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H. A. Lardner
Western Beef Development Centre, blardner.wbdc@pami.ca

D. Damiran
University of Saskatchewan

S. Hendrick
Western College of Veterinary Medicine

K. Larson
Western Beef Development Centre

R. Funston
University of Nebraska–Lincoln, rick.funston@unl.edu

Effect of development system on growth and reproductive performance of beef heifers[1,2]

H.A. Lardner,*†[3] D. Damiran,*† S. Hendrick,‡ K. Larson,* and R. Funston§

*Western Beef Development Centre, Humboldt, SK S0K 2A0, Canada; †Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK S7N 5B5, Canada; ‡Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine, Saskatoon, SK S7N 5B4, Canada; and §West Central Research and Extension Center, University of Nebraska–Lincoln, North Platte 69101

ABSTRACT: Reproductive performance was evaluated in beef heifers born over a 2-yr period to determine the effects of target breeding weight (TBW) and development system (SYS) on growth and subsequent reproductive efficiency. Spring-born Angus heifers (253 ± 0.7 kg) were randomly allocated over 2 consecutive yr (yr 1, *n* = 80; yr 2, *n* = 96) to be developed to either 55% (350 kg) of mature BW (moderate gain, MG) or 62% (395 kg) of mature BW (high gain, HG). Each MG and HG group was further assigned to 1 of 2 replicated systems: (1) bale graze bromegrass-alfalfa round bales in field paddocks (BG) or (2) fed bromegrass-alfalfa round bales in drylot pens (DL). Heifers were fed a diet of bromegrass-alfalfa hay (56.9% TDN; 9.8% CP) and barley grain supplement (85.1% TDN; 12.3% CP). After the 202-d development period, heifers were exposed to bulls for a 63-d breeding season. Target BW × SYS interactions were not detected for any measured parameters. During the winter development period, MG heifers had lower ($P = 0.01$) ADG than HG heifers and MG heifers had lighter ($P = 0.01$) BW at breeding. The proportion of heifers attaining puberty by 14.5 mo of age was less ($P = 0.05$) in MG (20 ± 4%) than HG heifers (52 ± 3%). From the end of the 202-d development period to pregnancy diagnosis, ADG was greater ($P = 0.04$) in MG heifers than HG heifers (0.83 vs. 0.71 kg/d). First-calf pregnancy rates were 86 and 88% for MG and HG heifers, respectively ($P = 0.41$). Second- and third-calf pregnancy rates of cows, developed in either a MG or HG system as heifers, were not different ($P = 0.74$; 94.7 vs. 95.9% and 93.8 vs. 93.9%, respectively). Economic analysis revealed a $58 reduced development cost for heifers developed to 55% compared with 62% of mature BW without a loss in reproductive performance.

Key words: bale grazing, heifer development, reproduction, system cost, target breeding weight

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INTRODUCTION

Beef heifers should be managed to achieve puberty early, conceive early in the first breeding season, calve unassisted, and breed back early for their second calf (Wiltbank et al., 1966; Funston and Deutscher, 2004). Traditionally, the recommendation has been that heifers be developed to reach 60 to 65% of mature BW by the onset of the breeding season (Patterson et al., 1992). However, recent research has demonstrated heifers reaching less than 58% of mature BW by breeding do not display impaired reproductive performance (Funston and Deutscher, 2004; Martin et al., 2008; Funston et al., 2012). In today's beef industry, meeting heifer maintenance and gestation nutrient requirements can increase overall development costs for beef producers. Therefore, in response, beef producers in western Canada are moving from conventional drylot wintering systems, where cattle are housed in pens to the adoption of extensive wintering systems (Van De Kerckhove et al., 2011; Krause et al., 2013). Advantages of extensive winter grazing are decreased stored feed requirements, direct deposition of nutrients from urine and manure in field, and reduced yardage costs (Johnson and Wand, 1999; Jungnitsch et al., 2011). One of most commonly used extensive wintering

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[3]Corresponding author: blardner.wbdc@pami.ca

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system in western Canada is bale grazing (**BG**; Kelln et al., 2011), as the round bale is the main method for preserving winter feed in western Canada. In a BG system, bales are placed in a grid pattern on the wintering site in the fall, before feeding, and animal access to bales is controlled using electric wire to limit consumption and wastage (Kallenbach, 2000; Kelln et al., 2011). However, studies on developing heifers in extensive wintering systems or breeding at different target body weights are limited in western Canada. The objectives of this study were to evaluate the effects of developing heifers to a prebreeding target BW of 55 or 62% of mature BW, and managing heifers postweaning in an extensive bale grazing system or drylot pen on estimated DMI, heifer reproductive efficiency, first- and second-calf performance, and system cost.

MATERIALS AND METHODS

Development Systems and Heifer Management

A 3-yr study was conducted with April-born Angus, nulliparous heifers (253.1 ± 0.7 kg) to compare 1 of 4 development systems on growth and reproductive performance. The study was conducted at Western Beef Development Centre's (**WBDC**) Termuende Research Ranch near Lanigan, Saskatchewan, Canada (51°51 'N, 105°02 'W). All experimental procedures were approved by University of Saskatchewan Animal Research Ethics Board (Protocol No. 20090107), and heifers were cared for in accordance with the Canadian Council of Animal Care guidelines (CCAC, 2009).

At pasture turnout in late May, spring-born heifer calves were vaccinated against bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea, and parainfluenza 3 (STARVAC 4 plus; Novartis Animal Health Inc., Mississauga, Ontario, Canada), and a *Clostridium* 8-way modified live vaccine (Covexin 8; Schering-Plough Animal Health, Guelph, Ontario, Canada). Heifers (n = 176) were weaned (late October) approximately 21 d before being randomly allocated by age and BW to 1 of 4 replicated (n = 2) heifer development treatments: (1) moderate gain (**MG**), fed to reach 350 kg at breeding (55% of MBW) in an extensive bale grazing (**BG**) system; (2) MG in an intensive drylot (**DL**) feeding system; (3) high gain (**HG**), fed to reach 395 kg at breeding (62% of MBW) in an extensive BG system; and (4) HG in an intensive DL feeding system. Mature BW was calculated using adjusted dam BW and historical cow BW (637 kg) from cows 5 yr old and older within the main WBDC herd according to Richards et al. (1986).

Heifers assigned to either MG or HG in the extensive BG system were managed from November 12 to June 2 each year on a 4-ha Russian wild ryegrass (*Psathyrostachys juncea* (Fisch.) Nevski) pasture site. The soils were a mixture of Oxbow Orthic Black and carbonated Oxbow with a loam texture (Saskatchewan Soil Survey, 1992). The site was divided into 4 (100 × 100 m) paddocks located opposite each other with a centralized winter watering system. Three portable windbreaks (10 × 16 m each) were supplied in each replicate paddock for wind shelter. Each replicated (n = 2) BG paddock was where smooth bromegrass (*Bromus inermis* L.) and alfalfa (*Medicago sativa* L.) round hay bales were set out onsite during the fall, in 6 rows of 7 bales each, and each paddock contained 42 bales placed on a grid with on-center spacing 17 m apart across the paddock width and 12 m down the length (6 × 7 = 42 bales/paddock); heifers grazed the bales in field paddocks, with access to feed restricted for a 3-d period using a portable electric fence (Fig. 1).

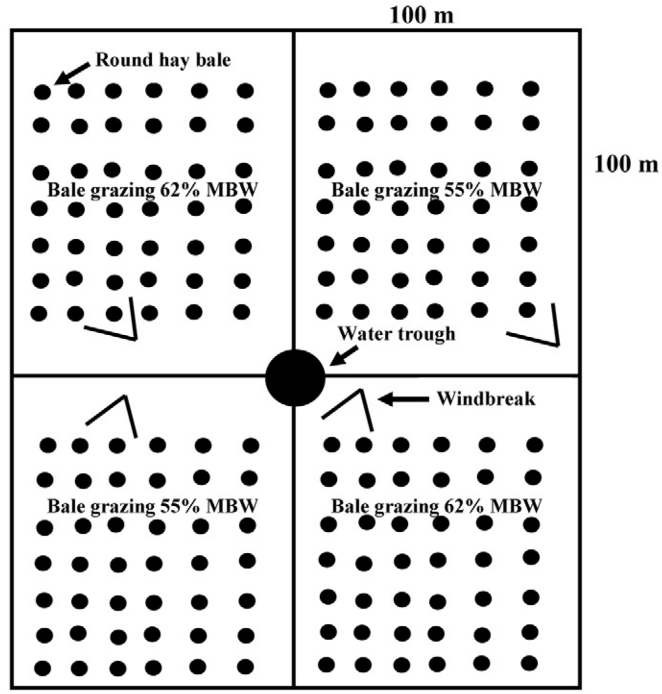

Figure 1. Plan of the bale grazing site showing 4 paddocks (100 × 100 m each) and location of bales, water troughs, and windbreaks.

The intensive DL pen system was located 0.5 km away where either MG or HG heifers were housed in 4 outdoor pens (50 × 120 m) and fed smooth bromegrass (*Bromus inermis* L.) and alfalfa (*Medicago sativa* L.) round bale hay in circular bale feeders. Each replicated (n = 2) DL pen (50 m × 120 m) was surrounded by wooden slatted fences with 20% porosity fencing and contained an open-faced shed (cattle shelter) and a round bale feeder, and water was supplied to each pen in troughs.

All heifers received smooth bromegrass-alfalfa hay (9.8% CP, 39.2% ADF, 58.0% NDF, 56.9% TDN) as the base forage along with supplemental barley (*Hordeum vulgare*) grain (12.3% CP, 5.8% ADF, 17.1% NDF, 85.1% TDN) as an energy source to reach the desired target BW prebreeding. Daily supplement was offered (0.63 to 2.4 kg/d) in drylot and while grazing.

All heifers also had ad libitum access to a commercial 2:1 mineral supplement (15.5% Ca; 7.0% P; 30 mg/kg Se; 20 mg/kg Co; 200 mg/kg I; 1,500 mg/kg Cu; 5,000 mg/kg Mn; 5,000 mg/kg Zn; 1,000 mg/kg Fe; 1 mg/kg F; 500,000 IU/kg Vitamin A (min); 50,000 IU/kg Vitamin D3 (min); 2,500 IU/kg Vitamin E (min); Cargill Animal Nutrition, Winnipeg, Manitoba, Canada), and cobalt-iodized salt-Windsor (99.0% NaCl (min), 39.0% Na, 180 mg/kg I, 120 mg/kg Co; The Canadian Salt Company Ltd., Pointe-Claire, Quebec, Canada) over the course of the trial.

Heifers were moved from BG sites or DL pens on June 2 and placed on summer pasture before breeding. During the breeding season and until pregnancy diagnosis (October), heifers were managed as a single group on mixed (crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.); smooth bromegrass (*Bromus inermis* Leyss.)) grass pasture.

For the period from pregnancy determination to calving, pregnant heifers grazed in field paddocks on swathed barley (69.3% TDN, 10.8% CP) from November 1 to February 15, followed by drylot feeding free-choice grass-legume hay (86.6% DM, 9.7% CP, 58.5% TDN) with a daily supplemented range pellet (2.7 kg/d; 13.6% CP, 79.5% TDN) from February 15 to May 30. The winter and calving diets were designed to meet NRC (1996) recommended protein and energy requirements for pregnant beef heifers similar to the animals used in the current study.

Measures of BW were taken over 2 consecutive days at the beginning (November 12) and end (June 2) of the winter feeding (development) 202-d period. Heifer BW was also measured every 14 d during the winter, and feed amounts were adjusted to obtain the desired targeted BW gains. Ultrasound measurements of subcutaneous body fat (rib fat, mm) and *longissimus dorsi* area fat (rump fat, mm) were determined by an individual technician at the start and end of the development period using an Aloka 500V real-time ultrasound machine (3.5 MHz; Aloka Inc., Wallingford, CT) equipped with a 17-cm linear array transducer according to Bergen et al. (1997). Prebreeding pelvic area also was measured using a Rice Pelvimeter (Lane Manufacturing, Denver, CO; Deutsher, 1987). Frame score was estimated using the following equation (Beef Improvement Federation, 2010):

$$\begin{aligned}\text{Frame Score} &= -11.7086 + \\ &\left(0.4723 \times \text{Hip height, cm}^2\right) - \\ &\left(0.0239 \times \text{Age, cm}^2\right) + \left(0.0000146 \times \text{Age2}\right) + \\ &\left(0.0000759 \times \text{Hip height, cm}^2 \times \text{Age}\right)\end{aligned}$$

Progesterone concentration was used as an indicator of pubertal status. All heifers were bled via coccygeal venipuncture into 5-mL vacutainer tubes (Fischer Scientific, Pittsburgh, PA), 14 d apart before initiation of the breeding season. Blood samples were cooled immediately on ice (to 4°C), and serum was harvested via centrifugation at 2,500 × *g* and stored at –20°C until analyzed to determine concentrations of progesterone. Serum progesterone concentrations were determined by the double-antibody procedure developed and validated by Staigmiller et al. (1979). Heifers with progesterone concentration greater than 1.0 ng/mL were classified as cycling at the time of breeding as described by Martin et al. (2007).

Before breeding, heifers were vaccinated against bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea, and parainfluenza 3 (Express 5; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO), and a *Clostridium* 8-way modified live vaccine (Covexin 8; Schering-Plough Animal Health, Guelph, Ontario, Canada), and anthrax spore vaccine (Colorado Serum Company, Denver, CO). Heifers were exposed to bulls for 63 d at ratio of 1 bull to 25 heifers. Estrus was synchronized with a single 2-mL injection of cloprostenol sodium, an analogue of prostaglandin $F_{2\alpha}$ (Estroplan; Parnell Technologies Pty Ltd, Alexandria, NSW, Australia), administered 5 d after bulls were placed with heifers. Pregnancy rates were determined in the fall by rectal palpation at approximately 50 d after bulls were removed. Body weight, rib and rump fat, and body condition score (BCS) were also determined at pregnancy diagnosis. Body condition score was assigned on a scale of 1 to 5 (1 = emaciated to 5 = grossly fat; Lowman et al., 1976; Marx, 2004). All heifer and cow BW data was adjusted for conceptus gain using the following equation from NRC (1996):

$$\begin{aligned}&\textit{Conceptus weight}\left(kg\right) = \\ &\left(\textit{calf birth weight} \times 0.01828\right) \times \\ &e\left[\left(0.02 \times t\right) + \left(0.0000143 \times t \times t\right)\right]\end{aligned}$$

Date of conception was determined by subtracting 282 d from the subsequent calving date (DeRouen et al., 1994).

Each year, precalving BW and BCS were recorded on approximately February 28, and calving began on approximately March 15. Calving difficulty was recorded and calving assistance was provided as needed. Calving difficulty was evaluated on a 1 to 5 score, where 1 = no assistance, 2 = easy pull, 3 = mechanical pull, 4 = hard mechanical pull, and 5 = Caesarean section. All calves were weighed within 24 h of birth and received a subcutaneous injection of vitamins A, D, and E; castrated using rubber castrator rings; and individually identified with a visual plastic management ear tag. Reproductive data collected included calf birth date and calf birth weight. Heifer conception rate was calculated after 42 and 63 d of bull exposure using calf birth date and a 282-d gestation length. The first and last day of calf born, calving pattern, and calving interval were calculated for all heifers.

Following calving, cows and calves were managed as a single group on grass-legume pastures similar to the first year, from early May until the beginning of the second breeding season. All 2-yr- and 3-yr-old cows were exposed to bulls for a 63-d breeding season beginning June 23. In late September, all cows were evaluated for pregnancy by rectal palpation and then managed on swathed annuals and bale grazing until 45 d before calving, and then they received free-choice grass-legume hay (9.7% CP, 58.5% TDN) along with a daily supplemented pellet (2.7 kg/d; 13.6% CP, 79.5% TDN) through calving until pasture turnout. All birth weight, weaning weight, reproductive, and calving data for primiparous cows was collected similar to the previous year. Each cow's calving date was assigned a number (84 to 132 Julian date) corresponding with calving span. All nonpregnant heifers and cows, as well as cows that lost calves, were removed from the study each year. Calves from 2-yr-old cows were weaned on October 4. Calves from 3-yr-old cows were weaned on October 15. All calf weaning weights were 205-d adjusted weaning weights.

Calculations and Laboratory Analysis

Utilization and estimated daily DMI of hay (allocated minus residue forage) were determined 3 times (initiation, middle, and end) during the development period each year using techniques as described in McCartney et al. (2004) and Kelln et al. (2011). In each replicate field paddock or drylot pen, before grazing, 21 hay bales were weighed to determine average bale weight and placed on a 2 × 2 m tarp to facilitate remaining residue weighing postgrazing. Moisture samples were taken to determine weight of hay available on a DM basis. To determine postgrazed residual weight of remaining hay, all residue material was weighed using a portable platform scale. Before weighing residual feed, any manure and foreign debris not associated with the residue was removed. Average daily hay DMI was then estimated by calculating the difference between pregrazed and postgrazed weight of offered hay in each paddock or pen using the following equation:

$$\begin{aligned} &DMIhay\,(kg) = \\ &\quad (kg\ DM\ allocated - kg\ DM\ residual, kg)\,/\,, \\ &\quad (d\ xn) \end{aligned}$$

where d = feeding period, day and n = number of heifers per experimental unit. Average hay utilization was determined 3 times over a 12-d period in each paddock/pen at the start, middle, and end of each 202-d development period in each year, for each experimental unit. Utilization was calculated as the difference between total bale forage allocated minus remaining wastage (residue).

Hay and barley supplement were further sampled for chemical analysis. Additionally, during the summer grazing and breeding period, pasture samples were collected from 4 separate transects by clipping bimonthly representative samples (250 g) taken from different locations on each transect. Before laboratory analysis, all samples were dried at 55°C for 48 h and ground to pass through a 1-mm screen with a Wiley mill (Model 4; Arthur H. Tomas Co., Philadelphia, PA). Once ground, samples were dried at 100°C for 24 h to determine total DM (method 930.15; AOAC, 1990). Crude protein was determined using a Leco FP-2000 nitrogen analyzer (Leco Corporation, St. Joseph, MI; method 984.13; AOAC 1990). Acid detergent fiber and NDF with heat stable α-amylase and sodium sulfite were analyzed according to the procedure of Van Soest et al. (1991) using a fiber analyzer (ANKOM Technology Corporation, Fairport, NY). Forage TDN values were calculated from ADF for both hay (TDN = 88.9 – [0.79 × ADF%]; Moore and Undersander, 2002) and barley grain (TDN = 92.2 – [1.12 × ADF%]; Van Soest et al., 1979). Using the relationship provided by NRC (1996), TDN was converted to DE using the equation (Mcal/kg = TDN, % × 0.044). Total diet (hay + barley) nutrient density (DQ; CP, NDF, ADF, TDN, and DE) was calculated using the following equation:

$$\mathrm{DQ}\,(\%, \mathrm{DM}) = \left(\sum \mathrm{I}i\left(\mathrm{DQ}i/100\right)/\sum \mathrm{I}i\right)100,$$

where I_i is the DMI of each diet (hay + barley) during feeding period (kg/d) and DQ_i = nutrient composition of each diet i (%, DM).

Economic Analysis of Development Systems

Each heifer development system was analyzed for economic viability and prices considered included feed, bedding, labor, equipment, depreciation, repair, and manure cleaning costs. All dollar values expressed are in Canadian dollars. Costs that did not vary between systems (i.e., vaccination) were not included in the analysis. The economic procedures described in Kelln et al. (2011) were used in part for this analysis. Feed and bedding costs used were from actual amounts fed and actual price paid for hay, straw, barley, and mineral. Labor and equipment costs were based on estimated time required to feed animals. A price of $15/h was charged for labor, and equipment costs were from published custom rates in the Saskatchewan Ministry of Agriculture's Farm Machinery Custom and Rental Rate Guide (SMA, 2008). Manure cleaning costs were adapted from Kelln et al. (2011). Depreciation (buildings and infrastructure) and building and fence repair costs were an average from previous research studies conducted at Western Beef Development Centre (Kumar et al., 2012; Krause et al., 2013).

Statistical Analysis

Statistical data were analyzed using the MIXED procedure of SAS 9.2 (SAS Inst. Inc., Cary, NC) for a

Table 1. Estimated hay utilization, daily DM, and nutrient intake of heifers during development period (DM)

Item	Targeted BW[1] Moderate gain BG[2]	DL	High gain BG	DL	SEM	P-value TBW	SYS	TBW×SYS
Hay utilization, %	85.1	85.2	83.3	82.3	1.82	0.22	0.82	0.99
Daily DMI, kg								
Brome-alfalfa hay	4.8	5.5	4.2	5.1	0.28	0.03	0.01	0.89
Barley grain	0.9	0.6	2.4	2.1	0.07	< 0.01	< 0.01	0.64
Total	5.7	6.1	6.6	7.2	0.29	< 0.01	0.11	0.98
Daily nutrient intake, kg								
Crude protein	0.6	0.6	0.7	0.8	0.05	0.02	0.25	0.71
Total digestible nutrients	3.5	3.7	4.4	4.6	0.2	< 0.01	0.39	0.99
Daily DE intake, Mcal	15.5	16.3	19.5	20.3	0.89	< 0.01	0.39	0.99

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

completely randomized design (**CRD**) with subsampling and with a 2 × 2 factorial arrangement of treatments. The model used was $Y_{ij} = \mu + TBW_i + SYS_j + (TBW \times SYS)_{ij} + e_{ij}$, where Y_{ij} = response variable, μ = mean, targeted BW (TBW) and heifer development system (SYS) were both fixed effects, TBW_i = targeted BW to reach either 55 or 62% of MBW at time of breeding, SYS_j = heifer development system (BG or DL), and error was e_{ij}. Each replicate group of heifers (n = 10 and 12 for yr 1 and yr 2, respectively) was considered an experimental unit for a total of 16 experimental units over the 2-yr study. Based on initial heifer BW, and to be within 10 units of mean BW with 90% power at the 5% significance level (Kuehl, 2000), would require a minimum of 12 animals per replicate (Martin et al., 1987).

Forage nutritive analysis data were analyzed as a CRD with subsampling. The model used for the analysis was $Y_{ij} = \mu + M_i + e_{ij}$, where Y_{ij} is observation of the dependent variable ij, μ is the population mean for the variable, M_i is the fixed effect of sampling time (month), and e_{ij} is the random error associated with the observation ij. Year was treated as a random variable in all analyses, and differences between treatment means were determined using Tukey's multiple range test and were considered significant when $P < 0.05$. Calving pattern data were analyzed using the GLIMMIX macro (SAS Inst. Inc.) with a binomial error structure and logit data transformation. Targeted BW × SYS interactions were not detected for any measured parameters and were removed from the model.

RESULTS AND DISCUSSION

Dry Matter and Nutrient Intake

Hay utilization was not different ($P > 0.05$) between heifers in different systems and averaged 84.0% (± 0.87) of offered hay during the 202-d winter feeding period (Table 1). Hay intake was least ($P = 0.01$) for heifers on bale grazing (4.5 kg/d) compared with heifers in the drylot (5.3 kg/d) system, whereas MG heifers had greater ($P = 0.03$) hay intake (5.2 kg/d) compared with HG heifers (4.7 kg/d; Table 1). As expected, HG heifers had greater ($P < 0.01$) CP intake (0.75 vs. 0.60 kg/d), TDN intake (4.5 vs. 3.6 kg/d), DE intake (19.86 vs. 15.9 Mcal/d), and total DMI (6.9 vs. 6.0 kg/d) compared with MG heifers (Table 1). By design, MG and HG heifers were supplemented at different levels in BG or DL systems, which accounted for differences in DM and nutrient intakes (Table 1). According to the NRC (1996), a medium framed, 255-kg heifer, targeted to gain 0.5 kg/d, needs TDN and CP intakes of 3.5 and 0.6 kg/d, respectively, with a total DMI of 6.1 kg/d. In the current study, calculated DM and nutrient intakes of all heifers targeted at either moderate or high gain were meeting NRC (1996) recommended requirements.

Crude protein density of diets offered to heifers was not different ($P > 0.05$); however, the HG diet was greater ($P < 0.05$) in TDN (66.0 vs. 60.3%) and DE (2.9 vs. 2.65 Mcal/kg) but lower ($P = 0.02$) in ADF (27.4 vs. 34.0%) and NDF (45.0 vs. 53.6%; $P < 0.05$) compared with nutrient density of diets offered to MG heifers (Table 2). Over the 202-d winter development period MG heifers consumed 14.5% less feed than HG heifers, which resulted in reduced ADG and lighter BW (Table 3). A review by Moore et al. (1999) on the effects of energy supplementation of cattle consuming forages ad libitum concluded that voluntary forage DMI was decreased when supplemented energy intake was greater than 0.7% of BW and forage TDN:CP ratio was less than 7. This was observed in the current study, where an increased level of barley supplement to either BG or DL heifers resulted in a reduced DMI of mixed hay.

The reduced hay intake observed for BG heifers may have been a result of the combined effects of extreme

Table 2. Diet nutrient density (DM basis) during winter feeding period

	Targeted BW[1]							
	Moderate gain		High gain			*P*-value		
Item	BG[2]	DL	BG	DL	SEM	TBW	SYS	TBW×SYS
Crude protein, %	10.6	10.3	10.8	11.1	0.83	0.54	0.98	0.71
Acid detergent fiber, %	33.2	34.8	26.4	28.5	2.52	0.02	0.47	0.93
Neutral detergent fiber, %	52.4	54.8	43.9	46.2	2.35	< 0.01	0.33	0.98
Total digestible nutrients, %	61.1	59.5	66.9	65.1	1.21	< 0.01	0.19	0.89
Digestible energy, Mcal/kg	2.7	2.6	3.0	2.9	0.05	< 0.01	0.18	0.85

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

cold temperatures, snow depth, and naive animals. Studies conducted in Montana (Adams et al., 1986) and Saskatchewan (Kelln et al., 2011) revealed adverse weather can reduce both grazing activity and subsequent DMI for less-experienced animals. During February in the current study, snow depth was greater compared with the 30-yr average for the Lanigan area, potentially affecting accessibility to forage. Beef cattle in an extensive grazing system require 18 to 21% more energy than cattle fed in a drylot system because of the increased requirements associated with walking, environmental stress, and activities involved in foraging (McCartney et al., 2004; Kelln et al., 2011; Kumar et al., 2012). A 400- to 425-kg heifer during breeding season requires a diet containing 8.1% CP and 60% TDN (NRC, 1996), which based on summer and fall, June (12.2% CP, 34.9% ADF, 57.5% NDF, 61.3% TDN) to September (10.1% CP, 38.2% ADF, 58.3% NDF, 58.7% TDN), pasture quality in the current study was meeting or exceeding heifer requirements.

Heifer Performance

Heifer performance during winter and first pregnancy rates are presented in Table 3. There was no difference ($P = 0.08$) in initial BW between systems; however, differences were detected ($P < 0.05$) for winter ADG, prebreeding BW, final rib and rump fat, percent pubertal, pelvic area, frame score, summer ADG, and pregnancy diagnosis BW between systems (Table 3). The targeted prebreeding BW was based on an average mature BW of 637 kg and targeted to be 350 and 395 kg for MG and HG heifers, respectively. Heifers developed to 62% of mature BW gained approximately 0.2 kg/d more than heifers developed to 55% of mature BW (0.71 vs. 0.49 kg/d; Table 3; $P < 0.01$) during the 2-yr study. High gain heifers had greater final BW (396 vs. 353 kg), rib fat (3.1 vs. 2.3 mm), rump fat (2.6 vs. 1.4 mm), pelvic area (191.0 vs. 184.0 cm^2), and frame score (3.2 vs. 2.8) compared with MG heifers (Table 3).

Therefore, ADG (0.71 kg/d) acquired by HG heifers in the current study was close to this recommended level. The present study further showed nutritional restrictions during the prebreeding period clearly affected heifer performance. When nutritionally restricted animals are placed on a higher plane of nutrition, they will subsequently gain BW faster and have a lower feed-to-gain ratio than animals not nutritionally restricted (Fox et al., 1972; Grings et al., 1998; Kelln et al., 2011). However, in the current study, BW differences following the winter development period were present until the first calving period (approximately 10 mo after the development period) and first-calf weaning period (approximately 17 mo after the development period), respectively.

Heifer performance following breeding through summer grazing was different ($P < 0.05$) for BW and BCS at pregnancy diagnosis (Table 3). Although ADG was reduced in MG heifers during winter development, ADG from the end of the development period to fall pregnancy diagnosis was greater ($P = 0.04$) for MG (0.83 kg/d) than HG (0.70 kg/d) heifers. This greater ADG likely suggests compensatory BW gain during breeding and summer pasture after the winter development period (Funston and Larson, 2011; Mulliniks et al., 2013), even though MG heifers still had lower BW ($P = 0.01$) than HG heifers at pregnancy diagnosis.

Moderate gain developed heifers compensated for their minimal prebreeding ADG and gained more during the breeding season than HG heifers due to the ability to respond to improved forage quality at the start (12.2% CP, 61.3% TDN) of the summer grazing period. Pasture protein (10.8% CP) and energy (59.1% TDN) content was more than adequate from June through September for growing heifers (NRC, 1996). Once heifers were placed on greater quality forage in early summer, the MG heifers gained 0.83 kg/d, achieving 71% of their mature BW by October; however, they still weighed 29 kg less at pregnancy diagnosis than HG heifers. Pregnancy rates were similar ($P = 0.41$) for heifers developed to 55% of mature BW in either BG or DL systems compared with heifers developed to 62% mature BW and averaged 87.1% across systems (Table 3). This is surprising given the proportion of MG heifers pubertal by 14 mo of age

Table 3. Growth and reproductive performance of beef heifers from start of development period to first pregnancy diagnosis

	Targeted BW[1]							
	Moderate gain		High gain			*P*-value		
Item	BG[2]	DL	BG	DL	SEM	TBW	SYS	TBW×SYS
n	44	43	43	41				
Initial BW, kg	255	252	253	251	1.2	0.08	0.09	0.41
Final BW, kg	357	350	397	396	7.8	< 0.01	0.65	0.68
ADG[3], kg	0.5	0.5	0.7	0.7	0.03	< 0.01	0.86	0.78
Percent of mature BW	55	55	62	62	1.2	< 0.01	0.64	0.69
Initial rib fat, mm	2.3	2.3	2.6	2.5	0.21	0.24	0.70	0.75
Final rib fat, mm	2.2	2.3	3.1	3.1	0.14	< 0.01	0.63	0.74
Initial rump fat, mm	1.4	1.4	1.6	1.5	0.06	0.06	0.19	0.23
Final rump fat, mm	1.4	1.5	2.9	2.4	0.15	< 0.01	0.13	0.08
Cycling at start of breeding[4], %	9.0	30.2	44.8	59.0	4.71	0.05	0.26	0.84
Pelvic area at 14 mo, cm^2	186.9	181.1	190.2	191.8	2.87	0.03	0.47	0.24
Frame score at 14 mo[5]	2.8	2.8	3.2	3.2	0.12	< 0.01	0.92	0.98
Pregnancy diagnosis BW, kg	453	447	478	480	7.6	0.01	0.79	0.55
Pregnancy diagnosis BCS	2.6	2.6	2.8	2.8	0.08	0.02	0.44	0.34
ADG[6], kg	0.83	0.83	0.69	0.72	0.04	0.04	0.61	0.48
Pregnancy rate, %	84.2	88.1	90.6	85.4	2.27	0.41	0.78	0.09

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

[3]ADG during November to June (202 d) winter development period

[4]Percentage of heifers determined to have reached puberty, if serum progesterone concentrations > 1 ng/mL.

[5]Frame score estimated following Beef Improvement Federation (2010) guidelines.

[6]ADG during June to September (117 d) summer grazing to pregnancy diagnosis.

and at the start of breeding were 32% less than HG heifers (Table 3). Funston et al. (2012) reported that the relationship between prebreeding BW, puberty, and heifer pregnancy rate appears to have changed over time. Research reports published through the 1980s demonstrated a much greater negative effect of limited postweaning growth on age of puberty and subsequent pregnancy rate (Short and Bellows, 1971; Wiltbank et al., 1985; Patterson et al., 1989). More recent studies (Buskirk et al., 1995; Freetly and Cundiff, 1997; Lynch et al., 1997; Funston and Larson, 2011) suggest less of a negative impact of delayed puberty on pregnancy rates. Evidenced by the findings in the current study, decreased winter BW gain of MG heifers in the extensive BG system resulted in greater BW gain during the breeding season, which may explain overall pregnancy rates. A major reason heifer reproductive performance has not been affected by developing to reduced percent of mature BW before breeding may be related to genetic changes in beef heifers at the age of puberty (Funston et al., 2012). Earlier studies have indicated heifers should exhibit 2 or 3 estrous cycles before the start of the breeding season; as Byerley et al. (1987) reported, the first estrus pregnancy rate was 21% lower compared with heifers bred on the third estrus. The 63-d breeding season may have allowed more heifers to achieve puberty and become pregnant; however, the percentage of heifers pregnant after 45 d (98 and 95% for MG and HG, respectively; data not shown) of the breeding season in the current study is similar to other studies where heifers were exposed to bulls for a 45-d breeding season (Martin et al., 2008).

The BW differences between the winter development systems were maintained over the second winter, breeding, and summer grazing periods; thus, precalving BW was greater ($P = 0.02$) for HG than for MG heifers (Table 4). Larson (2007) noted heifers should reach 80 to 85% of mature BW by first calving. In the current study, all heifers averaged 77% (range of 75 to 79%) of mature BW at first calving, slightly less than the recommended level. However, by the second calving, the average cow BW ranged from 86 to 92% of mature BW. Neither the MG nor the extensive BG systems had a negative effect on heifer reproductive performance during the first and second reproduction cycle in the current study. Calf birth BW in the current study (35.2 kg) was greater than the suggested birth BW (31 kg) for Angus breed cattle (NRC, 1996). Although pelvic area size and frame score were different among heifer groups (Table 3), calving score was similar ($P = 0.93$) for heifers across development systems (Table 4). This is similar to a study by Funston and Deutscher (2004), where calving difficulty was similar between low and high gain heifers developed in drylot. In contrast, Patterson et al. (1991) reported heifers developed to 55% mature BW before breeding and had

Table 4. Growth, reproductive and calf performance of beef heifers from first calving through re-breeding as 2-yr-old cows

	Targeted BW[1]							
	Moderate gain		High gain			*P*-value		
Item	BG[2]	DL	BG	DL	SEM	TBW	SYS	TBW×SYS
n	44	43	43	41				
Pre-calving BW, kg	483	478	492	504	6.7	0.02	0.60	0.23
Pre-calving BW, % of MBW	76	75	77	79	1.1	0.02	0.61	0.22
Pre-calving BCS	2.4	2.3	2.4	2.4	0.04	0.75	0.34	0.34
First calf born, Julian date	72	71	68	71	3.3	0.51	0.88	0.56
First calf birth BW, kg	35.4	34.9	34.6	35.2	0.69	0.73	0.93	0.46
Calving difficulty score[3]	1.1	1.0	1.0	1.1	0.58	0.92	0.94	0.11
Calved in first 21 d, %	43	55	50	68	12.7	0.47	0.25	0.82
First-calf weaning BW[4], kg	226	228	223	232	11.2	0.95	0.63	0.77
Pregnancy diagnosis BW[5], kg	534	553	554	555	12.1	0.43	0.43	0.50
second pregnancy rate, %	94.7	94.6	96.9	95.0	3.68	0.74	0.79	0.81

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

[3]Scoring system 1 to 5: 1 = no assistance; 2 = easy pull; 3 = mechanical pull; 4 = hard mechanical pull; and 5 = Caesarean section.

[4]205-d adjusted weaning weight.

[5]BW at second pregnancy diagnosis.

a 24% increase in proportion of heifers requiring assistance during calving compared with heifers developed to 65% mature BW before breeding. Likewise, Bellows and Short (1978) reported heifers raised on a lower plane of nutrition from weaning to breeding tended to experience a greater incidence and severity of dystocia.

High gain heifers had greater ($P = 0.02$) precalving BW than MG heifers (479 vs. 450 kg; SEM = 5.4) and a greater percent mature BW (78.3 vs. 75.5%; SEM = 0.74) at precalving. However, there was no difference ($P = 0.73$) for calf birth BW, date of first calf born ($P = 0.51$), calving difficulty score, and proportion of heifers calving in the first 21 d ($P = 0.47$). The proportion of heifers exposed to bulls that calved within the initial 45 d of the calving season was not affected ($P = 0.46$) by targeted BW and was 77.7% for MG and 86.5% for HG heifers. Overall, 82% of pregnant heifers from all development systems calved in the first 45 d of the first calving season. Heifers calving early during their first calving season have a greater lifetime calf production than those calving late and are more likely to become pregnant sooner at 2 yr of age (Lesmeister et al., 1973). Heifer development treatment did not affect the first-calf pregnancy rate or the number of heifers calving in the first 21 d, nor did it affect the second calving performance of cows. Calf 205-d adjusted weaning weight (225 ± 5 kg) was not different ($P = 0.95$) between MG and HG heifers. At weaning, first-calf heifer BW was similar ($P > 0.05$) between heifers previously developed in BG or DL, HG or MG systems (Table 4).

No SYS or targeted BW effects were detected ($P > 0.05$) for second calving, cow BW, BCS, or re-breeding performance measured parameters (Table 5). At second calving, cow BW (568.2 ± 8.4 kg), percentage of MBW (89.2 ± 1.3%), second pregnancy rate (95.3 ± 6.7%), second-calf birth BW (39.4 ± 0.6 kg), date of first calf born (90 ± 1), proportion of cows calving in the first 21 d, second-calf 205-d adjusted weaning BW (267 ± 7 kg), and third pregnancy rate were not different ($P > 0.05$) between cows exposed previously to the different development systems as heifers. The proportion of heifers exposed to bulls that calved within the initial 45 d of the calving season was not affected ($P = 0.50$) by targeted BW and was 88.1% for MG and 96.8% for HG heifers. Overall, during second calving, 93% of pregnant cows of all treatment groups calved in the first 42 d of the calving season. Finally, the proportion of heifers exposed for breeding as yearlings remaining in the herd as pregnant 3 yr olds was similar ($P = 0.89$) between systems, averaging 76.9 and 75.9% for MG and HG systems, respectively (Table 5).

Economic Analysis

The economic analyses of winter development from weaning to breeding are summarized in Table 6. Total costs were calculated using development system costs for feed, bedding, labor, equipment, depreciation, repair, and manure for 2010 and 2011. Total feed and daily costs were lower ($P < 0.01$) for the MG than the HG system. Comparatively, BG heifers had a small economic advantage (6% lower) over DL heifers during development. However, when compared over a 202 d development period, developing heifers in the HG system increased total costs $58/head (21% higher), mainly due to an increase in feed and labor costs (Table 6). Developing heifers to attain a target BW of 55% of

Table 5. Growth, reproductive and calf performance of beef heifers from second calving through re-breeding as 3-yr-old cows

	Targeted BW[1]							
	Moderate gain		High gain			*P*-value		
Item	BG[2]	DL	BG	DL	SEM	TBW	SYS	TBW×SYS
Cows, n	37	38	39	34				
Cow BW at calving, kg	557	581	560	585	16.1	0.61	0.14	0.81
Cow BW, % of MBW	87.4	91.2	87.9	92.0	2.53	0.61	0.14	0.82
Cow BCS	2.3	2.4	2.4	2.4	0.07	0.45	0.45	0.45
Calving interval, d	382	385	371	384	6.2	0.36	0.26	0.41
Second-calf birth BW, kg	39	40	41	38	1.1	0.60	0.33	0.16
Calving difficulty score[3]	1.0	1.0	1.0	1.0				
First calf born, Julian date	84	93	92	93	1.6	0.07	0.06	0.07
Calved in first 21 d, %	69	68	62	62	11.4	0.50	0.22	0.24
Second-calf weaning BW,[4] kg	268	275	263	266	4.2	0.15	0.33	0.66
Pregnancy diagnosis BW,[5] kg	587	610	592	605	2.3	0.99	0.27	0.75
third pregnancy rate, %	93.8	93.8	90.1	97.8	3.93	0.75	0.41	0.41
3-yr-old retention, %	77.1	76.7	75.8	76.1	6.32	0.89	0.99	0.95

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

[3]Scoring system 1 to 5: 1 = no assistance; 2 = easy pull; 3 = mechanical pull; 4 = hard mechanical pull; and 5 = Caesarean section.

[4]205-d adjusted weaning weight.

[5]BW at third pregnancy diagnosis.

[6]Percentage of heifers exposed to bulls during initial breeding season that became pregnant as 3-yr-old cows.

mature BW is a practical method for reducing heifer development cost. This agrees with other studies (Funston and Deutscher, 2004; Roberts et al., 2007, Roberts et al., 2009; Martin et al., 2008; Larson et al., 2011) that demonstrated that developing replacement heifers to lighter target BW ranging from 50 to 57% of mature BW before breeding reduced development costs, but had no negative effect on reproductive performance or subsequent calf performance. Funston and Larson (2011) reported that developing heifers on corn residue or winter range reduced development costs by $45/pregnant heifer. The advantages of developing heifers in extensive winter grazing systems are decreased stored feed requirements, direct deposition of manure nutrients on the wintering site, and reduced yardage costs (Jungnitsch et al., 2011; Kelln et al., 2011).

Summary And Conclusions

The primary reason for developing heifers to reach 60 to 65% of mature BW at the start of breeding was that pregnancy rate was shown to be dependent on the proportion of heifers exhibiting puberty before or during the breeding season (Short and Bellows, 1971; Patterson et al., 1992). The results of the current study provide additional evidence that postweaning development of heifers to achieve 55% of mature BW before breeding did not negatively affect reproductive performance during first and second calving compared with developing heifers to achieve 62% of mature BW. Similarly, developing heifers to 55% of mature BW can save nearly $60 per heifer compared with developing to 62% in drylot without negatively affecting reproductive performance.

Table 6. Economic analysis of winter heifer development from weaning to breeding (CAN$/heifer/d)

	Targeted BW[1]							
	Moderate gain		High gain			*P*-value		
Item	BG[2]	DL	BG	DL	SEM	TBW	SYS	TBW×SYS
Total feed cost	0.68	0.72	0.96	0.99	0.027	< 0.01	0.68	0.67
Labor	0.15	0.18	0.15	0.20	0.015	0.23	< 0.02	0.31
Other[3]	0.20	0.16	0.20	0.16	0.015	0.23	0.02	0.07
Manure cleaning	0.00	0.03	0.00	0.03	0.001	0.53	< 0.01	0.11
Total cost	1.03	1.09	1.31	1.38	0.021	< 0.01	0.03	0.69
Total development costs, 202 d	208.06	220.18	264.62	278.76	4.141	< 0.01	0.02	0.81

[1]Targeted BW (TBW); moderate gain = 55% of mature BW at start of breeding; high gain = 62% of mature BW at start of breeding season.

[2]Development system (SYS); BG = heifers developed in field paddocks bale grazing and supplemented barley grain; DL = heifers developed in drylot pens and supplemented barley grain.

[3]Other = bedding, equipment, repairs, and depreciation.

This study further suggests developing heifers in an extensive bale grazing system can be a viable alternative to reduce development costs. Nevertheless, environmental conditions (e.g., snowfall, temperature) may limit forage intake in winter bale grazing systems. Therefore, careful management and supplementation practices must be considered when using extensive grazing systems during the winter season in western Canada. Finally, this study, which evaluates the influence of nutrition on heifer development, contributes to a limited number of long-term studies about the impacts of heifer development strategies on cow longevity.

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