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Reproductive Performance, Calf Growth, and Milk Production of First-Calf Heifers Sired by Seven Breeds and Raised on Different Levels of Nutrition

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ABSTRACT: We evaluated heifers crossbred from seven breeds of sires (Hereford, Angus, Belgian Blue, Piedmontese, Brahman, Boran, and Tuli) and three breeds of dams (Angus, Hereford, and MARC III [four-breed composite]). Heifers were mated to Red Poll sires to calve at 2 yr of age. Heifers were placed in two treatments from weaning to breeding and raised on a high nutrition level (15.8 Mcal ME/d) or on 80% of the high nutrition level (12.6 Mcal ME/d). Breeds differed in the age of the heifers at parturition (P = .03). Birth weights of calves differed by maternal grandsire (P < .001) but not by heifer treatment (P = .91) or maternal grandam (P = .19). Heifers differed in their postpartum interval to estrus by sire breed (P = .001). Calf age at weaning (P = .02), calf ADG (P < .001), and 205-d weight (P < .001) differed between breeds of maternal grandsires. Milk production from 50 to 200 d of lactation was greatest for heifers of Belgian Blue (1,070 ± 30 kg) and Brahman (1,029 ± 38 kg) sires. Milk production did not differ with treatment group (P = .84). This study suggests that over a diverse group of breeds, accelerated rates of gain during the postweaning period within the ranges of this study do not result in increased production efficiency of the cows.

Key Words: Cattle, Heifers, Milk Production, Pregnancy, Nutrition

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Introduction

Differences in production traits among breeds of cattle (Laster et al., 1976, 1979; Gregory et al., 1979) allow for the selection of breeds that are suitable for a given production system. Alteration in prepubertal nutrition management can reduce heifer development cost (Clanton et al., 1983; Freetly and Cundiff, 1997). Previous studies have demonstrated that changing prepubertal nutritional management can alter age at puberty and subsequent cow performance (Sorensen et al., 1959; Wiltbank et al., 1966; Ferrell, 1982). Heifers from seven breeds of sires (Hereford, Angus, Piedmontese, Belgian Blue, Brahman, Boran, and Tuli) were raised on two levels of nutrition (Freetly and Cundiff, 1997). Heifers on the Low level ate 20% less dry matter than the heifers on the High level and tended to reach puberty 5 d later than High heifers. Feeding levels did not differ in the number of heifers that became pregnant with their first calf. There were breed differences in growth rates as well as differences in the age at which they reached puberty. In the current study, the effect of breed type and previous nutrition on first-calf heifer production characteristics were evaluated.

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Materials and Methods

Mating schemes and prebreeding heifer management were described in detail in a previous study (Freetly and Cundiff, 1997). Briefly, crossbred heifers were produced by top-crossing multiple sires within seven breeds (Hereford, n = 30; Angus, n = 42; Belgian Blue, n = 25; Piedmontese, n = 17; Brahman, n = 21; Boran, n = 8; and Tuli n = 9;) on Angus (n ≈ 500), Hereford (n ≈ 350), and MARC III composite (1/4 Angus, 1/4 Hereford, 1/4 Pinzgauer, 1/4 Red Poll; n ≈ 550) dams. Calves were produced over a 3-yr period (1992 to 1994).

Management and Nutrition. Calves (n = 1,275) were weaned at an average of 186 ± 12 d of age and placed in a drylot. Heifers were allowed to adjust to the drylot for a 42-d period and then were assigned to treatment groups. Within sire breeds, calves were randomly divided into two treatments. Heifers were penned by sire breed and treatment. Hereford- and Angus-sired crossbred heifers were treated as a single-sire breed.

The **High** nutrition treatment received 15.8 Mcal ME/d. The **Low** nutrition treatment (12.6 Mcal ME/d) was pair-fed by pen to the High nutrition treatment of the same sire breed. The Low treatment received 80% of the daily feed of the High treatment, resulting in a 20% decrease in nutrients. From weaning until mid-March, heifers were fed a 75% corn silage, 23% alfalfa haylage, and 2% protein mix (as-fed). The diet contained approximately 2.34 Mcal ME/kg DM and was approximately 11.6% CP. From mid-March through the end of the feeding period (early May), heifers were fed a 59% corn silage, 39% alfalfa haylage, and 2% protein mix (as-fed). The diet contained approximately 2.24 Mcal ME/kg DM and was approximately 12.3% CP. In general, the average daily gain for heifers in the Low treatment was 66% of that of the heifers in the High treatment (.66 kg/d), but there were treatment × sire breed interactions for weight gain in the drylot (Freetly and Cundiff, 1997). Heifers were removed from the drylot in early May and placed on grass pasture as a single herd for 14 d before breeding. Heifers were exposed to Red Poll bulls for a 63-d breeding season. During the following winter, pregnant heifers were fed corn silage in addition to pasture. Corn silage was not fed after the end of April and was stopped before milk production measurements began.

Data Collection. Eight heifers had twins, and their data were excluded from the study. Three were sired by Belgian Blue and one each from Hereford, Piedmontese, Brahman, Boran, and Tuli sires. At birth, calves were weighed. In the first 2 yr, heifers from MARC III dams were placed in a separate herd to determine milk production. Forty-five days after the birth of the first calf, vasectomized bulls were placed with the remaining heifers to facilitate detection of estrus for the determination of postpartum interval. Heifers were checked visually twice daily for behavioral estrus through the end of the breeding season. Heifers used for milk production estimates were not monitored for estrus, and they are not included as observations for postpartum interval to estrus. Heifers were randomly assigned to be bred

Table 1. Least squares means and standard errors for calving percentage, heifer age, and calf birth weight

Sire breed	Heifers exposed	Heifers calved, %	Heifers calved	Heifer's age at parturition, d	Calf birth weight, kg
Hereford	117	89 ± 4[a]	102	703 ± 2[ab]	35.8 ± .5[a]
Low	60	88 ± 5	51	700 ± 3	35.5 ± .8
High	57	89 ± 5	51	705 ± 3	36.1 ± .8
Angus	78	84 ± 4[a]	66	706 ± 2[a]	34.4 ± .6[abc]
Low	40	92 ± 7	35	707 ± 4	34.6 ± 1.1
High	38	76 ± 7	31	705 ± 4	34.3 ± 1.1
Belgian Blue	193	84 ± 4[a]	162	699 ± 2[b]	36.0 ± .5[a]
Low	97	84 ± 4	81	697 ± 2	35.8 ± .6
High	96	84 ± 4	81	701 ± 2	36.3 ± .6
Piedmontese	60	92 ± 5[a]	55	699 ± 3[b]	35.8 ± .7[ab]
Low	30	88 ± 7	26	698 ± 4	36.4 ± 1.0
High	30	97 ± 7	29	699 ± 4	35.3 ± 1.0
Brahman	190	80 ± 3[a]	152	705 ± 2[a]	34.4 ± .4[bc]
Low	95	77 ± 4	73	704 ± 2	34.2 ± .6
High	95	84 ± 4	79	706 ± 2	34.6 ± .6
Boran	192	92 ± 4[a]	173	699 ± 2[b]	33.3 ± .5[c]
Low	95	94 ± 5	87	700 ± 2	33.4 ± .6
High	97	90 ± 5	86	698 ± 2	33.2 ± .6
Tuli	199	89 ± 4[a]	175	701 ± 2[ab]	34.1 ± .5[c]
Low	100	91 ± 5	90	702 ± 2	34.1 ± .6
High	99	86 ± 5	85	700 ± 2	34.0 ± .6
		Probability levels			
Sire (S)		.15		.03	<.001
Treatment (T)		.67		.67	.91
Dam (D)		.87		.65	.19
Year (Y)		.95		.51	.006
S × T		.36		.63	.95
D × T		.68		.68	.13
S × D		.35		.29	.94
S × Y		.39		.09	.39
D × Y		<.001		.13	.59
T × Y		.77		.25	.72

[a,b,c]Sire breed means within a column lacking a common superscript letter differ ($P < .05$).

either to Charolais- or Belgian Blue-cross (Belgian Blue × Angus, Belgian Blue × MARC III) bulls for their second calf. Multiple bulls were used for natural service over a 63-d breeding season with a heifer:bull ratio of 25:1. Piedmontese-cross heifers were bred by artificial insemination, and subsequent palpation and second pregnancy data have been excluded from the study. Heifers were palpated approximately 65 d following breeding to determine whether they were pregnant. Hip height was measured at palpation. Body condition score (1 to 9 scale) was determined at breeding and at palpation. Within year, all calves, were weaned on the same day.

Heifers with MARC III dams were used to estimate milk production. Milk production was determined with the weigh-suckle-weigh method when calves averaged 52, 72, 93, 115, 142, 170, and 198 d of age. The standard deviation for age at milk production was 13. Calves were separated from their dams at 1500, and milk production was determined 16 h later.

Data Analysis. Calf ADG was calculated as the difference between weaning weight and birth weight divided by days of age at weaning. Body weight at 205 d was calculated as individual calf ADG before weaning multiplied by 205 d plus birth weight. Data were analyzed with a least squares procedure (Harvey, 1985), and least squares means and SE are presented in the text and tables. Heifers that failed to wean a calf were excluded from data analysis for postpartum interval to estrus (Table 2), prebreeding data (Table 3), and palpation data for second calf (Table 5). Cows that never expressed a behavioral estrus are not included in the calculation of postpartum interval (Table 2). Data for age, BW, ADG, body condition score, hip height, percentage of heifers bred, and weaning percentage were analyzed with a mixed model that included sire breed, sire nested within sire breed, treatment, dam breed, birth year, sire breed-treatment, dam breed-treatment, sire breed-dam breed, sire breed-birth year, dam breed-birth year, and treatment-birth year (Tables 1, 3, 4, and 5). Sire breed, dam breed, treatment, and birth year were treated as fixed effects. Sire breed was tested using sire nested within sire breed as the source of error. Data for postpartum interval (Table 2) were analyzed with a fixed model that included sire breed, treatment, dam breed, birth year, sire breed-treatment, dam breed-treatment, sire breed-dam breed, sire breed-birth year, and treatment-birth year. Sire breed means across treatments and within treatments were tested with nonorthogonal contrasts. Means for Low and High nutrition treatment within sire breed were tested with nonorthogonal contrasts.

Daily milk production was calculated as the average hourly milk production multiplied by 24. A third-order polynomial regression was fit for each animal; milk production was the dependent variable, and calf age was the independent variable. Using a step-down approach, the third-order polynomial was chosen as the highest-order polynomial appropriate to describe the data. Individual animals were fit with a sixth-order polynomial:

$$f(x) = b_6x^6 + b_5x^5 + b_4x^4 + b_3x^3 + b_2x^2 + b_1x + b_0$$

The coefficient for the sixth-order term (b_6) was then tested with the hypothesis that $b_6 \neq 0$ ($P < .05$). The hypothesis was rejected, and the process was repeated for the fifth-, fourth-, and third-order polynomial until the hypothesis was accepted. Milk production was calculated for each individual animal by integrating the area under the curve:

$$\text{milk production} = \int b_3x^3 + b_2x^2 + b_1x + b_0$$

Total milk production during the observation period was calculated for calf ages from 50 to 200 d. Milk production was also calculated for calf ages 50 to 100 d (early), 100 to 150 d (middle), and 150 to 200 d (late). Breed and treatment differences in regression coefficients and milk production were analyzed with a model that included sire breed, treatment, birth year,

Table 2. Least squares means and standard errors for postpartum interval to detected estrus after first parturition

Sire breed	Heifers observed	Postpartum interval, d
Hereford	60	68 ± 4[abc]
Low	29	69 ± 4
High	31	68 ± 5
Angus	28	59 ± 5[b]
Low	17	56 ± 6
High	11	63 ± 6
Belgian Blue	100	68 ± 2[bd]
Low	46	70 ± 3
High	54	67 ± 3
Brahman	71	71 ± 3[cde]
Low	35	68 ± 4
High	36	74 ± 3
Boran	94	78 ± 2[e]
Low	47	80 ± 3
High	47	76 ± 3
Tuli	87	76 ± 2[ae]
Low	45	79 ± 3
High	42	73 ± 3
	Probability levels	
Sire (S)		<.001
Treatment (T)		.89
Dam (D)		.87
Year (Y)		.009
S × T		.37
D × T		.66
S × D		.50
S × Y		.03
T × Y		.33

[a,b,c,d,e]Sire breed means within a column lacking a common superscript letter differ ($P < .05$).

sire breed-treatment, sire breed-birth year, and treatment-birth year. All milk production model effects were tested with the model residual as the source of error (Table 6). Responses with probabilities less than .05 were considered to be different.

Results

Parturition. Calving percentage expressed as heifers calved per heifer exposed did not differ between sire breeds (P = .15; Table 1). Calving percentage did not differ (P = .67) between heifers fed on the Low (88 ± 2%) and the High (86 ± 2%) levels. Calving percentage did not differ (P = .87) between heifers from Hereford (88 ± 3%), Angus (86 ± 3%), or MARC III (87 ± 3%) dams.

Heifer age at parturition (P = .03) differed with sire breed (Table 1). Heifer age at parturition did not differ (P = .67) between the Low (701 ± 1 d) and High (702 ± 1 d) nutrition treatments. Heifer age at parturition did not differ (P = .65) between heifers from Hereford (700 ± 2 d), Angus (702 ± 1 d), or MARC III (703 ± 1 d) dams.

Calf birth weight (P < .001) differed with maternal-grandsire breed (Table 1). Calf birth weight did not differ (P = .91) between the Low (34.9 ± .3 kg) and High (34.8 ± .3 kg) nutrition treatments. Calf birth weight did not differ (P = .19) between heifers from Hereford (34.7 ± .5 kg), Angus (34.5 ± .4 kg), or MARC III (35.4 ± .4 kg) dams.

Postpartum Interval to Estrus and Prebreeding. Sire breeds differed (P < .001) in the duration of the postpartum interval to detected estrus (Table 2). The duration of the postpartum interval did not differ (P = .89) between the Low (70 ± 2 d) and High (70 ± 1 d) nutrition treatments. The duration of the postpartum interval did not differ (P = .87) between heifers from Hereford (71 ± 2 d), Angus (70 ± 2 d), or MARC III (70 ± 2 d) dams.

Prebreeding BW differed (P < .001) between sire breeds (Table 3). Heifers raised on the Low nutrition treatment tended (P = .08) to have lower BW (442 ± 4 kg) at breeding than heifers raised on the High treatment (449 ± 4 kg). Heifers with MARC III dams had lower breeding BW (436 ± 4 kg) than heifers with Hereford (452 ± 5 kg) or Angus (448 ± 4 kg) dams.

Table 3. Least squares means and standard errors for heifer before breeding

Sire breed	n	Weight, kg	Condition score[ab]	Hip height, cm[a]
Hereford	85	480 ± 6[c]	6.2 ± .1	131.0 ± .5[c]
Low	43	484 ± 8	6.1 ± .2	131.9 ± .7
High	42	477 ± 9	6.4 ± .2	130.1 ± .7
Angus	59	468 ± 6[cd]	6.0 ± .1	129.8 ± .5[cd]
Low	32	457 ± 10	5.9 ± .2	130.1 ± .8
High	27	479 ± 10	6.1 ± .2	129.5 ± .9
Belgian Blue	142	442 ± 6[e]	4.4 ± .1	129.7 ± .5[d]
Low	66	434 ± 7	4.3 ± .1	129.2 ± .6
High	76	451 ± 6	4.5 ± .1	130.2 ± .6
Brahman	123	455 ± 5[de]	6.3 ± .1	134.9 ± .4[e]
Low	61	452 ± 6	6.2 ± .1	134.9 ± .5
High	62	457 ± 6	6.3 ± .1	134.9 ± .5
Boran	154	410 ± 7[f]	6.5 ± .1	128.8 ± .6[d]
Low	78	408 ± 8	6.5 ± .2	128.8 ± .7
High	76	413 ± 8	6.5 ± .2	128.8 ± .7
Tuli	146	418 ± 7[f]	6.2 ± .1	128.9 ± .6[d]
Low	76	416 ± 8	6.2 ± .1	128.6 ± .7
High	70	419 ± 8	6.2 ± .2	129.1 ± .7
		Probability levels		
Sire (S)		<.001	<.001	<.001
Treatment (T)		.08	.10	.69
Dam (D)		.003	<.001	.42
Year (Y)		.10	.89	.71
S × T		.38	.47	.19
D × T		.58	.56	.11
S × D		.16	.02	.009
S × Y		.06	.66	.14
D × Y		.32	<.001	.005
T × Y		.49	.21	.54

[a]Sire breed × dam breed interaction is presented in the text.
[b]Body condition score scale is 1 to 9.
[c,d,e,f]Sire breed means within a column lacking a common superscript letter differ (P < .05).

Sire breeds differed across dam breeds for body condition score at breeding (*P* = .02). On Hereford dams, sire breeds ranked Belgian Blue (4.5 ± .2), Angus (6.2 ± .2), Tuli (6.6 ± .2), Brahman (6.8 ± .2), and Boran (6.8 ± .2). On Angus dams, sire breeds ranked Belgian Blue (4.3 ± .1), Brahman (6.3 ± .2), Tuli (6.3 ± .1), Hereford (6.3 ± .1), and Boran (6.6 ± .1). On MARC III dams, sire breeds ranked Belgian Blue (4.4 ± .1), Angus (5.8 ± .2) Brahman (5.8 ± .1), Tuli (5.8 ± .1), Hereford (5.9 ± .2), and Boran (6.1 ± .1). There was no difference (*P* = .10) in body condition score at breeding between the Low (5.9 ± .1) and High (6.0 ± .1) treatments. Sire breeds differed across dam breeds for hip height at breeding (*P* = .009). On Hereford dams, sire breeds ranked Boran (129 ± .9 cm), Belgian Blue (129 ± 1.0 cm), Tuli (129 ± 1.0 cm), Angus (132 ± 1.1 cm), and Brahman (135 ± .9 cm). On Angus dams, sire breeds ranked Tuli (128 ± .6 cm), Boran (128 ± .7 cm), Belgian Blue (129 ± .6 cm), Hereford (131 ± .6 cm), and Brahman (135 ± .7 cm). On MARC III dams, sire breeds ranked Angus (128 ± 1.0 cm), Tuli (129 ± .6 cm), Boran (130 ± .6 cm), Hereford (131 ± .7 cm), Belgian Blue (131 ± .5 cm), and Brahman (134 ± .5 cm).

Weaning. Sire breeds differed in the percentage of calves weaned per heifer exposed, but not in the percentage of calves weaned per heifers that calved (Table 4). Percentage of calves weaned per heifer exposed did not differ (*P* = .57) with heifers from Hereford (74 ± 4%), Angus (72 ± 3%), or MARC III (77 ± 3%) dams. There was no difference (*P* = .66) in percentage of calves weaned per heifer exposed between the Low (74 ± 3%) and High (75 ± 3%) treatments. Maternal-grandsire breeds differed in the age of calf at weaning, weaning BW, 205-d BW, and preweaning ADG of the calves (Table 4). Preweaning ADG did not differ (*P* = .11) between calves from heifers with Hereford (.75 ± .01 kg/d), Angus (.77 ± .01 kg/d), or MARC III (.78 ± .01 kg/d) dams. There was no difference (*P* = .95) in preweaning ADG

Table 4. Least squares means and standard errors for calf age, body weight, and average daily gain

Sire breed of heifer	Calves weaned	Weaned, % Heifers exposed	Weaned, % Heifers calved	Weaning Age, d	Weaning Weight, kg	205-d wt, kg	ADG, kg/d
Hereford	85	74 ± 5[ab]	84 ± 4[a]	214 ± 2[ab]	191 ± 3[ab]	184 ± 3[abc]	.72 ± .01[ab]
Low	43	71 ± 7	82 ± 6	215 ± 3	196 ± 5	188 ± 4	.74 ± .02
High	42	77 ± 7	85 ± 6	214 ± 3	186 ± 5	181 ± 5	.71 ± .02
Angus	59	75 ± 5[ab]	88 ± 5[a]	213 ± 2[ab]	198 ± 4[ac]	191 ± 3[ad]	.77 ± .01[c]
Low	32	84 ± 9	92 ± 8	213 ± 4	199 ± 6	192 ± 5	.77 ± .02
High	27	65 ± 9	84 ± 9	214 ± 4	197 ± 7	190 ± 6	.76 ± .03
Belgian Blue	143	73 ± 4[ab]	87 ± 3[a]	216 ± 2[a]	200 ± 3[c]	192 ± 3[d]	.76 ± .01[c]
Low	67	67 ± 5	80 ± 4	217 ± 2	199 ± 4	190 ± 3	.75 ± .02
High	76	79 ± 5	94 ± 4	215 ± 2	202 ± 4	195 ± 3	.77 ± .01
Piedmontese	50	78 ± 6[ab]	85 ± 5[a]	215 ± 2[ab]	202 ± 4[cd]	194 ± 4[d]	.77 ± .02[c]
Low	23	72 ± 9	82 ± 8	215 ± 3	205 ± 6	197 ± 5	.78 ± .02
High	27	85 ± 9	87 ± 7	215 ± 3	199 ± 6	192 ± 5	.76 ± .02
Brahman	123	64 ± 4[a]	80 ± 3[a]	208 ± 2[c]	210 ± 3[d]	208 ± 3[e]	.85 ± .01[d]
Low	61	59 ± 5	78 ± 5	208 ± 2	206 ± 4	204 ± 3	.83 ± .01
High	62	69 ± 5	82 ± 4	208 ± 2	215 ± 4	213 ± 3	.87 ± .02
Boran	154	83 ± 5[b]	90 ± 3[a]	213 ± 2[ab]	201 ± 4[c]	194 ± 3[d]	.79 ± .02[c]
Low	78	85 ± 6	90 ± 4	214 ± 2	203 ± 4	196 ± 4	.79 ± .02
High	76	81 ± 6	90 ± 4	212 ± 2	198 ± 4	193 ± 4	.78 ± .02
Tuli	146	75 ± 4[b]	84 ± 3[a]	211 ± 2[bc]	185 ± 4[b]	181 ± 3[c]	.72 ± .01[b]
Low	76	77 ± 5	85 ± 4	210 ± 2	185 ± 4	182 ± 4	.72 ± .02
High	70	72 ± 5	84 ± 4	212 ± 2	185 ± 4	181 ± 4	.72 ± .02
				Probability levels			
Sire (S)		.03	.33	.02	<.001	<.001	<.001
Treatment (T)		.66	.46	.86	.67	.76	.95
Dam (D)		.57	.28	.44	.08	.09	.11
Year (Y)		.24	.06	<.001	<.001	<.001	<.001
S × T		.16	.51	.92	.26	.14	.20
D × T		.89	.56	.49	.87	.43	.65
S × D		.78	.38	.18	.07	.43	.43
S × Y		.54	.86	.14	.07	.21	.31
D × Y		<.001	.02	.58	.001	<.001	<.001
T × Y		.59	.64	.03	.36	.97	.88

[a,b,c,d]Maternal-grandsire breed means within a column lacking a common superscript letter differ (*P* < .05).

between calves from heifers in the Low (.77 ± .01 kg/d) and High (.77 ± .01 kg/d) treatments. The 205-d BW did not differ (P = .09) between calves from heifers with Hereford (188 ± 3 kg), Angus (193 ± 2 kg), or MARC III (195 ± 2 kg) dams. There was no difference (P = .76) in 205-d BW between calves from heifers in the Low (193 ± 2 kg) and High (192 ± 2 kg) treatments.

Palpation. There tended (P = .05) to be a sire breed × dam breed interaction for the percentage of heifers pregnant with a second calf. On Hereford dams, sire breeds ranked Brahman (85 ± 5%), Tuli (98 ± 5%), Boran (100 ± 5%), Belgian Blue (101 ± 6%), and Angus (109 ± 8%). On Angus dams, sire breeds ranked Tuli (92 ± 3%), Boran (93 ± 3%), Belgian Blue (96 ± 3%), Hereford (99 ± 4%), and Brahman (99 ± 4%). On MARC III dams, sire breeds ranked Angus (74 ± 6%), Brahman (93 ± 3%), Hereford (94 ± 4%), Tuli (96 ± 3%), Boran (96 ± 3%), and Belgian Blue (98 ± 3%). There was no difference (P = .33) between the Low (94 ± 2%) and High (97 ± 2%) treatments for the percentage of heifers pregnant with a second calf.

Sire breeds differed (P < .001) in body condition score at palpation (Table 5). Heifers with Hereford dams (5.7 ± .1) tended to have a higher body condition score than did heifers with Angus (5.5 ± .1) or MARC III (5.5 ± .1) dams. At palpation, body condition score was lower (P = .04) in heifers raised on the Low treatment (5.5 ± .1) compared with heifers raised on the High treatment (5.7 ± .1).

Sire breeds differed (P < .001) in body weight at palpation (Table 5). At palpation, heifers with Hereford dams (475 ± 5 kg) tended to weigh more than heifers with Angus (466 ± 4 kg) or MARC III (464 ± 4 kg) dams. Heifers that had been raised on the Low treatment tended to weigh (465 ± 4 kg) less than heifers raised on the High treatment (472 ± 4 kg).

Sire breeds differed (P < .001) in hip height at palpation (Table 5). At palpation, heifers from Angus dams (130.4 ± .3 cm) were shorter at the hip than were heifers from Hereford (131.4 ± .4 cm) or MARC III (131.6 ± .3 cm) dams.

Milk Production. Total milk yield did not differ between the Low (926 ± 20 kg) and High (921 ± 19 kg) treatments; however, there were differences between heifers with different sire breeds (Table 6).

Table 5. Least squares means and standard errors for heifers at palpation

Sire breed	n	Pregnant, %	Weight, kg	Body condition score[a]	Hip height, cm
Hereford	85	98 ± 3	506 ± 6[b]	5.6 ± .1[b]	131.9 ± .5[b]
Low	43	100 ± 4	504 ± 8	5.5 ± .1	132.2 ± .7
High	42	96 ± 5	507 ± 9	5.7 ± .2	131.6 ± .8
Angus	59	91 ± 3	489 ± 6[bc]	5.4 ± .1[b]	130.9 ± .6[bc]
Low	32	82 ± 5	475 ± 9	5.2 ± .2	130.6 ± .8
High	27	101 ± 6	502 ± 10	5.6 ± .2	131.3 ± .9
Belgian Blue	142	98 ± 3	466 ± 6[d]	4.0 ± .1[c]	130.3 ± .5[c]
Low	66	97 ± 3	459 ± 7	3.9 ± .1	129.9 ± .6
High	76	100 ± 3	473 ± 6	4.0 ± .1	130.8 ± .6
Brahman	123	92 ± 2	477 ± 5[cd]	6.0 ± .1[e]	135.0 ± .5[d]
Low	61	92 ± 3	479 ± 6	6.0 ± .1	134.9 ± .6
High	62	93 ± 3	475 ± 6	6.1 ± .1	135.0 ± .6
Boran	154	96 ± 3	432 ± 8[e]	6.3 ± .1[d]	129.0 ± .7[e]
Low	78	100 ± 3	433 ± 8	6.3 ± .1	129.4 ± .7
High	76	93 ± 3	431 ± 8	6.4 ± .1	128.7 ± .7
Tuli	146	95 ± 3	439 ± 7[e]	6.0 ± .1[e]	129.5 ± .7[ce]
Low	76	94 ± 3	438 ± 8	6.0 ± .1	129.7 ± .7
High	70	96 ± 3	441 ± 8	6.1 ± .1	129.3 ± .7
		Probability levels			
Sire (S)		.40	<.001	<.001	<.001
Treatment (T)		.33	.08	.02	.94
Dam (D)		.09	.09	.11	.002
Year (Y)		.77	<.001	.03	.08
S × T		.10	.20	.77	.35
D × T		.20	.49	.82	.11
S × D		.05	.10	.53	.52
S × Y		.60	.01	.08	.03
D × Y		.65	.02	.04	.55
T × Y		.97	.48	.50	.72

[a]Body condition score scale 1 to 9.
[b,c,d,e]Sire breed means within a column lacking a common superscript letter differ (P < .05).

Table 6. Means and standard errors for the polynomial regression coefficients for daily milk production and estimated cumulative milk yields

		Coefficients for daily milk production, kg/d $f(x) = b_3x^3 + b_2x^2 + b_1x + b_0$				Estimated milk yields, kg			
Sire breed	n	$b_3 \times 10^{-6}$	$b_2 \times 10^{-4}$	$b_1 \times 10^{-2}$	b_0	Early 50–100 d	Middle 100–150 d	Late 150–200 d	Total 50–200 d
Hereford	24	1.209 ± 1.238[abc]	−6.922 ± 4.866[ab]	9.175 ± 5.980[ab]	3.046 ± 2.170[abc]	323 ± 17[a]	301 ± 18[a]	218 ± 14[a]	842 ± 45[a]
Low	14	2.670 ± 1.648	−13.094 ± 6.683	17.141 ± 8.509	.284 ± 3.231	338 ± 19	320 ± 21	226 ± 15	883 ± 46
High	10	−.838 ± 1.762	1.719 ± 6.380	−1.977 ± 7.017	6.914 ± 2.219	302 ± 32	273 ± 31	209 ± 28	784 ± 88
Angus	28	−.987 ± 1.153[c]	1.787 ± 4.238[b]	−1.643 ± 4.867[b]	7.581 ± 1.783[a]	346 ± 18[ab]	318 ± 15[a]	241 ± 13[ab]	905 ± 40[a]
Low	13	−2.548 ± 1.508	7.216 ± 5.401	−7.358 ± 6.229	9.493 ± 2.306	349 ± 22	327 ± 27	247 ± 24	923 ± 63
High	15	.366 ± 1.677	−2.918 ± 6.293	3.311 ± 7.258	5.925 ± 2.659	344 ± 28	309 ± 17	236 ± 15	889 ± 53
Belgian Blue	39	4.838 ± 1.384[a]	−20.717 ± 5.480[a]	25.223 ± 6.749[a]	−.990 ± 2.526[c]	406 ± 9[c]	378 ± 12[b]	287 ± 15[cd]	1,070 ± 30[b]
Low	19	4.997 ± 1.891	−21.835 ± 7.484	27.345 ± 9.174	−2.258 ± 3.359	393 ± 13	375 ± 20	280 ± 23	1,048 ± 47
High	20	4.687 ± 2.061	−19.655 ± 8.160	23.207 ± 10.072	.216 ± 3.816	418 ± 12	381 ± 16	293 ± 20	1,092 ± 37
Piedmontese	18	−1.735 ± 2.075[bc]	6.445 ± 7.785[bc]	−8.884 ± 9.245[bc]	10.297 ± 3.283[ab]	329 ± 18[ab]	294 ± 18[a]	257 ± 18[ab]	879 ± 44[a]
Low	8	−2.287 ± 3.132	7.885 ± 10.976	−9.805 ± 12.269	10.528 ± 4.073	335 ± 38	306 ± 35	259 ± 32	899 ± 80
High	10	−1.294 ± 2.914	5.293 ± 11.436	−8.147 ± 14.029	10.113 ± 5.129	324 ± 16	284 ± 19	255 ± 22	863 ± 50
Brahman	37	−.391 ± 1.627[bc]	−1.795 ± 6.132[bc]	5.285 ± 7.203[bc]	4.436 ± 2.591[abc]	358 ± 13[b]	370 ± 13[b]	301 ± 17[c]	1,029 ± 38[b]
Low	18	−2.547 ± 2.064	6.805 ± 7.626	−5.408 ± 8.847	8.316 ± 3.102	352 ± 20	358 ± 18	295 ± 21	1,005 ± 50
High	19	1.652 ± 2.455	−9.943 ± 9.318	15.415 ± 10.970	.760 ± 4.001	365 ± 18	382 ± 19	306 ± 26	1,052 ± 56
Boran	41	2.891 ± 1.614[ab]	−12.591 ± 5.549[ac]	16.464 ± 6.266[ac]	−.233 ± 2.468[c]	306 ± 15[a]	314 ± 12[a]	279 ± 15[bc]	899 ± 25[a]
Low	21	2.113 ± 1.481	−10.088 ± 5.608	13.585 ± 6.861	1.117 ± 2.811	321 ± 16	321 ± 11	267 ± 15	909 ± 33
High	20	3.708 ± 2.959	−15.219 ± 9.869	19.487 ± 10.793	−1.650 ± 4.165	291 ± 27	307 ± 22	290 ± 27	889 ± 38
Tuli	37	2.674 ± 1.169[abc]	−12.015 ± 4.553[ac]	15.237 ± 5.544[ac]	.798 ± 2.055[bc]	324 ± 14[a]	313 ± 12[a]	252 ± 13[ab-d]	888 ± 33[a]
Low	18	2.516 ± 1.777	−11.916 ± 7.012	15.574 ± 8.560	.462 ± 3.108	319 ± 22	309 ± 20	237 ± 19	864 ± 53
High	19	2.823 ± 1.578	−12.109 ± 6.062	14.918 ± 7.358	1.116 ± 2.792	328 ± 18	316 ± 14	266 ± 18	911 ± 40
		Probability levels							
Sire (S)		.02	.02	.02	.02	<.001	<.001	.002	<.001
Treatment (T)		.47	.58	.70	.54	.77	.44	.59	.84
Year (Y)		.12	.05	.03	.03	.70	.99	.001	.12
S × T		.70	.61	.53	.53	.78	.69	.94	.76
T × Y		.66	.76	.88	.97	.98	.52	.93	.81
S × Y		.10	.09	.08	.07	.002	.09	.41	.03

[a,b,c,d]Sire breed means within a column lacking a common superscript letter differ ($P < .05$).

Milk yields from 50 to 200 d of lactation did not differ between Brahman- (1,029 ± 38 kg) and Belgian Blue- (1,070 ± 30 kg) sired heifers. The Brahman- and Belgian Blue-sired heifers had higher 50- to 200-d milk yields than the Hereford- (842 ± 45 kg), Angus- (905 ± 40 kg), Piedmontese- (879 ± 44 kg), Boran- (899 ± 25 kg), and Tuli- (888 ± 33 kg) sired heifers. Milk yields from 50 to 200 d did not differ in Hereford-, Angus-, Piedmontese-, Boran-, and Tuli-sired heifers. The pattern of milk production differed between the breeds (Figure 1). In early lactation (50 to 100 d), heifers with Belgian Blue sires produced more milk than heifers sired by the other breeds (Table 6). In the middle of lactation (100 to 150 d) heifers with Belgian Blue and Brahman sires did not differ in the amount of milk produced, but both breeds produced more milk than heifers sired by other breeds (Table 6).

Discussion

The feed required to develop replacement heifers represents a large cost to the cow herd. A number of studies have demonstrated that restricting growth during the prebreeding period can reduce feed cost (Clanton et al., 1983; Freetly and Cundiff, 1997). However, if the feed restriction is too severe, heifers will fail to reach puberty before the end of the breeding period. In order to reduce the age at which heifers reach puberty, many management systems accelerate the growth rate of heifers; however, overfeeding heifers during the prebreeding period is not only expensive, it can also have a long-term impact on production performance of the heifer as a cow. It has been demonstrated that overfeeding heifers can reduce milk production and decrease the weaning weights of their calves (Johnsson and Obst, 1984). In this study, DM intake was reduced by 20% during the period from weaning until breeding across a wide range of breed

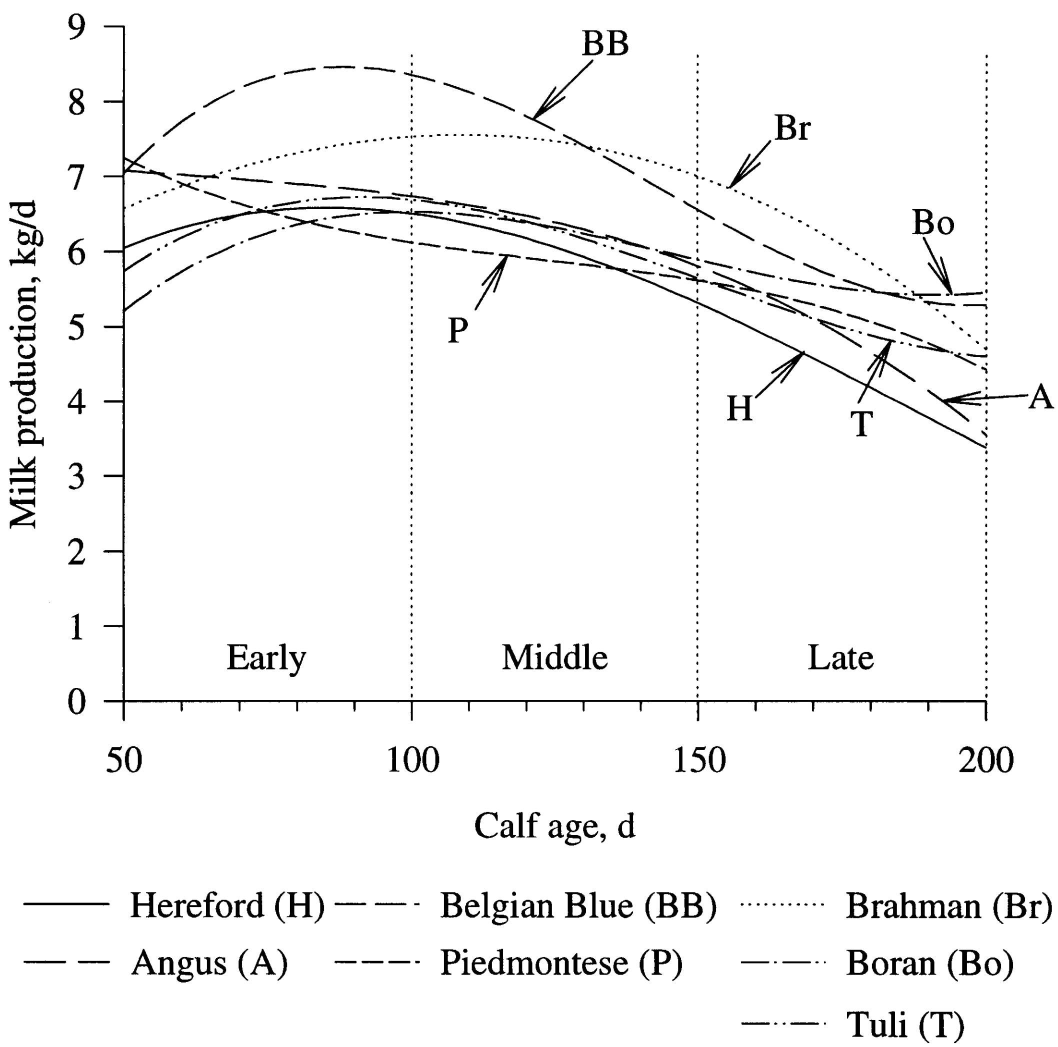

Figure 1. Estimated milk production from 50 to 200 d of lactation by heifers with Hereford, Angus, Belgian Blue, Piedmontese, Brahman, Boran, or Tuli sires and MARC III composite dams (1/4 Angus, 1/4 Hereford, 1/4 Pinzgauer, 1/4 Red Poll).

types. It was previously reported (Freetly and Cundiff, 1997) that the percentage of the heat-tolerant breeds to reach puberty at breeding was less than that of the Continental and British breeds. However, by the end of breeding the percentage of Boran- and Tuli-sired heifers that had reached puberty was similar to that of the Continental and British breeds. Byerley et al. (1987) reported that heifers bred on their third estrus are more fertile than heifers bred on their first estrus. In the current study, Tuli- and Boran-sired heifers had calving percentages similar to those of Continental and British breeds and were among the younger heifers at calving. These findings suggest that a high proportion of the Tuli- and Boran-sired heifers conceived on their first estrus.

Average birth weights of Brahman- (46.3 kg) and Boran- (43.4 kg) sired F_1 calves ranked higher than calves sired by other breeds (Hereford 42.8 kg, Angus 41.0 kg, Tuli 38.9 kg, Piedmontese 42.0 kg, and Belgian Blue 42.0 kg; LSD .05 = 1.5; Cundiff et al., 1996). However, the average birth weight of calves from Brahman- and Boran-sired heifers tended to be less than that of calves from the *Bos taurus* breeds. These observations are consistent with the work of Ferrell (1991), who suggested that the uterine environment of Brahman cows limits fetal growth. It was previously found that the heifers that were reared on the lower plane of nutrition had lower weights at first palpation (Freetly and Cundiff, 1997), but there was not a treatment effect on birth weight of the calves. Studies in Africa (Hetzel, 1988) have indicated that Tuli cattle have an advantage in the percentage of calves weaned compared with the Brahman and Boran. In the current study, Tuli- and Boran-sired heifers weaned more calves per heifer exposed than did the Brahman-sired heifers. Even though sire breeds did not differ in calving percentage or calves weaned per heifer calved, the Tuli- and Boran-sired heifers were numerically higher for both of these traits.

Previous studies have demonstrated that overfeeding of heifers can result in a decrease in milk production. This decrease in milk production has been shown to persist through the third lactation in beef cows. Heifers gaining .55 kg/d before 8 mo of age had higher milk productions than heifers allowed to gain over .67 kg/d (Johnsson and Obst, 1984). Ferrell et al. (1982) determined that heifers fed to achieve weight gains of .6 kg/d for the first 184 d following weaning had an advantage in milk production compared with heifers gaining .4 kg/d or .8 kg/d. Peri et al. (1993) demonstrated that Holstein heifers fed to achieve prepuberal ADG of .77 kg/d and greater had lower milk production than heifers fed to achieve .62 kg/d. In the current study, no difference in milk production was observed between the Low and High treatments. Postweaning gains in the Low treatment ranged from .37 kg/d for the Tuli-sired heifers to .52 kg/d for the Hereford-sired heifers, and the High treatment ranged from .57 kg/d for the Tuli-sired heifers to .79 kg/d for the Angus-sired heifers (Freetly and Cundiff, 1997). These findings suggest that both heifer development strategies were intermediate to the minimal and maximal gains that result in depressed milk production.

There were breed differences in milk production. The Belgian Blue- and the Brahman-sired heifers had higher milk production than heifers of the other breeds. The higher milk production for Brahman-sired heifers compared to Angus- and Hereford-sired heifers in first-calf heifers is consistent with previous observations in mature cows (Cundiff et al., 1986; Green et al., 1991). The relative periods of high milk yield differed between the breed types. The *Bos indicus* breeds (Brahman and Boran) had higher milk yields from 100 to 150 d of lactation than in the period from 50 to 100 d. This higher milk yield in middle lactation is in contrast to the *Bos taurus* and Sanga breeds (Hereford, Angus, Belgian Blue, Piedmontese, and Tuli), which had higher milk yields 50 to 100 d of lactation compared to the period from 100 to 150 d. Green et al. (1991) reported that peak yields occurred at a similar time during lactation for Brahman-cross (68 d), Hereford-cross, and Angus-cross cows (60 d). In the current study, calculation of time of peak milk yield based on the first derivative of the milk production curve suggests that Brahman-cross heifers (109 d) peak later than Hereford-cross (85 d) and Angus-cross (<50 d) heifers. The difference in estimation of time of peak milk yield between the two studies may be partially due to differences in the functions used to fit the milk production curves. In the current study, milk production was fit using a polynomial function, whereas in the study of Green et al. (1991) data were fit with a predetermined natural log function. Calves from Brahman-cross heifers had higher ADG than most of the other breeds, suggesting that higher milk yields resulted in higher rates of gain. Even though the milk yields for the Belgian Blue-cross heifers was high, the ADG for their calves was intermediate. The advantage in ADG in Brahman-cross calves compared with the Belgian Blue-cross calves may result from a number of factors, including differences in efficiency of nutrient usage, differences in nursing patterns, or differences in milk composition. The low body condition scores in Belgian Blue heifers at palpation suggest that more of the body tissue was mobilized to support the higher milk yields.

In conclusion, these studies suggest that over a diverse group of breeds, accelerated rates of gain during the postweaning period do not result in increased production efficiency of the cows. These studies further suggest that moderate heifer development combined with high-quality forage during breeding can be used to decrease the use of harvested forages and increase the use of grazed forages.

Implications

Proper selection of the appropriate breed for a production system can improve optimum performance of the cow herd. Moderate heifer growth within the range studied between weaning and breeding can be used to decrease cost associated with heifer development without reducing performance of the cows.

Literature Cited

Byerley, D. J., R. B. Staigmiller, J. G. Berardinelli, and R. E. Short. 1987. Pregnancy rates of beef heifers bred either on puberal 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.

Cundiff, L. V., K. E. Gregory, R. M. Koch, and G. E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. Third World Congr. Genet. Appl. Livest. Prod., IX:271–282.

Cundiff, L. V., K. E. Gregory, T. L. Wheeler, S. D. Shackelford, M. Koohmaraie, H. C. Freetly, and D. D. Lunstra. 1996. Germplasm evaluation program. Progr. Rep. No. 15. Roman L. Hruska U. S. Meat Animal Research Center, ARS, USDA, Clay Center, NE.

Ferrell, C. L. 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. J. Anim. Sci. 55:1272–1283.

Ferrell, C. L. 1991. Maternal and fetal influences on uterine and conceptus development in the cow: I. Growth of tissues of the gravid uterus. J. Anim. Sci. 69:1945–1953.

Freetly, H. C., and L. V. Cundiff. 1997. Postweaning growth and reproduction characteristics of heifers sired by bulls of seven breeds and raised on different levels of nutrition. J. Anim. Sci. 75:2841–2851.

Green, R. D., L. V. Cundiff, G. E. Dickerson, and T. G. Jenkins. 1991. Output/input differences among nonpregnant, lactating *Bos indicus-Bos taurus* and *Bos taurus-Bos taurus* F_1 cross cows. J. Anim. Sci. 69:3156–3166.

Gregory, K. E., D. B. Laster, L. V. Cundiff, G. M. Smith, and R. M. Koch. 1979. Characterization of biological types of cattle–Cycle III: II. Growth rate and puberty traits in females. J. Anim. Sci. 49:461–471.

Harvey, W. R. 1985. User's Guide for LSMLVM. Mixed model least squares and maximum likelihood computer program. The Ohio State Univ., Columbus (Mimeo).

Hetzel, D.J.S. 1988. Comparative productivity of the Brahman and some indigenous Sanga and *Bos indicus* breeds in East and Southern Africa. Anim. Breed. Abstr. 56:243–255.

Johnsson, I. D., and J. M. Obst. 1984. The effect of level of nutrition before and after 8 months of age on subsequent milk and calf production of beef heifers over three lactations. Anim. Prod. 38: 57–68.

Laster, D. B., G. M. Smith, L. V. Cundiff, and K. E. Gregory. 1979. Characterization of biological types of cattle (Cycle II) II. Postweaning growth and puberty of heifers. J. Anim. Sci. 48: 500–508.

Laster, D. B., G. M. Smith, and K. E. Gregory. 1976. Characterization of biological types of cattle IV. Postweaning growth and puberty of heifers. J. Anim. Sci. 43:63–70.

Peri, I., A. Gertler, I. Bruckental, and H. Barash. 1993. The effect of manipulation in energy allowance during the rearing period of heifers on hormone concentrations and milk production in first lactation cows. J. Dairy Sci. 76:742–751.

Sorensen, A. M., W. Hansel, W. H. Hough, D. T. Armstrong, K. McEntee, and R. W. Bratton. 1959. Causes and prevention of reproductive failures in dairy cattle. I. Influence of underfeeding and overfeeding on growth and development of Holstein heifers. Bull. 936:1–51. Cornell Univ. Agric. Exp. Sta., New York College of Agriculture, Ithaca.

Wiltbank, J. N., K. E. Gregory, L. A. Swiger, and J. E. Ingalls. 1966. Effects of heterosis on age and weight at puberty in beef heifers. J. Anim. Sci. 25:744–751.