heavier ($P<0.01$) than NW cows at the time of normal weaning. Body weight change and ADG throughout the 133-d period resulted in a weaning treatment × cow age interaction ($P<0.01$). All cows gained BW regardless of cow weaning treatment; however, early wean treated cows gained more BW and 2-yr-old NW treated cows gaining substantially less BW than 2-yr-old EW treated cows resulting in the interaction (Fig. 5).

4. Discussion

The authors were surprised that breeding performance was not improved for cows that had their calves removed at time of early weaning (start of breeding) in Exp. 1. This was especially surprising since cow size (weight and height) and milk production have generally increased (Dib et al., 2010; Northcutt and Wilson, 1993) in beef cattle since earlier reports by others (Laster et al., 1973; Lusby et al., 1981). Therefore, removal of the demands of lactation should favor reproduction and may have under more extreme environmental constraints then those experienced in the present study. Early weaning in Exp. 1 was applied at the start of breeding rather than 8 d prior to breeding (Laster et al., 1973) or early weaned 6–8 weeks

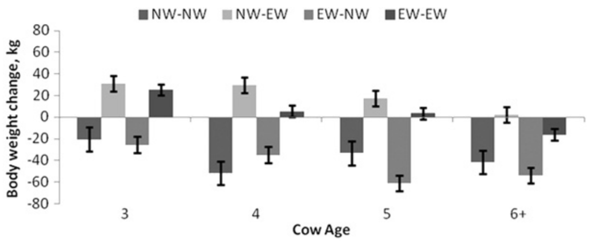

Fig. 4. Least squares means ± SEM for body weight change for cows receiving weaning treatments for 2 consecutive years (Exp. 1 and 2) an interaction of weaning treatments × cow age interaction ($P=0.04$) during the 133-d period between early (EW) and normal weaning (NW).

Table 4
Least squares means ± SEM for reproductive and production performance for cows that received weaning treatments in both Exp. 1 (2005) and 2 (2006).

	Treatment[b]						Cow age						
Item[a]	NW–NW	NW–EW	EW–NW	EW–EW	SEM	*P*-value	3	4	5	6+	SEM	*P*-value	Effect[c]
n=	33	52	44	103			71	46	76	39			
Reproduction													
AI pregnancy (%)	48.5	55.8	70.5	65.1	–	0.16	64.8	63.0	60.5	56.4	–	0.84	–
NW–NW							36.4	83.3	41.7	50.0			
NW–EW							66.7	50.0	50.0	55.6			
EW–NW							75.0	80.0	61.5	66.7			
EW–EW							69.7	56.3	70.3	52.9			
Overall pregnancy (%)	93.9	98.1	93.2	98.1	–	0.36	95.8	97.8	94.7	100.0	–	0.48	–
Conception date (d)	13.9	12.3	7.8	11.8	1.97	0.20	9.3	12.0	11.2	13.2	2.29	0.53	–
Calf birth BW SY (kg)	41.5	42.8	41.1	43.5	1.47	0.09	41.0	41.9	42.9	43.1	1.60	0.21	L
Calving interval (d)	370	369	363	368	4.56	0.41	363	370	365	373	4.50	0.15	–
BW and condition													
Cow BW at EW (kg)	576	550	588	588	9.69	< 0.01	527	570	597	607	9.19	< 0.01	L, Q
Cow BW at NW (kg)	539	570	545	592	9.32	< 0.01	530	557	579	579	8.83	< 0.01	L
ADG (kg/d)	−0.28	0.17	−0.33	0.04	0.03	< 0.01	0.03	−0.09	−0.13	−0.21	0.03	< 0.01	L
Cow BW at calving SY (kg)	580	602	567	619	9.90	< 0.01	559	587	606	616	9.25	< 0.01	L
Cow BCS at EW	4.3	4.2	4.8	4.8	0.15	< 0.01	3.8	4.8	4.7	4.6	0.15	< 0.01	L, Q
Cow BCS at NW	4.2	5.5	4.3	5.6	0.10	< 0.01	4.5	5.1	5.2	4.9	0.12	< 0.01	L, Q
BCS change (NW–EW)	0.1	1.8	−0.3	1.3	0.21	< 0.01	1.0	0.6	0.8	0.5	0.22	0.03	L
Cow BCS at calving SY	4.1	4.9	4.0	5.2	0.17	< 0.01	4.2	4.8	4.7	4.3	0.18	< 0.01	L, Q

[a] Subsequent year (SY); Body weight (BW); Body condition score (BCS).
[b] Treatment=Early weaning (EW); Normal weaning (NW) for Exp. 1 (2005) and Exp. 2 (2006), respectively.
[c] Significant ($P\leq 0.05$) orthogonal polynomials for cow age; Linear (L) and Quadratic (Q).

Table 5
Least squares means ± SEM for reproductive and production performance for cows receiving weaning treatments over 133-d period in 2005 (Exp. 3)

	Treatment[b]				Cow age						
Item[a]	NW	EW	SEM	*P*-value	2	3	4	5+	SEM	*P*-value	Effect[c]
$n=$	121	236			92	62	60	143			
Reproduction											
AI pregnancy (%)	53.3	65.3	–	0.03	62.0	64.5	63.3	58.5	–	0.83	–
NW	–	–	–		53.6	56.5	52.6	52.0	–		–
EW	–	–	–		65.6	69.2	68.3	62.0	–		–
Overall pregnancy (%)	87.5	93.2	–	0.07	91.3	95.2	93.3	88.7	–	0.45	–
Conception date (d)	12.2	8.4	1.41	0.03	10.0	9.8	11.8	9.7	1.99	0.84	–
Calf birth weight SY (kg)	40.4	40.3	0.57	0.96	39.1	40.7	40.2	41.4	1.09	0.04	L
Calving interval (d)	371	369	1.64	0.24	389	366	360	364	2.35	< 0.01	L, Q
Body weight											
Cow BW at EW (kg)	544	535	4.72	0.13	471	532	563	592	4.25	< 0.01	L, Q
Cow BW at NW (kg)	581	618	5.21	< 0.01	558	575	617	647	7.51	< 0.01	L

[a] Subsequent year (SY); Body weight (BW); Body condition score (BCS).
[b] Treatment = Early weaning (EW); Normal weaning (NW).
[c] Significant ($P \le 0.05$) orthogonal polynomials for cow age; Linear (L) and Quadratic (Q).

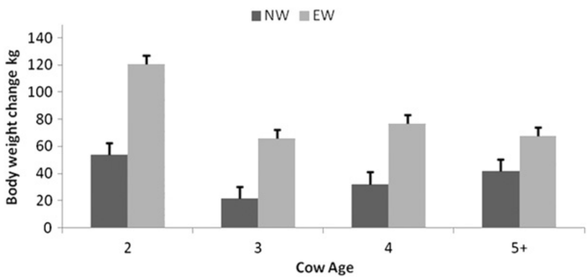

Fig. 5. Least squares means ± SEM for a weaning treatment × cow age interaction for body weight change ($P < 0.01$) during a 133-d period between early (EW) and normal weaning (NW) in 2005 (Exp. 3).

after parturition which was approximately 22 d prior to breeding (Lusby et al., 1981). The excellent body condition of cows in Exp. 1 at onset of breeding coupled with availability of high quality forage early in breeding season may have masked reproductive responses in the present study.

Effects of permanent weaning at the start of an estrous synchronized breeding season (Exp. 2 and 3) that used protocols capable of inducing cyclicity in cows are absent in the literature. While early weaning did not improve AI or breeding season pregnancy rates in Exp. 2, it is noteworthy that among 2-yr and 3-yr-old early wean treated cows there was a 19% and 11% numerical increase in pregnancy rates compared to cows that had their calves removed at normal weaning. Previously reported research supports the potential for increased pregnancy rates of young cows following early weaning (Laster et al., 1973; Myers et al., 1999a). Temporary 48-h calf removal just before breeding has also been reported to increase AI pregnancy rate (Geary et al., 2001; Kiser et al., 1980; Smith et al., 1979). It is possible that the estrous synchronization protocol used in the current study may have masked the benefits of early weaning because of its ability to induce estrous cycles in anestrous cows (Lamb et al., 2001; Lucy et al., 2001; Twagiramungu et al., 1995). In Exp. 3, more early weaned cows conceived to AI ($P > 0.05$) than normal weaned cows. The improved fertility in this herd, even though the same estrous synchronization protocol was used in Exp. 3 as was used in Exp. 2, is unclear, but suggests that the potential for improved breeding performance exists. However, the reproductive performance of cows in Exp. 1 and 2 (especially older cows) demonstrates that a beneficial effect of early weaning on reproduction does not always occur.

In Exp. 1, 2, and 3, breeding occurred coincident with availability of high quality forage. Precipitation was near normal for all three experiments (Fig. 1). Thus, forage quality and quantity (Table 1) were not considered limiting for mature cows in the environments in which this research was conducted. Forage extrusa characteristics were consistent across both years at LARRL. Forage NDF increased and digestibility decreased from time of early weaning to normal weaning. However, forage digestibility was less in Exp. 2 which was reflected in the BW measurements (Table 3). The losses of BW and BCS observed in Exp. 1 and 2 between the times of early and normal weaning for NW treated cows is typical for this herd and suggests not all requirements were met for lactating cows between early July and mid-November. Typically, as summer progresses, temperatures increase while precipitation decreases, followed by decreases in forage quality that continue through fall and winter, negatively impacting livestock production (Adams and Short, 1988). Furthermore, interannual variation in timing and amount of precipitation received accompanied with variable ambient temperatures greatly influence forage production (Grings et al., 2005; Sims and Singh, 1978a,b). In Exp. 3, cows calved earlier in the year and both EW and NW treated cows gained BW during the 133-d time period between early and normal weaning.

Cows subjected to early weaning either maintained or increased in BCS compared to normal wean treated cows throughout the 133-d period in Exp. 1 and 2, respectively. Compared to their cohorts who nursed until the time of normal weaning, these cows had an advantage of 1 BCS at time of normal weaning. We were unable to collect body condition scores of cows in Exp. 3. However, Corah et al. (1991) estimated that a 34 kg difference in weight corresponded to one body condition score. Thus at the time of normal weaning, EW treated cows in Exp. 3 may have also had an approximately 1.1 BCS advantage over NW treated contemporaries. This consistent advantage in BCS for cows subjected to early weaning should allow them to arrive at calving in a more favorable BCS with less supplemental feed during winter than normal weaned contemporaries. Improved weight gains from early weaning reported by Galindo-Gonzalez et al., (2007), Lusby et al. (1981), and Myers et al. (1999b) are similarly interpreted to confer an advantage in body condition.

In Exp. 1 and 2, cows subjected to early weaning treatment had heavier calves at birth the subsequent year than cows that received normal weaning treatment the previous year. This difference was not observed in Exp. 3. Following the rationale above, the nutritional environment (i.e., forage quality) at LARRL may have been inadequate to meet all requirements between early July and mid-November whereas Judith Gap cows were an earlier calving herd. Thus, the imposed early weaning treatment allowed nutrients used to support lactation to be repartitioned towards maternal tissues, such as reproduction, in the nursing cows at LARRL, and consequently benefit endocrine mechanisms that influence uptake and utilization of nutrients by the conceptus (Robinson et al., 1999). Furthermore, prior to calving, cows that received the early weaning treatment in Exp. 1 and 2 were in greater BW and BCS indicating a greater capacity to endure parturition, rebound through uterine involution, and regain reproductive competency (Rae et al., 1993).

5. Conclusion

When initiating this research, potential for an interaction between the weaning treatment effects and cow age of the cows was anticipated with early weaning being potentially more advantageous for younger cows. This interaction was not consistently detected. Thus, at least under these conditions, effects of early weaning were independent of cow age.

Early weaning calves can increase the opportunity for cows to gain weight and improve body condition before winter. This may facilitate over-wintering cows using less harvested feedstuffs. Under some circumstances, early weaning may also increase the likelihood of the cow becoming pregnant early in the breeding season.

Conflict of interest statement

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