Effects of Prebreeding Body Weight or Progestin Exposure Before Breeding on Beef Heifer Performance Through the Second Breeding Season

J. L. Martin
University of Nebraska-Lincoln

K. W. Creighton
University of Nebraska-Lincoln

Jacqueline A. Musgrave
University of Nebraska-Lincoln, jmusgrave1@unl.edu

Terry J. Klopfenstein
University of Nebraska-Lincoln, tklopfenstein1@unl.edu

R. T. Clark
University of Nebraska-Lincoln

See next page for additional authors

Authors
J. L. Martin, K. W. Creighton, Jacqueline A. Musgrave, Terry J. Klopfenstein, R. T. Clark, Don C. Adams, and Richard N. Funston

Effect of prebreeding body weight or progestin exposure before breeding on beef heifer performance through the second breeding season[1]

J. L. Martin,* K. W. Creighton,* J. A. Musgrave,* T. J. Klopfenstein,† R. T. Clark,‡ D. C. Adams,* and R. N. Funston*[2]

*University of Nebraska West Central Research and Extension Center, North Platte 69101;
†Department of Animal Science, and ‡Department of Agricultural Economics,
University of Nebraska-Lincoln 68583

ABSTRACT: Two experiments evaluated prebreeding target BW or progestin exposure for heifers developed lighter than traditional recommendations. Experiment 1 evaluated the effects of the system on heifer performance through subsequent calving and rebreeding over 3 yr. Heifers (229 kg) were assigned randomly to be developed to 55% of mature BW (299 kg) before a 45-d breeding season (intensive, INT; n = 119) or 50% of mature BW (272 kg) before a 60-d breeding season (relaxed, RLX; n = 142). Prebreeding and pregnancy diagnosis BW were greater ($P \leq 0.006$) for INT than RLX heifers. Overall pregnancy rate did not differ (88.4%; $P = 0.51$), but RLX heifers had later calving dates (7 d; $P < 0.001$) and lighter calf weaning weights (194 ± 4 vs. 199 ± 4 kg; $P < 0.07$) compared with INT heifers. Calf birth weight, calving difficulty, second-calf conception rates, and 2-yr-old retention rate did not differ ($P > 0.15$) between systems. Cost per pregnant 2-yr-old cow was less for the RLX than the INT heifer development system. Of heifers that failed to become pregnant, a greater proportion ($P = 0.07$) of heifers in the RLX than in the INT system were prepubertal when the breeding season began. Therefore, a second 2-yr experiment evaluated melengestrol acetate (MGA, 0.5 mg/d) as a means of hastening puberty in heifers developed to 50% of mature BW. Heifers were assigned randomly to the control (n = 103) or MGA (n = 81) treatment for 14 d and were placed with bulls 13 d later for 45 d. Prebreeding and pregnancy diagnosis BW were similar (280 and 380 kg, respectively; $P > 0.10$) for heifers in the control and MGA treatments. The proportion of heifers pubertal before breeding (74%), pregnancy rate (90%), calving date, calf weaning weight, and second breeding season pregnancy rate (92%) were similar ($P > 0.10$) between treatments. Developing heifers to 50 or 55% of mature BW resulted in similar overall pregnancy rates, and supplementing the diets of heifers developed to 50% of mature BW with MGA before breeding did not improve reproductive performance.

Key words: beef heifer, heifer development, progestin, target body weight

J. Anim. Sci. 2008. 86:451–459
doi:10.2527/jas.2007-0233

INTRODUCTION

Energy requirements of the cow herd account for the majority of energy inputs in beef production systems (Ferrell and Jenkins, 1985). Traditional recommendations advocate substantial energy inputs for replacement heifer development because pregnancy rates in heifers depend on the number displaying estrus early in the breeding season (Short and Bellows, 1971). Byerley et al. (1987) reported that heifers should experience 2 or 3 estrous cycles before onset of the breeding season because fertility of the first estrus is less than in subsequent estrous cycles. Therefore, time of puberty is an important factor in determining pregnancy rates in heifers (Patterson et al., 1992). Studies of sexual maturity in numerous species provide evidence for the importance of diet during development and suggest that factors other than chronological age can control the physiological changes necessary for puberty (Frisch, 1984). Numerous studies have reported inverse correlations between postweaning growth rate and age at puberty (Arije and Wiltbank, 1971; Short and Bellows, 1971; Wiltbank et al., 1985). Therefore, it is commonly recom-

[1]A contribution of the University of Nebraska Agricultural Research Division, supported in part by funds provided through the Hatch Act. Mention of a trade name, proprietary products, or company name is for presentation clarity and does not imply endorsement by the authors or the University of Nebraska.

[2]Corresponding author: rfunston2@unl.edu

Received April 23, 2007.
Accepted October 17, 2007.

mended that heifers be developed to between 60 and 65% of mature BW before breeding.

Feeding replacement heifers to traditional target BW increases development costs relative to low-input heifer development (Funston and Deutscher, 2004; Clark et al., 2005). Funston and Deutscher (2004) reported similar pregnancy rates from the initial through fourth breeding season for heifers developed to reach either 53 or 58% of mature BW before breeding as yearlings. Further research is needed to evaluate developing replacement heifers to target BW less than 55% of mature BW at breeding. The objectives of this study were 1) to determine the effects of developing heifers to a prebreeding target BW of 50 or 55% of mature BW, and 2) to determine the effects of supplementing heifers developed to 50% of mature BW with progestin before breeding.

MATERIALS AND METHODS

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment. Two experiments were conducted using crossbred MARC II (one-quarter each Angus, Hereford, Simmental, and Gelbvieh) × Husker Red (three-quarters Red Angus, one-quarter Gelbvieh or Simmental) heifers at Gudmundsen Sandhills Laboratory (**GSL**), Whitman, Nebraska. Upland range sites at GSL contain predominantly little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon hallii* Hack.), sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood], and blue grama [*Bouteloua gracillis* (H.K.B.) Lag. ex Griffiths]. Subirrigated meadows at GSL are mainly smooth bromegrass (*Bromus inermis* Leyss.), redtop bent (*Agrostis stolonifera* L.), timothy (*Phleum pratense* L.), slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners], quackgrass [*Elytrigia repens* (L.) Nevski], and Kentucky bluegrass (*Poa pratensis* L.; Adams et al., 1998).

Exp. 1

Two hundred sixty-one heifers (229 ± 18 kg of BW; n = 88, 90, and 83 in 2001, 2002, and 2003, respectively) were assigned randomly to development in an intensive (**INT**; n = 119) or relaxed (**RLX**; n = 142) system. Heifers in the INT system were developed to 55% of mature BW before a 45-d breeding season. In the RLX system, heifers were developed to 50% of mature BW before a 60-d breeding season. The INT prebreeding BW was established from previous work by Funston and Deutscher (2004) in which heifers developed to 53 or 58% of mature BW before the breeding season as yearlings had similar reproductive performance. An estimated mature BW of 544 kg was used because mature cows 4 yr old and older in this herd weighed 531 ± 60 kg at weaning in the fall of the previous 5 yr. To ensure that an adequate number of heifers would remain in the herd as 2 yr olds, more heifers were developed in the RLX system because a reduced heifer pregnancy rate was expected.

Table 1. Winter rations for heifers developed in an intensive (INT) or relaxed (RLX) system (Exp. 1)[1]

	Feedstuff, kg/heifer daily, DM		
System	Meadow hay	Protein supplement[2]	Corn
INT			
2001	4.9	1.6	—
2002	4.1	1.1	0.5
2003	4.3	1.3	0.9
RLX			
2001	5.9	0.6	—
2002	5.4	0.3	—
2003	5.3	0.6	—

[1]Heifers in INT developed to 56.5% of mature BW at initiation of the breeding season. Heifers in RLX developed to 50.9% of mature BW at initiation of the breeding season.
[2]Protein supplement composition is reported in Table 2.

At the initiation of the study each year, heifers were weighed on 2 consecutive days, stratified by first-day BW and birth date, and assigned randomly to treatment. Treatments were initiated on January 1 in 2001 and on December 1 in 2002 and 2003. Heifers were placed in hay-feeding grounds, by treatment, for the winter feeding period and were fed a diet consisting of meadow hay and protein supplement. Supplementation of INT heifers with whole corn as an energy source was required to achieve the desired target BW in 2002 and 2003 (Table 1). Protein supplement composition and hay nutrient analyses are summarized in Table 2. Heifers were weighed monthly, and feed amounts were subsequently adjusted to obtain the desired BW gains.

At the end of the winter feeding period (May 15), heifers were weighed and BCS (Wagner et al., 1988) was determined. Heifers were bled via coccygeal venipuncture 10 d apart before initiation of the breeding season to determine the number of heifers initiating estrous cycles before breeding. Blood samples were allowed to coagulate for 1 h at ambient temperature, samples were centrifuged at 1,300 × g for 20 min at 4°C, and serum was frozen at −20°C. Serum samples were analyzed for progesterone by direct solid-phase RIA (Coat-A-Count, Diagnostic Products Corporation, Los Angeles, CA; Schneider and Hallford, 1996) without extraction, as described by Melvin et al. (1999). Inter- and intraassay CV were 6 and 5%, respectively. Assay sensitivity was approximately 0.04 ng/mL. A progesterone concentration greater than 1 ng/mL in either sample was interpreted to indicate attainment of puberty.

To eliminate the possibility of service sire effects, heifers were combined and grazed on native Sandhills upland range for breeding. Beginning on May 20 of each year, heifers were exposed to fertile bulls at a bull:heifer ratio of 1:25. After a 45-d breeding season, INT heifers

Table 2. Ingredient composition of protein supplements and nutrient composition of meadow hay fed during heifer development

	Year				
Item	2001	2002	2003	2004	2005
Protein supplement ingredient composition, % of DM					
Wheat middlings	51.9	44.9	44.9	10.6	10.6
Dried distillers grains	20.6	—	—	62.0	62.0
Dried corn gluten feed	—	40.0	40.0	5.0	5.0
Cottonseed meal	—	—	—	9.0	9.0
Soybean hulls	10.0	10.0	10.0	—	—
Cull beans	12.8	—	—	—	—
Cane molasses	2.5	2.5	2.5	3.0	3.0
Calcium carbonate	—	—	—	3.0	3.0
Urea	—	—	—	2.0	2.0
Other[1]	2.2	2.6	2.6	5.4	5.4
Monensin, mg/kg	100	100	100	178	178
Meadow hay nutrient analysis, % of DM					
CP	9.1	9.6	8.8	8.8	8.1
TDN	57.7	57.2	55.1	56.5	60.2
NDF	59.4	60.0	58.3	—	—
ADF	40.1	45.6	40.7	41.5	38.2

[1]Other consists of monensin (Rumensin, Elanco Animal Health, Indianapolis, IN), trace minerals, and binder.

were removed from the breeding pasture, whereas RLX heifers remained with the bulls an additional 15 d. Sixty days after the end of the breeding season for RLX heifers (approximately September 10), pregnancy diagnosis was performed for both INT and RLX heifers via rectal palpation. Nonpregnant heifers were sorted at the time of palpation and sold as yearlings.

After pregnancy diagnosis, heifers were maintained as a single group on subirrigated meadow regrowth during fall (September to October). During the subsequent winter, pregnant heifers received 0.68 kg/heifer daily of the same supplement used during development and ad libitum access to meadow hay. Each year, precalving BW and BCS were recorded on approximately February 15, and calving began on approximately March 1. Calf birth weight was recorded within 24 h of birth. After calving, primiparous cows were maintained on meadow hay and supplement until May 10, at which time they were placed on subirrigated meadow until June 5. Native upland Sandhills range was grazed for the remainder of the study. Two-year-old cows were exposed to bulls (bull:cow ratio of 1:25) for 60 d beginning June 5. In early September, a rebreeding pregnancy diagnosis was performed and the calves were weaned. Calf weaning weight and cow BW and BCS were recorded at this time.

Economic Analysis, Exp. 1

Each heifer development system was analyzed for economic feasibility to determine which strategy might be optimal for replacement heifer production by using annual average prices for feed (Mark et al., 2003), pasture (Helmers and Johnson, 2003), and cattle (Feuz et al., 2003) to compare costs. Similar costs per heifer were charged against both systems for summer pasture the first year because compensating cattle have increased intakes relative to BW (Jordon, 2000; Creighton et al., 2003). Supplement costs used were an average of the actual costs paid over the 3-yr period. A price of $11.02/metric ton ($10/ton) for feed delivered was charged for labor and equipment operating costs. Interest (6%) was charged on the entire animal costs and half of the feed costs. Total and net costs were calculated by combining treatment means for production factors with feed and cattle prices for each year between 1992 and 2001.

Data were analyzed by using development costs for each treatment within year as the experimental unit with PROC MIXED (SAS Inst. Inc., Cary, NC) for a completely randomized design with a model including year and treatment. The interaction of year × treatment was not significant and was therefore removed from the final analysis. Means reported are the average costs over the 10-yr analysis period for each system.

Exp. 2

One hundred eighty-four heifers (215 ± 15 kg of BW; n = 104 and n = 80 in 2004 and 2005, respectively) were developed to achieve 50% of mature BW before a 45-d breeding season and were assigned randomly to the control (n = 103) or progestin [n = 81; melengestrol acetate (**MGA**) 0.5 mg/d, Pfizer Animal Health, New York, NY] treatment. Heifers were managed in a common group, except during progestin treatment. After weaning in late September of each year, heifers grazed subirrigated meadow regrowth and were supplemented with 0.45 kg/d of a dried distillers grains (**DDG**)-based cube (Table 2) until approximately January 1. Beginning approximately January 1 of each year, heifers were maintained in a drylot and fed meadow hay ad libitum and 0.45 kg/d of supplement. Heifers fed MGA received 0.5 mg of MGA/heifer per d in the supplement for 14 d, beginning 27 d before initiation of their initial 45-d breeding season. Estrous cyclicity was determined from 2 blood samples collected 10 d apart immediately before the breeding season, as described for Exp. 1. Control heifers received a similar supplement without MGA during this time. Heifers were moved to upland range at the beginning of the breeding season and remained on upland range pasture through October. Pregnancy was determined via transrectal ultrasonography approximately 60 d after the conclusion of breeding.

After the summer grazing period, heifers grazed corn crop residue and received 0.45 kg/d of the DDG-based supplement from November 1 to February 22 each year. During the precalving period, heifers were allowed ad libitum access to meadow hay. After calving and until early May, 0.45 kg/d of the DDG-based supplement was fed in addition to free-choice meadow hay. Primiparous cows and calves grazed subirrigated meadows from early May until the beginning of the second (60 d; 1:25 bull:cow ratio) breeding season on June 12 of each year. Pregnancy was determined via transrectal ultrasonography approximately 60 d after removal of bulls. Cow-calf pairs remained on native range throughout the remainder of the study.

Statistical Analysis, Exp. 1 and 2

Data were analyzed by using the mixed models procedures of SAS for a completely randomized design. Year was treated as a random variable, and differences between treatments were determined by using LSD. Binomial data, including pregnancy, cyclicity, and 2-yr-old retention rate, were transformed to the logit scale and analyzed with animal as the experimental unit by mixed models procedures (Cox, 1988; Martin et al., 2005). Means for fixed factors were estimated by using weighted least squares procedures (Gianola, 1982; Rutledge and Gunsett, 1982). The logit scale ensures that estimated pregnancy and cyclicity rates lie between 0 and 100%, and the weighted least squares corrected for the differences in number of heifers within each system. The weighting factor has been described by Gart and Zweifel (1967).

RESULTS AND DISCUSSION

Exp. 1

Performance. Performance results for heifers from treatment initiation through the first breeding season are reported in Table 3. There was no difference (P = 0.99) in beginning BW between the 2 systems. There was a difference (P < 0.001) in prebreeding BW, prebreeding BCS, and winter ADG between systems (Table 3). Target prebreeding BW for both systems was based on an expected mature BW of 544 kg, and was expected to be 272 and 299 kg for heifers in the RLX and INT systems, respectively. Heifers in both systems exceeded their targeted prebreeding BW, which resulted in RLX heifers averaging 50.9% and INT heifers averaging 56.5% of mature BW before the initial breeding season (Table 3).

Heifers in the RLX system weighed less than those in the INT system at the beginning of breeding, as designed by the winter feeding program for each system. Body weight at pregnancy diagnosis was greater (P = 0.006) for INT heifers compared with RLX heifers; however, the difference was less than that seen at the initiation of breeding (277 and 308 ± 7 vs. 375 and 384 ± 7 at the beginning of breeding and pregnancy diagnosis, respectively). This indicates the RLX heifers were able to compensate during summer grazing for some of the difference in BW created by the winter development system. A similar pattern was observed for BCS, with RLX heifers having lesser (P < 0.001) prebreeding and pregnancy diagnosis BCS but gaining more condition throughout the summer than INT heifers.

Previous research (Arije and Wiltbank, 1971; Short and Bellows, 1971; Wiltbank et al., 1985) suggests that RLX heifers should have reached puberty later than INT heifers. However, the proportion of heifers pubertal before breeding did not differ (P = 0.39; Table 3) between the 2 systems. It is possible that more RLX heifers exhibited their pubertal estrus, shown to be less fertile than subsequent estrous cycles (Byerley et al. 1987), which may have influenced conception date (Table 4). Further characterization of nonpregnant heifers within each system revealed that 82.4% (14 of 17; Table 3) of open RLX heifers (after a 60-d breeding season) but only 45.5% (5 of 11) of nonpregnant INT heifers (after a 45-d breeding season) were prepubertal before the beginning of the breeding season. This lends support to the hypothesis that one of the major determinants of a heifer's ability to conceive during her first breeding season is the age at which she attains puberty, especially in relation to the onset of the breeding season (Short et al., 1990).

Pregnancy rate after the initial breeding season was not different (P = 0.51) between INT and RLX heifers and averaged 88.5% across systems. Wiltbank et al. (1985) fed heifers to similar prebreeding target BW (272 or 318 kg) as in the current study but exposed heifers to bulls for a 90-d breeding season. Heifers fed to weigh 272 kg before breeding had a 16% lower first-calf pregnancy rate than heifers that weighed 318 kg at the initiation of the first breeding season (66 vs. 82% pregnancy rate for 272- and 318-kg heifers, respectively). Conversely, research (Funston and Deutscher, 2004) conducted with the same herd as in the current study reported that pregnancy rates following a 45-d breeding season were similar in heifers developed to 53 or 58% of mature BW before breeding, averaging 90% for both treatments. Previous reports (Clanton et al., 1983; Lynch et al., 1997) indicated that delaying BW gain

Table 3. Growth, reproductive, and calf performance of heifers developed in an intensive (INT) or relaxed (RLX) system from treatment initiation through the first breeding season (Exp. 1)[1]

Item	RLX	INT	SEM	*P*-value
n	142	119		
Beginning BW, kg	229	229	3	0.99
Winter ADG, kg/d	0.34	0.54	0.02	<0.001
Prebreeding BW, kg	277	308	7	<0.001
Prebreeding BCS	5.2	5.7	0.1	<0.001
Prebreeding percentage mature BW, %	50.9	56.5	—	<0.001
Cycling at beginning of breeding season,[2] %	34.9	52.1	—	0.39
Pregnancy diagnosis BW, kg	375	384	7	0.006
Pregnancy diagnosis BCS	5.6	5.9	0.1	<0.001
Pregnancy rate, %	87.2	89.8	—	0.51
Percentage of nonpregnant heifers prepubertal before breeding season, %	82.4	45.5	—	0.07

[1]Heifers in INT developed to 56.5% of mature BW at initiation of the breeding season. Heifers in RLX developed to 50.9% of mature BW at initiation of the breeding season.
[2]Percentage of heifers determined to have reached puberty, as indicated by a serum progesterone concentration >1 ng/mL before the initial breeding season.

and taking advantage of compensatory gain did not have detrimental effects on reproductive performance. However, the majority of compensatory growth occurred before breeding in other studies; therefore, prebreeding BW were not different between treatments. Lemenager et al. (1980) reported that winter BW gains were more important than gains made during the breeding season when conception rate and date of conception were compared. It is difficult to determine whether the partial compensation experienced by the RLX heifers contributed to the ability of these heifers to breed with equal success as INT heifers following an extended breeding season.

Body weight differences created by the winter development system were maintained over the second wintering period; therefore, precalving BW and BW at pregnancy diagnosis were greater ($P \leq 0.005$; Table 4) for INT than RLX heifers. Precalving BCS was also greater ($P = 0.06$) for INT than RLX heifers. Calving rate during the initial calving season, based on the number of heifers exposed to bulls, was not affected ($P = 0.41$; Table 4) by the development system. Average calving date

Table 4. Calving and reproductive performance of heifers developed in an intensive (INT) or relaxed (RLX) system from initial calving season through rebreeding as 2-yr-old cows (Exp. 1)[1]

Item	RLX	INT	SEM	*P*-value
Precalving BW, kg	433	449	14	<0.001
Precalving BCS	5.3	5.4	0.04	0.06
Calf birth date, Julian d	77	70	1	<0.001
Calf birth BW, kg	33	33	1	0.95
Calving rate,[2] %	84.5	89.1	—	0.41
Calved within 45 d,[3] %	76.1	87.4	—	0.23
Calving difficulty,[4] %	31.3	24.7	—	0.18
Calf weaning BW, kg	194	199	4	0.07
Weaning rate,[5] %	81.0	84.0	—	0.75
Pregnancy diagnosis BW, kg	417	431	10	0.005
Pregnancy diagnosis BCS	5.07	5.16	0.09	0.10
Pregnancy rate, %	92.4	93.8	—	0.61
2-yr-old retention,[6] %	75.6	79.1	—	0.72

[1]Heifers in INT developed to 56.5% of mature BW at initiation of the breeding season. Heifers in RLX developed to 50.9% of mature BW at initiation of the breeding season.
[2]Percentage of heifers exposed to bulls during the initial breeding season that calved the subsequent year.
[3]Percentage of heifers exposed to bulls during the initial breeding season that calved within the first 45 d of their first calving season.
[4]Percentage of heifers requiring assistance during calving.
[5]Percentage of heifers exposed to bulls during the initial breeding season that weaned a calf the subsequent year.
[6]Percentage of heifers exposed to bulls during the initial breeding season that became pregnant as 2-yr-old cows.

was later ($P < 0.001$; Table 4) for RLX than INT heifers, primarily because of the 15-d longer breeding season for RLX heifers. Funston and Deutscher (2004) reported no difference in calving date following a 45-d breeding season between heifers developed to 53 or 58% of mature BW before breeding, indicating that the mean conception date was similar between treatments. Interestingly, the proportion of heifers exposed to bulls that calved within the initial 45 d of the calving season was not affected ($P = 0.23$; Table 4) by treatment, and was 76.1% for RLX and 87.4% for INT heifers. As expected, nearly all (98.1%) pregnant INT heifers calved in the first 45 d of the calving season, which tended to be greater ($P = 0.06$) than the 90.0% of RLX heifers that calved in a 45-d calving season. Because 87.2% of RLX heifers became pregnant and 90.0% of those calved within a 45-d calving season, approximately 78.5% of RLX heifers would have been expected to conceive in a 45-d breeding season.

Short and Bellows (1971) reported that heifers gaining 0.23 kg/d throughout the winter experienced a 10% increase in early embryonic mortality and loss of pregnancy compared with heifers fed to gain 0.45 and 0.68 kg/d. However, in the current study, analysis of calving rate expressed on a per pregnant heifer basis did not differ ($P = 0.16$; data not shown) between systems, with 4.0% of pregnant RLX heifers compared with 1.9% of pregnant INT heifers failing to calve. Furthermore, neither calf birth BW nor the proportion of heifers requiring assistance at calving were different ($P > 0.17$) between systems. This finding contrasts with previous reports that heifers raised on a lower plane of nutrition from weaning to breeding tended to experience a greater incidence and severity of dystocia (Bellows and Short, 1978; Patterson et al., 1991). Patterson et al. (1991) also reported that heifers developed to 55% of mature BW before breeding had a 24% increase in the proportion of heifers requiring assistance during calving compared with heifers developed to 65% of mature BW before breeding. In this same study, *Bos taurus* × *Bos indicus* heifers raised to the same prebreeding BW percentages did not differ in incidence of dystocia at calving. Therefore, the ideal target BW for development appears to vary with genetic composition.

Calf weaning weights tended to be greater ($P = 0.07$; Table 4) for INT than RLX heifers; however, differences in calf weaning BW are likely attributable primarily to the difference in calving date. Freetly et al. (2001) reported that limit-feeding heifers may decrease first-calf survival, but in the current study, weaning rate as a proportion of heifers exposed for breeding was similar ($P = 0.75$; Table 4) between treatments. Because most calves are weaned on a particular date, rather than on a BW- or age-constant basis, calves born late in the normal calving season are usually lighter than those born early, decreasing the lifetime productivity of their dams (Lesmeister et al., 1973).

Lesmeister et al. (1973) reported that heifers calving late as 2 yr olds often fail to rebreed or calve later as 3 yr olds. However, second-calf pregnancy rates were similar ($P = 0.61$) between treatments (92.4 vs. 93.8% for RLX and INT heifers, respectively; Table 4). This indicates that RLX heifers became pregnant during their second breeding season with similar efficiency as INT heifers. Therefore, the proportion of heifers exposed for breeding as yearlings remaining in the herd as pregnant 2 yr olds was similar ($P = 0.72$) between systems, averaging 75.6 and 79.1% for the RLX and INT system, respectively (Table 4). Cow BW and BCS at weaning and second pregnancy diagnosis (Table 4) remained greater ($P = 0.005$ and $P = 0.10$, respectively) for INT than RLX cows.

Economic Analysis. Economic analysis results are summarized in Table 5. Total and net costs were calculated by using treatment means with feed and cattle prices for each year from 1992 to 2001, and statistically analyzed for effects of year and treatment. Total and net first-year development costs, and the net cost to produce a bred yearling heifer were lower ($P \leq 0.001$) for the RLX than the INT system when compared on a per-heifer basis. Net cost to produce one pregnant yearling heifer differed by $24 between the 2 systems, primarily because of the greater winter feed costs incurred for INT heifers. Because of increased BW, and therefore increased nutrient requirements, INT heifers had greater second winter feed and summer pasture costs. However, INT heifers weaned heavier calves and generated more income from the sale of cull heifers. Nonetheless, the net cost per bred 2-yr-old cow remained lower ($P = 0.001$) for RLX ($577) than INT heifers ($594), but the difference between the 2 systems was reduced to $17 because of the greater income generated from the INT treatment.

Exp. 2

The target prebreeding BW for heifers in Exp. 2 was 272 kg, or 50% of predicted mature BW. Prebreeding BW were similar ($P = 0.55$; Table 6) for control and MGA-supplemented heifers, and averaged 280 ± 19 kg, slightly greater than the target breeding BW. As a result, heifers in Exp. 2 were developed to 51.5% of mature BW at the time of breeding, based on an expected mature BW of 544 kg. Body weights and BCS at pregnancy diagnosis were similar ($P = 0.47$ and $P = 0.13$, respectively) for control and MGA-supplemented heifers. Pregnancy rates were 91.3% for control heifers and 88.9% for MGA-supplemented heifers ($P = 0.69$), which is similar to the report by Funston and Deutscher (2004), indicating that the reproductive potential was maintained in the current study. These results were somewhat surprising because a greater proportion of nonpregnant RLX heifers than INT heifers were prepubertal in Exp. 1. However, a greater percentage of heifers in Exp. 2 than in Exp. 1 were pubertal when exposed to bulls. Additionally, the breeding season began 13 d after completion of MGA feeding. Because of estrous synchronization, heifers fed MGA should not have dis-

Table 5. Development costs ($) for heifers developed in an intensive (INT) or relaxed (RLX) system (Exp. 1)[1]

Item	RLX	INT	SEM	Cost difference[2]	*P*-value	
					Treatment	Year
First-year total development cost[3]	582	603	2	21	<0.001	<0.001
First-year net development cost[4]	479	515	3	36	<0.001	<0.001
Net cost per bred heifer[5]	577	601	2	24	<0.001	<0.001
Net cost per pregnant 2-yr-old cow[6]	577	594	2	17	<0.001	<0.001

[1]Heifers in INT developed to 56.5% of mature BW at initiation of the breeding season. Heifers in RLX developed to 50.9% of mature BW at initiation of the breeding season.

[2]Heifers in INT developed to 56.5% of mature BW at initiation of the breeding season. Heifers in RLX developed to 50.9% of mature BW at initiation of the breeding season. Economic difference expressed in dollars per heifer between the RLX and INT heifer development systems.

[3]Total first-year development cost, including the opportunity cost of owning the heifer, feed, pasture, labor and equipment, and 6% annual interest on the value of the heifer and half of the feed.

[4]Total first-year development cost less the value of nonpregnant heifers.

[5]Total first-year development cost less the value of nonpregnant heifers and an additional assumed cull rate of 4% for the first year.

[6]Net cost per bred heifer plus second year costs less the value of nonpregnant cows and an additional assumed cull rate of 2.5% for the second year.

played estrus until approximately 5 to 10 d after the beginning of breeding. Therefore, the failure of the current study to produce differences in pregnancy rate, calving date, or calf weaning weight in heifers developed to 50% of mature BW and administered MGA before breeding may be due to a high proportion of heifers cycling when the breeding season began and the timing of MGA withdrawal relative to the beginning of the breeding season.

Precalving BW and BCS were similar ($P = 0.22$ and $P = 0.34$, respectively; Table 7) between treatments. Heifer development treatment did not affect ($P > 0.50$) calf birth date, birth weight, or the proportion of heifers requiring assistance during calving. At weaning, similar calf BW ($P = 0.28$) were achieved by calves from the control and MGA-supplemented cows. Furthermore, cow BW and BCS at second pregnancy diagnosis were similar ($P > 0.40$) for control and MGA-supplemented cows. However, second breeding season pregnancy rates were greater ($P = 0.03$; 93.3 vs. 88.0%) for control than MGA-supplemented cows.

The target BW concept for heifer development suggests that heifers be fed to reach a certain percentage of mature BW before the first breeding season, with 65% being the typical target (Patterson et al., 2000). However, age at puberty is not solely a function of rate of gain during the weaning to prebreeding period, but also contains a genetic aspect. Cundiff et al. (1986) reported distinct between-breed differences in age and BW at puberty, as well as subsequent reproductive performance. In general, faster gaining breed groups of larger mature size reach puberty at later ages than do slower gaining breed groups of smaller mature size (Cundiff et al., 1986). However, Freetly and Cundiff (1998) reported that accelerated rates of gain during the postweaning period, over a diverse group of breeds, did not result in increased production efficiency in the cows. The ability for reproductive performance to be maintained at lower target BW (approximately 50% of mature BW) within the herd used in the current study may result from genotype × environment interactions. Heifers used in the current study were produced by Husker Red bulls (three-quarters Red Angus, one-quarter Gelbvieh or Simmental) mated to MARC II cows (one-quarter each of Angus, Hereford, Simmental, and Gelbvieh). The genetic composition and level of perfor-

Table 6. Growth, reproductive, and calf performance of heifers developed to 50% of mature BW with or without prebreeding progestin exposure (Exp. 2)[1]

Item	Control	MGA	SEM	*P*-value
n	103	81		
Prebreeding weight, kg	280	281	19	0.55
Cycling at beginning of breeding season,[2] %	71.8	77.8	—	0.69
Pregnancy diagnosis BW, kg	378	381	22	0.47
Pregnancy diagnosis BCS	5.8	5.9	0.2	0.13
Pregnancy rate, %	91.3	88.9	—	0.69

[1]Heifers fed melengestrol acetate (MGA) received 0.5 mg of MGA/heifer per d in supplement for 14 d, beginning 27 d before initiation of their 45-d initial breeding season. Control heifers were fed the supplement without MGA.

[2]Percentage of heifers determined to have reached puberty, as indicated by a serum progesterone concentration >1 ng/mL before the initial breeding season.

Table 7. Calving and reproductive performance of heifers developed to 50% of mature BW with or without prebreeding progestin exposure from the initial calving season through rebreeding as 2-yr-old cows (Exp. 2)[1]

Item	Control	MGA	SEM	*P*-value
Precalving BW, kg	420	426	7	0.22
Precalving BCS	5.3	5.3	0.1	0.34
Calf birth date, Julian d	66	66	1	0.69
Calf birth BW, kg	32	33	1	0.52
Calving difficulty,[2] %	38.4	32.0	—	0.56
Calf weaning BW, kg	193	197	7	0.28
Pregnancy diagnosis BW, kg	426	428	4	0.78
Pregnancy diagnosis BCS	5.2	5.2	0.1	0.44
Pregnancy rate, %	93.3	88.0	—	0.03

[1]Heifers fed melengestrol acetate (MGA) received 0.5 mg of MGA/heifer per d in supplement for 14 d, beginning 27 d before initiation of their 45-d initial breeding season. Control heifers were fed the supplement without MGA.

[2]Percentage of heifers requiring assistance during calving.

mance in the herd used for the current study appeared to allow heifers developed to lighter than traditional prebreeding BW to achieve puberty and maintain reproductive performance. Further work is needed to evaluate the importance of genotype × environmental interactions as they affect reproductive performance.

Developing heifers to reach a target BW of 50% of mature BW is an effective method for reducing the heifer development cost. Extending the breeding season beyond 45 d for heifers of lighter BW allows first-calf pregnancy rates to equal those of heifers heavier at the initiation of breeding; however, it also results in a later average calving date and reduced weaning weights. The later calving date does not affect the ability of heifers to rebreed during the second breeding season. Net costs to produce a pregnant yearling heifer or 2-yr-old cow were less when heifers were developed to 50 rather than 55% of mature BW, regardless of breeding season length. Therefore, development of heifers to 50% of mature BW before the first breeding season is economically viable. Administration of oral progestin to heifers developed to 50% of mature BW before breeding did not affect reproductive performance during the first breeding season when heifers were exposed to bulls 13 d after the end of progestin treatment.

LITERATURE CITED

Adams, D. C., R. T. Clark, P. E. Reece, and J. D. Volesky. 1998. Research and education for managing resources within the Nebraska Sandhills: The Gudmundsen Sandhills Laboratory. Rangelands 20:4–8.

Arije, G. F., and J. N. Wiltbank. 1971. Age and weight at puberty in Hereford heifers. J. Anim. Sci. 33:401–406.

Bellows, R. A., and R. E. Short. 1978. Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility. J. Anim. Sci. 46:1522–1528.

Byerley, D. J., R. B. Staigmiller, J. G. Berardinelli, and R. E. Short. 1987. Pregnancy rates of beef heifers bred either on pubertal or third estrus. J. Anim. Sci. 65:645–650.

Clanton, D. C., L. E. Jones, and M. E. England. 1983. Effect of rate and time of gain after weaning on the development of replacement beef heifers. J. Anim. Sci. 56:280–285.

Clark, R. T., K. W. Creighton, H. H. Patterson, and T. N. Barrett. 2005. Economic and tax implications for managing beef replacement heifers. Prof. Anim. Sci. 21:164–173.

Creighton, K. W., C. B. Wilson, T. J. Klopfenstein, and D. C. Adams. 2003. Undegradable intake protein supplementation of compensating spring-born steers and summer-born steers during summer grazing. J. Anim. Sci. 81:791–799.

Cox, C. 1988. Multinomial regression models based on continuation ratios. Stat. Med. 7:435–441.

Cundiff, L. V., M. D. MacNeil, K. E. Gregory, and R. M. Koch. 1986. Between- and within-breed genetic analysis of calving traits and survival to weaning in beef cattle. J. Anim. Sci. 67:27–33.

Ferrell, C. L., and T. G. Jenkins. 1985. Cow type and the nutritional environment: Nutritional aspects. J. Anim. Sci. 61:725–741.

Feuz, D. M., P. A. Burgener, and T. Holman. 2003. Historical cattle and beef prices, seasonal patterns, and future basis for Nebraska, 1960–2002. Cooperative Ext. Publ. No. PHREC 02-21. Univ. of Nebraska, Lincoln.

Freetly, H. C., and L. V. Cundiff. 1998. Reproductive performance, calf growth, and milk production of first-calf heifers sired by seven breeds and raised on different levels of nutrition. J. Anim. Sci. 76:1513–1522.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2001. Production performance of beef cows raised on three different nutritionally controlled heifer development programs. J. Anim. Sci. 79:819–826.

Frisch, R. E. 1984. Body fat, puberty and fertility. Biol. Rev. 59:161–188.

Funston, R. N., and G. H. Deutscher. 2004. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance. J. Anim. Sci. 82:3094–3099.

Gart, J. J., and J. R. Zweifel. 1967. On the bias of various estimators of the logit and its variance with application to quantal bioassay. Biometrika 54:181–187.

Gianola, D. 1982. Theory and analysis of threshold characters. J. Anim. Sci. 54:1079–1096.

Helmers, G. A., and B. Johnson. 2003. Stable but variable characterizes Nebraska agricultural land values. Cornhusker Economics, Univ. of Nebraska, Lincoln.

Jordon, D. J. 2000. Performance and slaughter breakeven analysis of calf and yearling systems and compensatory growth. PhD Diss., Univ. of Nebraska, Lincoln.

Lemenager, R. P., W. H. Smith, T. G. Martin, W. L. Singleton, and J. R. Hodges. 1980. Effects of winter and summer energy levels on heifer growth and reproductive performance. J. Anim. Sci. 51:837–842.

Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. J. Anim. Sci. 36:1–6.

Lynch, J. M., G. C. Lamb, B. L. Miller, R. T. Brandt Jr., R. C. Cochran, and J. E. Minton. 1997. Influence of timing of gain on growth and reproductive performance of beef replacement heifers. J. Anim. Sci. 75:1715–1722.

Mark, D., D. Feuz, R. Selley, and T. Barrett. 2003. Crop and livestock prices for Nebraska producers. Nebraska Cooperative Ext. No. EC03-883-C. Univ. of Nebraska, Lincoln.

Martin, J. L., R. J. Rasby, D. R. Brink, R. U. Lindquist, D. H. Keisler, and S. D. Kachman. 2005. Effects of supplementation of whole corn germ on reproductive performance, calf performance, and leptin concentration in primiparous and mature beef cows. J. Anim. Sci. 83:2663–2670.

Melvin, E. J., B. R. Lindsey, J. Quintal-Franco, E. Zanella, K. E. Fike, C. P. Van Tassell, and J. E. Kinder. 1999. Circulating concentrations of estradiol, luteinizing hormone, and follicle-stimulating hormone during waves of ovarian follicular development in prepubertal cattle. Biol. Reprod. 60:405–412.

Patterson, D. J., L. R. Corah, J. R. Brethour, M. F. Spire, J. J. Higgins, G. H. Kiracofe, J. S. Stevenson, and D. D. Simms. 1991. Evaluation of reproductive traits in *Bos taurus* and *Bos indicus* crossbred heifers: Effects of postweaning energy manipulation. J. Anim. Sci. 69:2349–2361.

Patterson, D. J., R. C. Perry, G. H. Kiracofe, R. A. Bellows, R. B. Staigmiller, and L. R. Corah. 1992. Management considerations in heifer development and puberty. J. Anim. Sci. 70:4018–4035.

Patterson, D. J., S. L. Wood, and R. F. Randle. 2000. Procedures that support reproductive management of replacement beef heifers. Proc. Am. Soc. Anim. Sci., 1999. http://www.asas.org/jas/symposia/proceedings/0902.pdf Accessed Oct. 15, 2006.

Rutledge, J. J., and F. C. Gunsett. 1982. Analysis of categorical data in animal sciences. J. Anim. Sci. 54:1072–1078.

Schneider, F. A., and D. M. Hallford. 1996. Use of a rapid progesterone radioimmunoassay to predict pregnancy and fetal numbers in ewe. Sheep and Goat Res. 12:33–42.

Short, R. E., and R. A. Bellows. 1971. Relationships among weight gains, age at puberty and reproductive performance in heifers. J. Anim. Sci. 32:127–131.

Short, R. E., R. B. Staigmiller, R. A. Bellows, and R. C. Greer. 1990. Breeding heifers at one year of age: Biological and economical considerations. Pages 93–106 in Proc. 39th Annu. Beef Cattle Short Course. Univ. of Florida, Gainesville.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603–612.

Wiltbank, J. N., S. Roberts, J. Nix, and L. Rowden. 1985. Reproductive performance and profitability of heifers fed to weigh 272 or 318 kg at the start of the first breeding season. J. Anim. Sci. 60:25–34.