Beef heifer development within three calving systems[1,2]

E. E. Grings,[3] T. W. Geary, R. E. Short, and M. D. MacNeil

Fort Keogh Livestock and Range Research Laboratory, USDA-ARS, Miles City, MT 59301

ABSTRACT: A 3-yr study was conducted to evaluate the effects of calving system, weaning age, and post-weaning management on growth and reproduction in beef heifers. Heifer calves (n = 676) born in late winter (average birth date = February 7 ± 9 d) or early spring (average birth date April 3 ± 10 d) were weaned at 190 or 240 d of age, and heifers born in late spring (average birth date May 29 ± 10 d) were weaned at 140 or 190 d of age. Heifers were managed to be first exposed to breeding at approximately 14 mo of age. After weaning, the calves were randomly assigned to treatments. Heifers on the constant gain treatment were fed a corn silage- and hay-based diet. Heifers on delayed gain treatments were placed on pasture but were fed grass hay or a supplement, or both, depending on the forage conditions. Three months before their respective breeding seasons, delayed gain heifers were moved to drylot and fed a corn silage- and barley-based diet (late winter or early spring) or moved to spring rangeland (late spring). The data were analyzed using mixed model procedures with calving system, weaning age, and post-weaning management options creating 12 treatments. Average daily gain was 0.36 ± 0.05 (SED) kg/d less ($P <$ 0.001) for delayed gain heifers during the initial phase, whereas these heifers gained 0.44 ± 0.03 kg/d more (P < 0.001) than constant gain heifers during the last 90 d before breeding. Body weights at the beginning of the breeding season did not differ (P = 0.97) between constant gain and delayed gain heifers but were affected by calving system and weaning age, reflecting some of the differences in initial BW. Prebreeding BW for heifers weaned at 190 d of age were 36 ± 6.4 kg heavier (P < 0.001) for those born in late winter and early spring compared with late spring and were 388, 372, and 330 kg for heifers weaned in October at 240, 190, or 140 d of age (linear effect, P < 0.001). The proportion of heifers exhibiting luteal activity at the beginning of the breeding season was not affected (P = 0.57) by treatment. Approximately half of the heifers were randomly selected for breeding. Treatment had no effect (P = 0.64) on pregnancy rates. In conclusion, heifers from varied calving systems and weaning strategies can be raised to breeding using either constant or delayed gain strategies without affecting the percentage of heifers cycling at the beginning of the breeding season. These results suggest that producers have multiple options for management of heifer calves within differing calving systems.

Key words: beef heifer, calving date, weaning

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INTRODUCTION

Development of heifers is a critical component of a beef production enterprise. Altering the dates of calving and weaning to match the nutritional requirements of the cow with the dynamics of forage quality affects the BW of the calf at weaning (Grings et al., 2005). These effects on weaning weight may affect subsequent management needs of the heifer calves in anticipation of their entry into the breeding herd. Altering the harvested feed inputs into the replacement heifer program can affect the cost of raising a heifer from weaning to breeding. Clanton et al. (1983) suggested that allowing heifers to make rapid rates of gain during the last 3 mo before breeding could decrease the feed costs through maintenance of a lighter-weight heifer in the early post-weaning period.

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[3]Corresponding author: elaine.grings@ars.usda.gov
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We previously observed no effect on number of heifers pubertal by a given date when early spring-born heifers were managed on fall pasture, followed by a period in the drylot, compared with heifers receiving corn silage-based diets throughout the same period (Grings et al., 1998). Other researchers have used alternating growth patterns for heifers between weaning and breeding as a means to not only affect the costs for harvested feed (Lynch et al., 1997; Freetly et al., 2001) but also as an attempt to manipulate future lactation potential (Park et al., 1989; Poland and Ringwall, 2001). Marston et al. (1995) reported that spring-born heifers wintered on low-quality forage with supplemental protein, followed by a 60-d period in which a high-energy diet was fed, reached puberty almost a month earlier than heifers that did not receive extra energy for 60 d before breeding. Season of birth, age at weaning, diet quality, and environmental conditions can all influence growth rates of heifers between weaning and first breeding.

The objective of this experiment was to evaluate the effect of differing nutrient intake patterns from birth until first breeding on BW gain and evidence of luteal activity before the first breeding for heifers born in 3 calving systems.

MATERIALS AND METHODS

Exp. 1

Care of heifers complied with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999). The study was approved by the Fort Keogh Livestock and Range Research Laboratory Animal Care and Use Committee.

This 3-yr study was conducted at the Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana (46° 22′ N 105° 5′ W). Crossbred beef heifers were from herds that had been managed separately to calve in late winter (average birth date = February 7 ± 9 d), early spring (average birth date April 3 ± 10 d), or late spring (average birth date May 29 ± 10 d) based on a 32-d, synchronized breeding season. Heifers were sired by bulls that were at least 25% composite breeding (50% Red Angus, 25% Charolais, 25% Tarentaise) crossed primarily with Hereford; however, the actual breed combinations varied by year. Dams were primarily crossbreds of British- and Continental-type breeding, including Hereford, Angus, Red Angus, Limousin, Tarentaise, Charolais, and Simmental. Heifers were weaned at 140 (late spring), 190 (late winter, early spring, late spring), or 240 (late winter, early spring) d of age. A complete description of the preweaning management and growth of these heifers is included in Grings et al. (2005).

At weaning, heifers were placed in drylots and adapted to bunk feeding with long-stem hay, followed by a transition to a corn silage diet. Approximately 2 wk after weaning, heifers were randomly assigned, within each calving system and weaning age combination, to 1 of 2 postweaning treatments. One treatment was intended to allow the heifers to grow at a constant rate from weaning to breeding (constant gain). The second treatment was intended to utilize lower-quality feeds for a period (phase 1) followed by a period (phase 2) of rapid growth (delayed gain). The combination of 3 calving times, 2 ages at weaning, and 2 postweaning feeding regimens resulted in 12 treatments (Table 1).

Constant gain heifers were fed a corn silage- and alfalfa hay-based diet throughout the experiment (Table 2), with the exception that late spring-constant gain heifers were moved to native rangeland for the final 88 d before breeding. During phase 1, delayed gain heifers grazed a mixed-grass seeded pasture. Heifers were provided large, round bales of grass hay placed in bale feeders or protein supplement (1.9-cm pellet) fed on the ground from a calibrated range cake feeder (Table 3), or both, as required by forage availability and environmental conditions, including snow cover. During phase 2, late winter-delayed gain and early spring-delayed gain heifers were fed a corn silage- and barley-based diet (Table 2), whereas late spring-delayed gain heifers grazed late spring and summer native rangeland. Native vegetation was grama-needlegrass-wheatgrass (*Bouteloua-Hesperostipa-Pascopyron*) rangeland (Kuchler, 1964). Approximate calendar dates of the diet change were January 9, March 6, and May 12 for the late winter, early spring, and late spring heifers, respectively.

While in the drylots, heifers within a calving system were confined in a single pen. A single pasture was used for delayed gain heifers from all calving systems during phase 1, with groups of heifers entering and leaving the pasture as appropriate for their specific calving system and weaning age.

Samples of the corn silage- and hay-based diets fed to the constant gain heifers and the corn silage-, hay-, and barley-based diet fed to the late winter-delayed gain and early spring-delayed gain heifers in phase 2 were collected weekly, dried at 60°C, and ground in a Wiley mill (Arthur A. Thomas Co., Philadelphia, PA) to pass through a 1-mm mesh screen. At the end of the feeding period each year, a composite sample was made and sent to a commercial laboratory (Iowa Testing Laboratory Inc., Eagle Grove, IA) for analysis of DM, CP, and ADF. Periodic samples of the grass hay and protein supplement were made throughout the feeding period and sent to the same commercial laboratory for analysis.

To obtain an estimate of diet quality for heifers on the delayed gain treatment during fall grazing, diet samples were collected twice during the fall of yr 2 and 3. Three to 4 cows that were cannulated at the esophagus were used to collect the diet samples on 2 d. Cows were placed in pens overnight without food and were then allowed to graze in the morning for 30 to 45 min. Cows were maintained on native rangeland between sampling periods and did not receive preconditioning to seeded pastures; however, the vegetation

Table 1. Management protocol for heifers born in late winter, early spring, or late spring calving systems, weaned at 2 ages, and raised from weaning to breeding on constant gain (CG) or delayed gain (DG) management strategies in Exp. 1

	Late winter				Early spring				Late spring			
	190 d of age		240 d of age		190 d of age		240 d of age		140 d of age		190 d of age	
Item	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG
Treatment delineation	1	2	3	4	5	6	7	8	9	10	11	12
No. of days, phase 1[1]	128	128	74	74	130	130	81	81	186	186	139	139
Feed source[2]	CSH	PA	CSH	PA	CSH	PA + Hay	CSH	Hay	CSH	Hay	CSH	Hay
No. of days, phase 2[3]	91	91	91	91	91	91	91	91	88	88	88	88
Feed source[4]	CSH	CSB	CSH	CSB	CSH	CSB	CSH	CSB	PA	PA	PA	PA
No. of days total	219	219	165	165	220	220	171	171	275	275	226	226

[1]Phase 1 = period of slower gains for the DG management strategy.
[2]CSH = corn silage- and hay-based diet; PA = primary forage source was pasture.
[3]Phase 2 = period of more rapid gains for the DG management strategy.
[4]CSB = corn silage- and barley-based diet.

within the seeded pastures was limited to a single vegetation type, and the diet selection was limited primarily to plant parts and not species. Samples were returned to the laboratory and frozen, followed by lyophilization and grinding in a Wiley mill to pass through a 1-mm mesh screen before chemical analysis. Samples were analyzed for DM and ash (methods 930.15 and 942.05, respectively; AOAC, 1990) and in vitro OM digestibility by the procedure of Tilley and Terry (1963). After being placed in a roller grinder for 12 h (Mortenson, 2003), the samples were analyzed for N by combustion techniques in a C-N analyzer (Flash EA1112, CE Elantech Inc., Lakewood, NJ). Nitrogen was multiplied by 6.25 to obtain CP, which was then expressed on an OM basis.

Heifers were weighed approximately 24 h after feed delivery at the beginning of the experiment, at the time of diet change, and 6 d before beginning the breeding season. Body condition scores (1 = emaciated to 9 = obese; Herd and Sprott, 1986) were determined by 2 trained technicians at the time of final weighing (BCS at breeding).

Blood samples were collected by coccygeal venipuncture 6 and 13 d before beginning the breeding season. Serum was collected by centrifugation (3,000 × g for 30 min), frozen, and subsequently analyzed for progesterone by RIA using a commercial kit (Diagnostic Products

Table 2. Ingredient and chemical composition of the corn silage- and hay-based diet used in phases 1 and 2 of the constant gain (CG) treatment and the corn silage- and barley-based diet used in phase 2 of the delayed gain (DG) management treatment in Exp. 1[1]

Item	CG (phase 1 and 2)	DG (phase 2)
Ingredient composition, % of DM		
Corn silage	33.4	60.8
Alfalfa hay	64.9	—
Barley	1.0	35.7
Soybean meal	0.5	2.45
Urea	0.1	0.5
Calcium carbonate	0.05	0.3
Salt	0.03	0.1
Trace mineral mix[2]	0.01	0.07
Vitamin A, D, and E mix[3]	0.01	0.07
Chemical composition		
DM, %	49.4	40.8
CP, % of DM	14.4	11.2
ADF, % of DM	33.1	24.0

[1]The corn silage- and hay-based diet was also used to develop heifers from weaning to breeding in Exp. 2.
[2]Trace mineral mix (United Agri Products, Billings, MT) included a minimum of 13.5% Mg, 2.7% S, 30,000 mg/kg of Cu, 880 mg/kg of Se, 120,000 mg/kg of Zn, 120,000 mg/kg of Mn, 81,000 mg/kg of Fe, 1,500 mg/kg of Co, and 6,580 mg/kg of I.
[3]Vitamin A, D, and E mix contained 4,400,000 IU/kg of vitamin A, 440,000 IU/kg of vitamin D, and 220 IU/kg of vitamin E.

Table 3. Chemical composition of grass hay used in phase 1 of the delayed gain (DG) management treatment in yr 1 through 3, the overall chemical composition of the supplement used in yr 2 and 3 and the chemical composition of esophageal extrusa samples collected in grazed pastures in yr 2 and 3[1]

	CP			
Feedstuff	(% of DM)	(% of OM)	ADF (% of DM)	IVOMD[2]
Grass hay				
yr 1	8.8	—	37.3	—
yr 2	11.0	—	36.3	—
yr 3	12.6	—	35.6	—
Supplement	26.4	—	12.0	—
Extrusa				
yr 2				
Oct. 31	—	13.2	—	64.3
Nov. 22	—	7.7	—	53.8
yr 3				
Nov. 6	—	9.8	—	63.2
Dec. 6	—	8.9	—	60.3

[1]In yr 1, no supplement was fed, and no extrusa samples were collected.
[2]IVOMD = in vitro OM digestibility.

Corp., Los Angeles, CA) as described by Bellows et al. (1991). Within- and between-assay CV were 5.3 and 6.7%, respectively. Sensitivity of the assay was 0.04 ng/mL. A heifer was assumed to be exhibiting luteal activity if at least 1 serum sample had a progesterone concentration of greater than 1 ng/mL.

Statistical analysis of BW, BCS, and ADG was conducted using SAS (SAS Inst. Inc., Cary, NC) with mixed model methodology. Treatment was considered a fixed effect, and year and year by treatment were considered as random effects. The denominator degrees of freedom was 22. When the overall treatment effect was significant, 11 nonorthogonal linear contrast statements were used to evaluate treatment effects (Table 5). Heifer pregnancy and calf survival data were analyzed using the CATMOD procedures of SAS, evaluating for treatment and year effects and their interactions. In yr 3, thirty-five randomly selected heifers from the late spring herd were sold at the time of diet change, so their data were dropped from the experiment, causing the late spring treatments to have fewer heifers compared with other calving systems.

Subsequent Heifer Performance. Approximately 50% of the heifers in Exp. 1 were selected for breeding and maintained in their herds until fall pregnancy diagnosis. The other heifers were sold because of the need to match animal numbers with forage supply. Selection of heifers for breeding was conducted randomly within treatment to maintain equal numbers per treatment for breeding. Heifers were placed with the mature cow herd for breeding. Heifers were mated by natural service in a 32-d breeding season that included an injection of $PGF_{2\alpha}$ (25 mg, i.m.; Pharmacia Animal Health, Kalamazoo, MI) 7 d after the bulls were joined with the cow herd. Eighteen to 25 bulls were used for breeding, and cow-to-bull ratios averaged 12:1 throughout the experiment. The same bulls were used in each of the 3 calving herds within a year. Breeding was from approximately April 6 to May 9, June 6 to July 9, and August 6 to September 9 (exact dates varied by year) for the late winter, early spring, and late spring calving systems, respectively. Pregnancy was evaluated by transrectal ultrasonography in the fall.

In subsequent years, these replacement females were culled if not pregnant in the fall or if they lost a calf before weaning. Cows remaining in their calving system herds were used to evaluate subsequent cow performance. Cow BW and BCS at approximately 69 d of age and at weaning, as well as fall pregnancy status, were measured on cows that remained in the herds as 2- and 3-yr-olds through 2003. Calf birth weight, BW at approximately 69 d of age, and BW at weaning were measured on calves.

Statistical analysis was conducted with SAS using mixed model methodology. Data from each cow age group were analyzed separately. Treatment was considered a fixed effect and year and year by treatment as random effects. Calf sex was included as a class variable in the calf weaning weight data, which were adjusted to 190 d of age. Eleven nonorthogonal linear contrast statements (Table 4) were used to evaluate treatment effects with 22 df. Categorical data were tested separately for 2- and 3-yr-old cows using CATMOD procedures and a model that considered treatment, year, and their interaction.

Exp. 2

Because late spring heifers in Exp. 1 were managed differently than late winter or early spring heifers during the final 90 d before breeding, the question remained as to the potential performance of late spring-constant gain heifers remaining in the drylot until breeding compared with late winter and early spring heifers. Therefore, heifers from all 3 calving systems (n = 156) born in the 2 yr following Exp. 1 (2002 and 2003) were fed the constant gain diet in drylot pens from weaning until breeding.

Calving system management was similar to that in Exp. 1 except that all heifers were weaned at approximately 190 d of age. Approximately 3 wk after weaning, heifers were placed on the corn silage-alfalfa hay diet as used in Exp. 1 (Table 1). Heifers were developed in 1 pen per calving season per year. Heifer BW was obtained about 3 wk after weaning and 1 wk before beginning the breeding season.

After collection of the prebreeding BW data, heifers were moved to native rangeland pastures that also contained cows from the respective calving system. Bulls were turned in with cows and heifers for 7 d, at which time $PGF_{2\alpha}$ (25 mg, i.m.) was given to cows and heifers. Bulls remained with the cow herd for completion of the 32-d breeding season. Cow herds were smaller than those in Exp. 1, and cow-to-bull ratios were 22:1. Pregnancy rates were determined by transrectal ultrasonography in October of each year.

Data were analyzed using mixed model methodology in SAS to evaluate the effect of calving system on heifer performance. Calving system was included as a fixed effect, with year and the year by calving system interaction as random effects. Individual heifer was the experimental unit. Calving system effects were evaluated using the same contrasts specific to calving system in Experiment 1, using 2 denominator df.

RESULTS AND DISCUSSION

Exp. 1

Length of feeding and amount of harvested feedstuffs offered to delayed gain heifers (Table 5) are indicative of the study conditions within each year. The winter of yr 2 (2000 to 2001) was harsher than that of yr 1 (1999 to 2000) in terms of both temperature and snow cover, and yr 3 (2001 to 2002) was somewhat intermediate (Figure 1). The average temperature for the November through February period was 0.2°, –11.7°, and –1.7°C for yr 1, 2, and 3, respectively (NOAA, 1999-2002). Al-

Table 4. Coefficients for contrasts representing various treatment effects for heifers born in late winter (LW), early spring (ES), or late spring (LS) calving systems, weaned at 2 ages, and raised from weaning to breeding on constant gain (CG) or delayed gain (DG) management strategies[1]

	Treatment											
Item	1	2	3	4	5	6	7	8	9	10	11	12
Effect of calving system												
LW vs. ES calving system for heifers weaned at 190 d of age	–0.5	–0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
LS vs. avg of LW and ES calving season for heifers weaned at 190 d of age	–0.25	–0.25	0.0	0.0	–0.25	–0.25	0.0	0.0	0.0	0.0	0.5	0.5
Effect of weaning age												
Linear effect of age at weaning in Oct.	0.0	0.0	–0.5	–0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0
240 vs. 190 d of age at weaning, LW and ES only	–0.25	–0.25	0.25	0.25	–0.25	–0.25	0.25	0.25	0.0	0.0	0.0	0.0
140 vs. 190 d of age at weaning, LS only	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–0.5	–0.5	0.5	0.5
Effect of postweaning management												
CG vs. DG postweaning management system	–0.1667	0.1667	–0.1667	0.1667	–0.1667	0.1667	–0.1667	0.1667	–0.1667	0.1667	–0.1667	0.1667
Interactions of calving system and weaning age												
Calving system × weaning age interaction for heifers from LW or ES calving systems	–0.25	–0.25	0.25	0.25	0.25	0.25	–0.25	–0.25	0.0	0.0	0.0	0.0
Interaction of calving system and postweaning management												
Calving system × postweaning management interaction for heifers from LW or ES calving systems weaned at 190 d of age	0.5	–0.5	0.0	0.0	–0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Calving system × postweaning management interaction for heifers from LS calving system vs. avg of LW and ES calving systems weaned at 190 d of age	0.25	–0.25	0.0	0.0	0.25	–0.25	0.0	0.0	0.0	0.0	–0.5	0.5
Interaction of weaning age and postweaning management												
Linear effect of weaning age × postweaning management interaction for heifers weaned in Oct.	0.0	0.0	0.5	–0.5	0.0	0.0	0.0	0.0	–0.5	0.5	0.0	0.0
Weaning age × postweaning management interaction for heifers born in the LS calving system	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	–0.5	–0.5	0.5

[1]df = 22.

Table 5. Length of feeding periods of grass hay and supplement and amount (kg of DM) of harvested feed provided per heifer in the delayed gain management treatment for each of 3 yr in Exp. 1

Feed type	Late winter	Early spring	Late spring
Hay	Total days of feeding period		
yr 1	19	76	118
yr 2	40	95	148
yr 3	25	80	133
Supplement			
yr 1	—	—	—
yr 2	11	66	119
yr 3	38	93	146
	Total kg of DM/heifer offered during the feeding period		
Hay			
yr 1	50	298	514
yr 2	230	433[1]	644[1]
yr 3	43	156	373
Supplement			
yr 1	—	—	—
yr 2	13	84	149
yr 3	27	73[2]	117[2]

[1]In yr 2, the hay inputs were less for heifers weaned in December than those weaned in October; therefore, early spring, 240 d of age at weaning = 264 kg and late spring, 190 d of age at weaning = 475 kg.

[2]In yr 3, the supplement inputs were less for heifers weaned in December than those weaned in October; therefore, early spring, 240 d of age at weaning = 65 kg and late spring, 190 d of age at weaning = 110 kg.

though delayed gain heifers in yr 1 were fed only grass hay during periods of limited pasture quantity, the environmental conditions of yr 2 required that heifers also be fed additional nutrients, which were supplied in the form of an oilseed and grain-based protein supplement (Table 3). This was continued in yr 3, using amounts appropriate for the environmental conditions, such as temperature and snow cover.

For heifers weaned at 190 d of age, those born in late spring were 27.1 ± 4.2 (SED) kg lighter ($P < 0.001$) at the beginning of the experiment than the average of those born in late winter or early spring (Tables 6 and 7). There was a linear effect ($P < 0.001$) of age at weaning in October on initial BW, and heifers weaned at 140, 190, or 240 d of age weighed 175 ± 9.3, 227 ± 7.4, and 261 ± 6.8 kg, respectively. Age of weaning effects ($P < 0.001$) were observed for initial BW within a calving season, with an age of weaning × calving system interaction ($P = 0.005$) for the late winter and early spring heifers. Although heifers from these 2 calving systems did not differ ($P = 0.89$) in BW when weaned at 190 d of age, early spring heifers were 20.2 ± 4.5 kg lighter ($P < 0.001$) than late winter heifers when weaned at 240 d of age. This could be related to differences in available forage quality from 190 to 240 d of age for these 2 systems (Grings et al., 2005). This period is from August to October for the late winter heifers compared with October to December for the early spring heifers.

During phase 1, delayed gain heifers gained 0.36 ± 0.05 kg/d less ($P < 0.001$) than constant gain heifers (Tables 6 and 7). Late spring heifers weaned at 190 d of age tended to gain 0.13 ± 0.07 kg/d faster ($P = 0.09$) than the average of late winter and early spring heifers weaned at the same age. The late spring heifers then gained more slowly during phase 2 ($P < 0.001$). The tendency toward increased gain in phase 1 for late spring heifers may be related to their decreased rate of growth before weaning while on poorer-quality range forage compared with that available to late winter and early spring heifers of the same age (Grings et al., 2005). An interaction ($P = 0.05$) between age at October weaning and postweaning management occurred. Constant gain heifers gained faster ($P = 0.04$) with increasing age at weaning, whereas delayed gain heifers exhibited slower ($P < 0.001$) rates of gain for phase 1 as age at October weaning increased. This could be related to the number of days on phase 1, which increased from 74 d for late winter heifers weaned at 240 d of age to 186 d for late spring heifers weaned at 140 d of age (Table 1). In addition, as age at weaning in October decreased, a greater proportion of the forage source was hay compared with pasture because of the seasonality of the feeding period (Tables 1 and 5). Although younger, lighter heifers may require feeds of equal or greater nutrient density for similar gains as older, heavier heifers, they require less total feed (NRC, 1996), which could give them an advantage in situations of limited availability of high-quality forages. Forage availability was not measured during the grazing portion of this study.

Weight at the end of phase 1, about 90 d before the beginning of the breeding season, differed ($P = 0.001$) for delayed gain compared with constant gain heifers (Tables 6 and 7), with heifers on delayed gain treatments averaging 40 ± 5.5 kg less than those on constant gain diets. Weight of delayed gain heifers across calving systems and weaning ages was remarkably similar at this time considering the varied number of strategies used to arrive at this point. This BW was measured at comparable ages for all treatment groups.

During phase 2, delayed gain heifers gained 0.44 ± 0.03 kg/d faster ($P < 0.001$) than constant gain heifers, allowing them to have similar ($P = 0.97$) ADG from weaning to breeding (Tables 6 and 7). A linear effect ($P < 0.001$) of age at weaning in October was observed for phase 2, with a decrease in ADG with increasing age at weaning. This is opposite the trend ($P = 0.11$) toward increased ADG with increasing age at weaning in phase 1. The length of phase 2 was similar across all treatments, whereas length of phase 1 differed with age at weaning.

Lynch et al. (1997) found spring-born heifers on a constant gain program had increased BW gain in the last 2 mo of the program, causing them to gain more rapidly overall than heifers on a delayed gain program. They suggested that photoperiod or temperature could play a role in increased gains. However, our data show

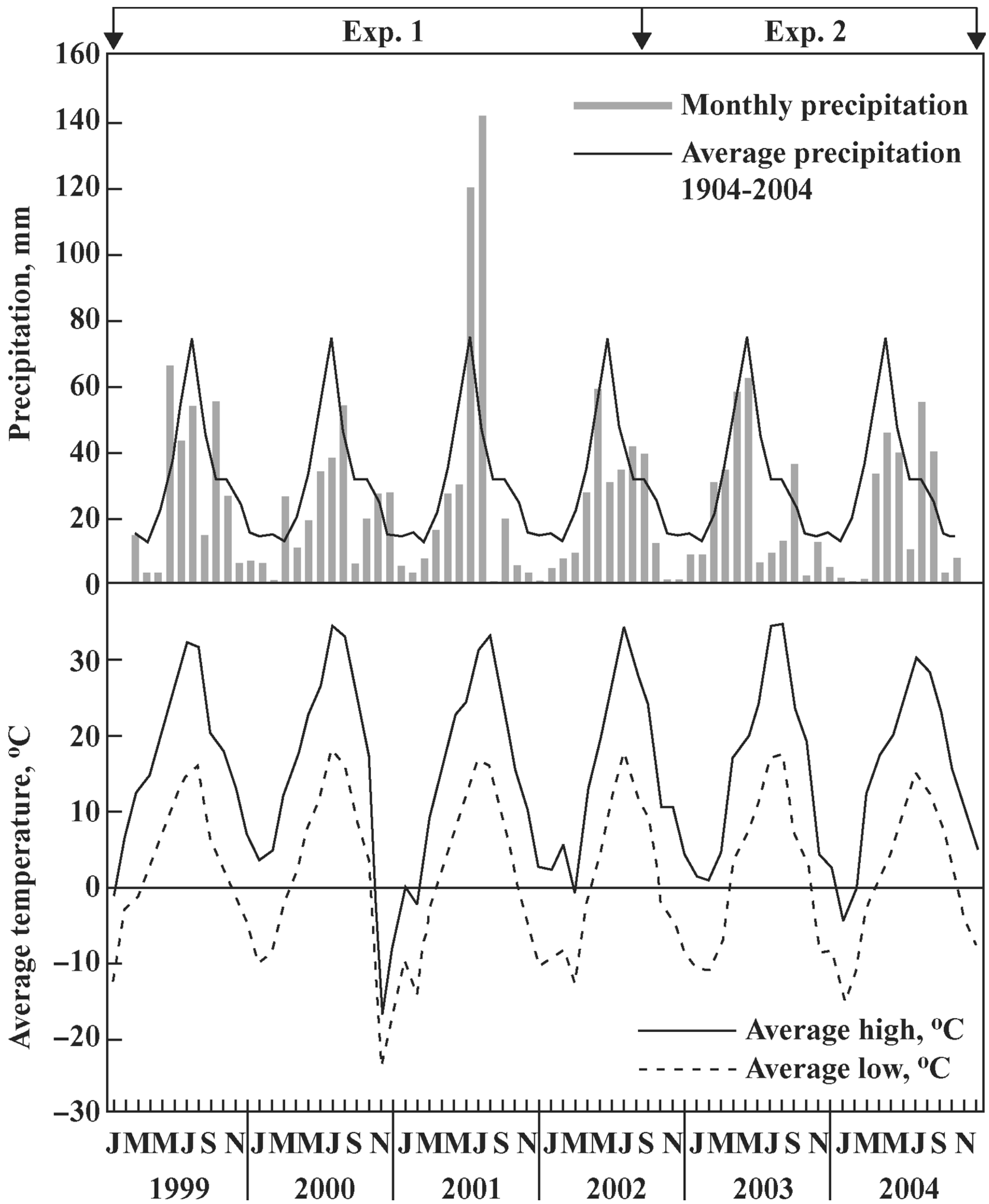

Figure 1. Actual (bars) and long-term average (solid line; upper panel) monthly precipitation and average high (solid line) and low (dashed line) monthly temperatures (lower panel) from 1999 through 2004 as recorded at Miles City, Montana (NOAA, 1999-2004). Experimental periods are noted above the upper panel.

no difference ($P = 0.13$) in the rate of gain during phase 2 between late winter and early spring heifers weaned at 190 d of age, suggesting no effects of photoperiod or temperature on gain associated with differing seasons. Phase 2 for late winter heifers occurred from about January 6 to April 6 and from about March 6 to June 6 for early spring heifers.

Late spring heifers weaned at 190 d of age on the constant gain treatment did not gain as rapidly ($P < 0.001$) while grazing rangeland during the last 88 d before breeding as late winter and early spring heifers weaned at 190 d of age that were continued on the constant gain diet until breeding (Tables 6 and 7). Previous research at this location (Heitschmidt et al., 1993; Grings et al., 2002) indicated that young cattle grazing late spring and early summer rangeland could potentially gain at rates similar to those observed for the late winter and early spring heifers during phase 2. Gains on early summer rangeland were less than expected and may have been related in part to heifer age. We have previously observed decreased gains on summer rangeland associated with decreased age in steers (Grings et al., 1996). Winter rate of gain also influences gain on summer pasture (Lewis et al., 1990),

Table 6. Probability values for contrasts representing various treatment effects for heifers born in late winter (LW), early spring (ES), or late spring (LS) calving systems, weaned at 2 ages, and raised from weaning to breeding on constant gain (CG) or delayed gain (DG) management strategies[1]

	Wt., kg			ADG, kg/d			BCS
Item	Initial	At end of phase 1[2]	Before breeding	Phase 1	Phase 2[3]	Overall	before breeding
Effect of calving system							
LW vs. ES calving system for heifers weaned at 190 d of age	0.89	0.80	0.13	0.76	0.13	0.14	0.13
LS vs. avg of LW and ES calving season for heifers weaned at 190 d of age	<0.001	0.54	<0.001	0.09	<0.001	0.09	<0.01
Effect of weaning age							
Linear effect of age at weaning in Oct.	<0.001	0.13	<0.001	0.11	<0.001	<0.001	<0.001
240 vs. 190 d of age at weaning, LW and ES only	<0.001	0.69	0.90	0.89	0.56	0.02	0.84
140 vs. 190 d of age at weaning, LS only	<0.001	0.35	0.12	0.40	0.68	0.14	0.69
Effect of postweaning management							
CG vs. DG postweaning management system	0.75	<0.01	0.97	<0.01	<0.001	0.97	0.04
Interactions of calving system and weaning age							
Calving system × weaning age interaction for heifers from LW or ES calving systems	0.005	0.75	0.37	0.16	0.47	0.55	0.48
Interaction of calving system and postweaning management							
Calving system × postweaning management interaction for heifers from LW or ES calving systems weaned at 190 d of age	0.80	0.49	0.66	0.63	0.43	0.83	0.29
Calving system × postweaning management interaction for heifers from LS calving system vs. avg of LW and ES calving systems weaned at 190 d of age	0.39	0.48	0.56	0.62	0.63	0.94	0.74
Interaction of weaning age and postweaning management							
Linear effect of weaning age × postweaning management interaction for heifers weaned in Oct.	0.90	0.99	0.67	0.05	0.43	0.58	0.31
Weaning age × postweaning management interaction for heifers born in the LS calving system	0.54	0.68	0.83	0.74	0.52	0.82	0.75

[1]The postweaning management strategies are described in Table 2. df = 22.
[2]Phase 1 = period of slower gains for the DG management strategy.
[3]Phase 2 = period of more rapid gains for the DG management strategy.

and this effect is noticeable in the reduced ($P < 0.001$) gain during phase 2 for the late spring-constant gain vs. late spring-delayed gain heifers (Table 7).

Overall rate of gain from weaning to breeding did not differ ($P = 0.97$) for heifers on delayed gain and constant gain treatments (Tables 6 and 7). Overall ADG aver-

Table 7. Performance characteristics of heifers born in late winter, early spring, or late spring calving systems, weaned at 2 ages, and raised from weaning to breeding on constant gain (CG) or delayed gain (DG) management strategies[1]

	Late winter				Early spring				Late spring				
	190 d of age		240 d of age		190 d of age		240 d of age		140 d of age		190 d of age		Avg
Item	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG	SE
No. of heifers	64	68	58	54	65	62	63	62	48	46	43	43	
BW, kg													
Initial	228	229	262	262	228	227	242	241	174	175	197	204	7.0
At end of phase 1[2]	313	274	314	272	317	265	301	271	299	256	304	270	13.0
Prebreeding	384	383	391	385	376	369	362	373	330	330	341	344	7.2
ADG, kg/d													
Phase 1	0.66	0.35	0.70	0.13	0.68	0.28	0.74	0.38	0.66	0.44	0.76	0.48	0.1
Phase 2[3]	0.78	1.19	0.84	1.24	0.65	1.15	0.68	1.12	0.37	0.85	0.43	0.84	0.07
Overall	0.71	0.71	0.78	0.75	0.67	0.64	0.70	0.77	0.57	0.57	0.63	0.62	0.04
BCS at breeding	6.0	6.4	6.1	6.4	5.9	6.0	5.8	5.9	5.4	5.4	5.4	5.6	0.29
Cycling, %	94	97	95	92	98	94	94	92	93	94	98	87	0.04

[1]The postweaning management strategies are described in Table 1. Refer to Table 6 for probability for contrasts shown in Table 5.
[2]Phase 1 = period of slower gains for the DG management strategy.
[3]Phase 2 = period of more rapid gains for the DG management strategy.

aged 0.68 ± 0.02 kg/d, which should be adequate for the majority of heifers to reach puberty before onset of the first breeding season (Short and Bellows, 1971). Achieving similar overall ADG did require slight differences in winter management each year for the delayed gain heifers (Table 5). Weaning age did affect overall gain, with both a linear effect ($P < 0.01$) of age at weaning in October (0.76, 0.66, and 0.57 kg/d for 240, 190, and 140 d of age, respectively) and an effect ($P = 0.02$) of weaning at 240 vs. 190 d of age for the late winter and early spring heifers, with heifers weaned at 240 d of age gaining 0.07 ± 0.02 kg/d more than heifers weaned at 190 d of age. Late spring heifers weaned at 190 d of age tended ($P = 0.09$) to gain less than the average of the late winter and early spring heifers weaned at the same age.

Weight at the beginning of the breeding season did not differ ($P = 0.97$) with postweaning management and averaged 366 ± 2.2 kg (Tables 6 and 7). Prebreeding BW was affected by calving system and weaning age, reflecting some of the differences in initial BW. Although prebreeding BW did not differ ($P = 0.13$) between late winter and early spring heifers weaned at 190 d of age, the average of these 2 groups was 36 ± 6.4 kg heavier ($P < 0.001$) than that of late spring heifers weaned at a similar age. A linear effect of age at weaning in October remained evident ($P < 0.001$) at the beginning of the breeding season, with heifers weaned at 240, 190, or 140 d of age weighing 388, 372, and 330 kg, respectively. This occurs, in part, because of decreased gains ($P < 0.001$) of late spring heifers while grazing rangeland during the last 88 d before breeding. Evidence for this is seen by the fact that these differences did not exist at the time of the diet change (Table 6 and 7).

Effects of calving system and weaning age on BCS at beginning of the breeding season were similar to those for BW (Tables 6 and 7), with the addition of an effect ($P = 0.04$) of postweaning treatment. Heifers on the delayed gain treatment averaged 0.19 ± 0.09 condition score greater than those on the constant gain treatment and may reflect a change in body composition gain associated with the more rapid gains observed in phase 2.

Proportion of heifers cycling at the beginning of the breeding season averaged 0.79 ± 0.02 and did not differ among treatments ($P = 0.57$; Tables 6 and 7). Lynch et al. (1997) reported that when heifers were developed on a program in which increased gains were delayed until 50 d before breeding, fewer heifers were cycling at the beginning of the breeding season compared with those on a constant gain program, yet there was no effect on overall pregnancy rate. Average overall gains in their study were 0.52 kg/d, which is slightly less than most of the overall gains in our study.

Other delayed gain programs have involved the use of high-starch supplements for a period before breeding. Marston et al. (1995) reported that heifers raised on dormant forage plus protein supplement followed by concentrate feeding for about 60 d reached puberty at younger ages than heifers on dormant forage plus supplement alone. Ciccioli et al. (2005) suggested that providing a starch supplement to lightweight heifers for 60 d before breeding could improve pregnancy rates.

Other researchers have reported no impairment of reproductive performance by development programs that use altering rates of gain, as long as heifers reach about 65% of their expected mature BW by breeding (Patterson et al., 1992). Mature cows in the calving system herds averaged about 570 kg at breeding (Grings et al., 2005); therefore, these heifers average about 64% of mature BW, although late spring heifers weaned at 140 d of age weighed only about 58% of mature BW at breeding. These percentages of mature BW are within general guidelines for heifers at first breeding (Patterson et al., 1992). Although late spring heifers might be considered slightly below recommendations, the similar luteal activity of these heifers compared with heifers from other calving systems agrees with the results of Funston and Deutscher (2004), who suggested that developing heifers to 55% of mature BW at first breeding might be acceptable. However, as patterns of nutrient availability in different breeding seasons differ for cows managed to calve in differing seasons, these recommendations may not be valid across all calving seasons.

Subsequent Cow Performance. Approximately 50% of the heifers were maintained in their respective calving system herds until fall pregnancy diagnosis. Pregnancy rates of heifers at first breeding were not affected ($P = 0.64$) by treatment (Table 8). Proportion of heifers pregnant in the fall was 6% greater for constant gain than delayed gain heifers. Although this difference could be economically significant, we did not find statistical differences ($P = 0.18$) between these treatment groups with the number of heifers used in this experiment.

The day of calving within the respective calving season was also not affected ($P = 0.58$) by treatment (data not shown). Heifers, on average, calved on d 12 ± 2 of their calving season. This could suggest that most heifers responded to the $PGF_{2\alpha}$ injection given on d 7 of the breeding season.

Proportion of calves surviving to weaning per cow exposed during breeding was also not affected ($P = 0.55$; Table 8) by pre- and postweaning treatment of heifers. Freetly et al. (2001) suggested that a period of limit-feeding of heifers during the postweaning period could affect calf crop. This did not occur in our experiment. Heifers in the study of Freetly et al. (2001) were restricted more severely (to about 0.2 kg/d of gain) but for a shorter period (84 d) than the delayed gain heifers in our study.

Pre- and postweaning treatment of dams as a heifer did not affect the weaning weight of its first ($P = 0.63$; Table 8) or second calf ($P = 0.17$; data not shown). Treatments also had no effect ($P > 0.70$) on pregnancy rates in the subsequent 2 yr of breeding (data not shown).

Table 8. Performance of heifers born in late winter, early spring, or late spring calving systems, raised from weaning to breeding on constant gain (CG) or delayed gain (DG) management strategies[1] and retained until fall pregnancy check

	Late winter				Early spring				Late spring					
	190 d of age		240 d of age		190 d of age		240 d of age		140 d of age		190 d of age			
Item	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG	CG	DG	Avg SE	*P*-value for treatment[2] effect
No. of heifers	32	35	25	30	29	25	30	28	30	30	29	31		
Proportion pregnant[3]	0.84	0.71	0.84	0.80	0.86	0.84	0.83	0.64	0.87	0.80	0.72	0.81	0.08	0.64
Calf crop[4]	0.72	0.63	0.84	0.80	0.86	0.80	0.77	0.57	0.73	0.80	0.69	0.81	0.09	0.55
BW of first calf at weaning, kg	221	223	216	220	206	212	208	231	206	203	194	202	9.9	0.17

[1]The postweaning management strategies are described in Table 1.
[2]Treatment is 1 of 12 combinations of calving system, age at weaning, and postweaning management.
[3]Number of cows pregnant per cow exposed.
[4]Number of calves surviving to weaning per cow exposed.

We conclude that no carryover effects of dam weaning age or heifer development treatment occurred through 3 yr of age. Clanton et al. (1983) also reported no effect of a delayed gain heifer development program on birth or weaning weights of the first calf. The lack of a calving system effect on subsequent breeding differs from that of Funston and Deutscher (2004), who found lower pregnancy rates at second breeding for summer-born compared with spring-born heifers.

Exp. 2

Heifers born and raised within 3 calving systems did not differ ($P = 0.66$) in BW at the beginning of the postweaning treatment period during Exp. 2 (Table 9). This differs from Exp. 1, in which heifers born in the late spring calving system and weaned at 190 d of age were lighter than heifers from the late winter and early spring systems. This is likely related, in part, to precipitation patterns during the first year of Exp. 2 (Figure 1), which provided favorable rangeland forage conditions for preweaning calf growth during autumn. Heifers from the 3 calving systems did not differ ($P > 0.45$) in prebreeding BW, ADG, or BCS.

Heifers from the 3 calving systems also did not differ ($P = 0.57$) in pregnancy rates, although the limited numbers of heifers in this experiment may preclude the ability to detect economically significant differences in pregnancy rates. The lack of difference in weaning BW among calving systems in Exp. 2 makes it difficult to conclude that maintaining late spring heifers on constant gain diets until breeding was more advantageous than placing them on pasture for the last 90 d before breeding as was done in Exp. 1. Pregnancy rates were numerically similar between the 2 studies for late spring heifers. Previous research has shown no effect of calving system on pregnancy rates of beef cows in the Northern Great Plains (Grings et al., 2005).

From these studies, we conclude that either constant or delayed gain management strategies can be used to develop heifers from weaning to breeding. This suggests that there are a wide variety of options available for rearing heifers. Heifers from varied calving pre- and postweaning management strategies performed similarly in initial reproductive performance and subsequent calf production. Heifers were a minimum of 58% of mature BW at first breeding, and our conclusions regarding calving system and postweaning manage-

Table 9. Body weight and BCS characteristics and proportion pregnant in the fall for heifers from 3 calving systems and reared on similar feedstuffs from weaning to breeding over 2 yr in Exp. 2

	Calving system				
Item	Late winter	Early spring	Late spring	Avg SE	*P*-value for calving system
No. of heifers	44	54	58		
Weaning BW, kg	228	216	211	14.2	0.66
Prebreeding BW, kg	390	375	378	21.3	0.46
ADG, kg/d	0.74	0.71	0.75	0.07	0.79
Prebreeding BCS[1]	6.4	5.5	5.7	0.56	0.61
Proportion pregnant[2]	0.84	0.89	0.81	0.07	0.57

[1]1 = emaciated to 9 = obese (Herd and Sprott, 1986).
[2]Number of heifers pregnant per heifer exposed.

ment programs should not be extended to heifers reaching less than this level of maturity. Heifers in this experiment were not bred in advance of the cow herd, as is a suggested practice to allow heifers more time to recover between first calving and second breeding. Thus, conclusions from this experiment may not be appropriate for systems in which heifers are bred before 14 mo of age.

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