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Birth and weaning traits in crossbred cattle from Hereford, Angus, Brahman, Boran, Tuli, and Belgian Blue sires[1,2]

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ABSTRACT: The objective of this study was to characterize breeds representing diverse biological types for birth and weaning traits in crossbred cattle. Gestation length, calving difficulty, percentage of unassisted calving, percentage of perinatal survival, percentage of survival from birth to weaning, birth weight, BW at 200 d, and ADG were measured in 2,500 calves born and 2,395 calves weaned. Calves were obtained by mating Hereford, Angus, and MARC III (one-fourth Hereford, one-fourth Angus, one-fourth Pinzgauer, and one-fourth Red Poll) mature cows to Hereford or Angus (British breed), Brahman, Tuli, Boran, and Belgian Blue sires. Calves were born during the spring seasons of 1992, 1993, and 1994. Sire breed was significant for all traits ($P < 0.002$). Offspring from British breeds and the Belgian Blue breed had the shortest gestation length (285 d) when compared with progeny from other sire breeds (average of 291 d). Calving difficulty was greater in offspring from Brahman sires (1.24), whereas the offspring of Tuli sires had the least amount of calving difficulty (1.00). Offspring from all sire breeds had similar perinatal survival and survival from birth to weaning (average of 97.2 and 96.2%, respectively), with the exception of offspring from Brahman sires, which had less (92.8 and 90.4%, respectively). Progeny of Brahman sires were heaviest at birth (45.7 kg), followed by offspring from British breed, Boran, and Belgian Blue sires (average of 42.4 kg). The lightest offspring at birth were from Tuli sires (38.6 kg). Progeny derived from Brahman sires were the heaviest at 200 d (246 kg), and they grew faster (1.00 kg/d) than offspring from any other group. The progeny of British breeds and the Belgian Blue breed had an intermediate BW at 200 d (238 kg) and an intermediate ADG (average of 0.98 kg/d). The progeny of Boran and Tuli sires were the lightest at 200 d (227 kg) and had the least ADG (0.93 kg/d). Male calves had a longer gestation length, had a greater incidence of calving difficulty, had greater mortality to weaning, were heavier, and grew faster than female calves. Sire breed effects can be optimized by selection and use of appropriate crossbreeding systems.

Key words: beef cattle, breed, germplasm, gestation length, growth, survival

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INTRODUCTION

The Germplasm Evaluation (**GPE**) program at the US Meat Animal Research Center (**USMARC**) has characterized breeds representing several biological types of cattle. Breed differences in performance characteristics are important genetic resources for improving the efficiency of beef production. Diverse breeds can be crossed to exploit heterosis or to match genetic potential with markets, feed resources, and climates. Reproduction rate, weaning weight per cow exposed, and cow efficiency are outstanding in *Bos indicus* × *Bos taurus* F_1 crosses, especially in subtropical environments (Olson et al., 1991; Thrift and Thrift, 2003), but their advantages are tempered by older age at puberty and reduced meat tenderness as the proportion of *B. indicus* increases (Crouse et al., 1989). Concerns about reproduction rate at young ages and meat quality prompted the introduction and evaluation of other tropically adapted germplasm into the GPE program and in research efforts at research stations in subtropical regions of the United States, as in Texas (Herring et al., 1996; Holloway et al., 2002) and Florida (Chase et al., 2000, 2004).

In the GPE program, birth and weaning traits have been evaluated for Cycles I (Smith et al., 1976), II

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Table 1. Number of offspring born by sire breed and dam breed in each year

		Sire breed					
Dam breed	Year	British	Brahman	Boran	Tuli	Belgian Blue	Total
Hereford	1992	25	27	28	27	25	132
	1993	23	16	17	22	21	100
	1994	16	19	21	16	10	82
Angus	1992	48	48	45	50	49	240
	1993	48	47	55	48	56	254
	1994	46	46	49	53	49	243
MARC III[1]	1992	47	55	52	65	61	280
	1993	181	86	88	99	97	551
	1994	213	92	101	112	100	618
Total		647	436	456	492	469	2,500

[1]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

(Gregory et al., 1978), III (Gregory et al., 1979), and IV (Cundiff et al., 1998). The fifth cycle of this program (Cycle V) included 2 *B. indicus* breeds (Brahman and Boran), 1 African Sanga breed (Tuli), 2 British breeds (Hereford and Angus), and Belgian Blue, which has a high frequency of the condition known as double muscling. The objective of this study was to characterize breeds representing diverse biological types for birth and weaning traits in crossbred cattle.

MATERIALS AND METHODS

Experimental procedures were approved and performed in accordance with USMARC Animal Care Guidelines and the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

Animals

Data were obtained from 2,500 calves born and 2,395 calves weaned at the USMARC. Hereford, Angus, and MARC III (one-fourth Hereford, one-fourth Angus, one-fourth Pinzgauer, and one-fourth Red Poll) mature dams (5 to 11 yr of age) were mated by AI to 31 Hereford, 43 Angus, 47 Brahman, 8 Boran, 9 Tuli, and 25 Belgian Blue sires. No purebred Hereford or Angus matings were made to avoid confounding sire breed effects with heterosis effects. Hereford and Angus were treated as 1 sire breed (British).

Dams were maintained on improved pasture from April to November. In April to June and later in September to November, they were maintained on predominantly cool-season smooth bromegrass (*Bromus inermis*). In June to September, they were maintained on warm-season mixtures of predominantly big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*), with some little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and sand lovegrass (*Eragrostis trichodes*). From December to April, the dams were fed grass and alfalfa hay (or corn silage and alfalfa hay) on pasture. Cows were observed closely for calving difficulty. Briefly, during calving season (February to May), cows were monitored once every hour for 24 h/d. Assistance was given if cows were in labor for 2 h.

Offspring were born during spring of 1992 (n = 652), 1993 (n = 905), and 1994 (n = 943), beginning in late March and ending in mid May. Table 1 shows the number of animals born by breed group and year. Calves were weighed, tattooed, and tagged for identification. Male calves were castrated within 24 h of birth. Calves were creep-fed whole oats from mid July until weaning in early October. Calves averaged 184 ± 13 d of age at weaning. Table 2 shows the number of animals weaned by breed group and year.

Traits

Traits analyzed included gestation length, calving difficulty, percentage of unassisted calving, percentage of perinatal survival, percentage of survival from birth to weaning, birth and weaning weights, BW at 200 d, and ADG. Gestation length was calculated as the difference between AI date and birth date. Calving difficulty was scored as 1 = no difficulty, 2 = little difficulty (assistance given by hand), 3 = little difficulty with a calf jack, 4 = slight difficulty (assistance given with a jack or calf puller), 5 = moderate difficulty (calf jack used), 6 = major difficulty (calf jack used and major difficulty encountered), and 7 = cesarean birth. Calves with abnormal presentation or posture were excluded from the analysis of calving difficulty. Unassisted calving was considered when a cow had a calving difficulty score of 1. If the calving difficulty score was 2 or greater, it was considered an assisted calving. Abnormal presentations were excluded from the calculation of percentage of unassisted calving. Percentage of perinatal survival included calves alive after 3 d of age. Percentage of survival from birth to weaning included calves alive at weaning. Consistent with previous reports (Cundiff et al., 1998), BW at weaning were adjusted to 200 d by multiplying ADG from birth to weaning by 200 and adding birth weight. Table 3 shows the number of observations, the mean and SD, and minimum and maximum values for each trait.

Table 2. Number of offspring weaned by sire breed and dam breed in each year

		Sire breed					
Dam breed	Year	British	Brahman	Boran	Tuli	Belgian Blue	Total
Hereford	1992	25	22	26	27	23	123
	1993	22	13	17	21	21	94
	1994	16	16	21	15	9	77
Angus	1992	45	48	42	48	49	232
	1993	45	43	53	45	54	240
	1994	43	43	47	51	47	231
MARC III[1]	1992	47	53	51	64	59	274
	1993	176	79	84	97	91	527
	1994	208	88	98	105	98	597
Total		627	405	439	473	451	2,395

[1]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

Statistical Analysis

Data were analyzed with the MIXED procedure (SAS Inst. Inc., Cary, NC). The model included the fixed effects of sire breed (British, Brahman, Boran, Tuli, and Belgian Blue), dam breed (Hereford, Angus, or MARC III), sex (male or female), and birth year (1992, 1993, or 1994). The model also included all possible 2-way interactions. The linear and quadratic effects of age of the cow at calving and the linear effect of Julian birth date were included in the model as covariates. The random effect of sire within sire breed was included in the model. The Kenward-Rogers option of the MIXED procedure of SAS was used to ascertain degrees of freedom. Hereford and Angus were treated as 1 sire breed (British), leaving the difference between reciprocal crossbred Hereford × Angus vs. Angus × Hereford to be accounted for as part of the sire breed–dam breed interaction. Least squares means and probability values for differences were estimated for significant effects. Probability values were corrected for multiple testing. A Bonferroni adjustment was applied to the probability values using a factor of 8, which is the number of traits analyzed.

RESULTS AND DISCUSSION

Levels of significance, least squares means, and SE of the means are shown in Tables 4 and 5 for the effects of sire breed, dam breed, and sex on gestation length, calving difficulty score, percentage of unassisted calving, percentage of perinatal survival, percentage of survival from birth to weaning, BW at different ages, and ADG. Interactions of sire breed × sex for gestation length, calving difficulty, percentage of perinatal survival and birth weight are shown in Table 6. The interaction of dam breed × sex for calving difficulty is shown in Table 7. Interactions of sire breed × dam breed for percentage of perinatal survival and survival from birth to weaning are shown in Table 8. Year of birth was significant ($P < 0.001$) for gestation length and birth weight. Estimates of year of birth were not reported because year effects cannot be predicted to recur in the future, and it is appropriate for producers to make decisions about sire breed and dam breed based on information averaged over several years.

Gestation Length

The overall mean for gestation length was 288 d. The effects of sire breed, dam breed, and sex were significant ($P < 0.001$) for gestation length (Table 4). Animals derived from Brahman, Boran, and Tuli sires had longer gestation lengths when compared with animals derived from British and Belgian Blue sires. Browning et al. (1995) compared the gestation length of animals derived from Angus, Brahman, and Tuli sires. They

Table 3. Number of observations, mean, SD, minimum, and maximum for the traits studied

Trait	n	Mean	SD	Minimum	Maximum
Gestation length, d	2,500	288	7	254	308
Calving difficulty[1]	2,446	1.06	0.47	1	7
Unassisted calving, %	2,500	96.0	0.2	0	100
Perinatal survival, %	2,500	97.2	0.2	0	100
Survival from birth to weaning, %	2,500	95.8	0.2	0	100
Birth weight, kg	2,500	42.7	6.5	22.7	70.8
BW at 200 d, kg	2,395	240	28	103	330
ADG, kg/d	2,395	0.99	0.13	0.40	1.42

[1]Calving difficulty scores: 1 = no difficulty to 7 = cesarean birth.

Table 4. Levels of significance, least squares means, and SE for factors affecting gestation length (GL, d), calving difficulty[1] (CD), unassisted calving (UC, %), perinatal survival (PS, %), and survival from birth to weaning (SBW, %)

	Trait				
Factor	GL	CD	UC	PS	SBW
Sire breed					
Significance	<0.001	<0.001	<0.001	<0.001	0.002
Least squares means					
British	285[a]	1.05[ab]	97.5[c]	98.1[b]	96.6[b]
Brahman	292[c]	1.24[c]	90.9[a]	92.8[a]	90.4[a]
Boran	292[bc]	1.05[ab]	95.6[bc]	97.6[b]	96.3[b]
Tuli	290[b]	1.00[a]	97.3[c]	97.6[b]	96.3[b]
Belgian Blue	285[a]	1.10[b]	93.0[ab]	96.8[b]	95.7[b]
SE	0.42	0.03	1.1	0.9	1.0
Dam breed					
Significance	<0.001	0.266	0.006	0.238	0.172
Least squares means					
Hereford	290[a]	1.14[a]	91.9[a]	95.5	93.5
Angus	287[b]	1.06[b]	95.7[b]	96.8	95.7
MARC III[2]	289[c]	1.06[b]	96.9[b]	97.4	96.0
SE	0.25	0.02	0.8	0.6	0.6
Sex					
Significance	<0.001	<0.001	<0.001	0.681	0.252
Least squares means					
Male	289[a]	1.15[a]	92.8[a]	95.9	94.0
Female	288[b]	1.02[b]	96.9[b]	97.3	96.1
SE	0.22	0.02	0.7	0.6	0.6

[a–c]Within column and factor, means without a common superscript differ ($P < 0.05$).

[1]Calving difficulty scores: 1 = no difficulty to 7 = cesarean birth.

[2]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

indicated that animals with Angus inheritance had the shortest gestation length (284 d) when compared with Brahman (294 d) and Tuli (288 d). Plasse et al. (1968) indicated that under subtropical conditions, the gestation length for Brahman cattle is 293 d. Results from the present study are similar to those found by Browning et al. (1995) and Plasse et al. (1968). A comparison of the results from the present study with previous studies showed that gestation length has not been modified by selection schemes in Brahman cattle in more than 30 yr. In the present study, progeny from Brahman sires had a 2 d longer gestation length when compared with the gestation length of progeny from Tuli sires. Chase et al. (2000) found similar differences between both breeds. Bennett et al. (2008), in a program designed to reduce calving difficulty in 2-yr-old heifers by using 7 breeds, found that selected lines within a breed for decreased calving difficulty had a shorter gestation length (2 d) when compared with control lines. This indicates that selection schemes affect gestation length regardless of breed.

Consistent with previous reports (Smith et al., 1976; Gregory et al., 1978, 1979; Cundiff et al., 1998), gestation length for progeny of Hereford dams was longer ($P < 0.001$) than gestation length for progeny of Angus dams. Progeny of MARC III dams had a gestation length intermediate between progeny of Hereford and progeny of Angus cows. Gestation length has not been reported previously for offspring of MARC III cows.

Table 5. Levels of significance, least squares means, and SE for factors affecting birth weight (BWT, kg), BW at 200 d (W200D, kg), and ADG (kg/d)

	Trait		
Factor	BWT	W200D	ADG
Sire breed			
Significance	<0.001	<0.001	<0.001
Least squares means			
British	42.1[b]	240[b]	0.99[ab]
Brahman	45.7[a]	246[a]	1.00[a]
Boran	42.9[b]	230[c]	0.93[c]
Tuli	38.6[c]	225[c]	0.93[c]
Belgian Blue	42.3[b]	237[b]	0.97[b]
SE	0.5	2	0.01
Dam breed			
Significance	<0.001	<0.001	<0.001
Least squares means			
Hereford	41.6[a]	221[a]	0.90[a]
Angus	42.0[a]	248[c]	1.03[c]
MARC III[1]	43.4[b]	237[b]	0.97[b]
SE	0.3	1	0.01
Sex			
Significance	<0.001	<0.001	<0.001
Least squares means			
Male	44.5[a]	244[a]	1.00[a]
Female	40.2[b]	227[b]	0.93[b]
SE	0.2	1	0.01

[a–c]Within column and factor, means without a common superscript differ ($P < 0.05$).

[1]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

Table 6. Levels of significance, least squares means, and SE for the interaction of sire breed × sex for gestation length (GL, d), calving difficulty[1] (CD), perinatal survival (PS, %), and birth weight (BWT, kg)

Sire breed	GL Male	GL Female	CD Male	CD Female	PS Male	PS Female	BWT Male	BWT Female
Significance	<0.001		<0.001		0.045		<0.001	
British	286 ± 0.3^{d}	284 ± 0.3^{e}	1.09 ± 0.03^{bc}	1.01 ± 0.03^{cd}	98.1 ± 1.1^{a}	98.1 ± 1.1^{a}	43.6 ± 0.4^{c}	40.6 ± 0.4^{de}
Brahman	293 ± 0.4^{a}	290 ± 0.4^{bc}	1.40 ± 0.04^{a}	1.07 ± 0.04^{bcd}	89.9 ± 1.2^{b}	95.7 ± 1.1^{a}	49.5 ± 0.5^{a}	42.0 ± 0.4^{d}
Boran	292 ± 0.6^{a}	291 ± 0.6^{b}	1.06 ± 0.04^{bcd}	1.04 ± 0.04^{cd}	98.5 ± 1.1^{a}	96.6 ± 1.1^{a}	45.9 ± 0.7^{b}	40.0 ± 0.7^{e}
Tuli	290 ± 0.6^{c}	290 ± 0.6^{c}	1.02 ± 0.04^{cd}	0.98 ± 0.04^{d}	97.4 ± 1.1^{a}	97.8 ± 1.1^{a}	39.7 ± 0.6^{e}	37.5 ± 0.6^{f}
Belgian Blue	285 ± 0.4^{d}	284 ± 0.4^{e}	1.17 ± 0.04^{b}	1.02 ± 0.04^{cd}	95.3 ± 1.2^{a}	98.2 ± 1.2^{a}	43.9 ± 0.5^{c}	40.8 ± 0.5^{d}

[a–f]Within a trait, means without a common superscript differ ($P < 0.05$).
[1]Calving difficulty scores: 1 = no difficulty to 7 = cesarean birth.

Gregory et al. (1991) reported that the average gestation length in 3 generations of MARC III cows was 287 d. Gestation lengths in MARC III cows in the present study are similar to those reported by Gregory et al. (1991).

Male calves averaged gestation lengths 1 d longer than those of female calves. This result is similar to studies from Smith et al. (1976), who reported differences of 1.7 d, Gregory et al. (1978), who reported differences of 1.3 d, Gregory et al. (1979), who reported differences of 2 d, and Cundiff et al. (1998), who reported differences of 1.8 d. Male calves have a longer gestation length than female calves.

Table 6 shows the interaction of sire breed × sex for gestation length. Male calves from Brahman sires had a 3 d longer gestation length compared with female calves. However, offspring from Tuli sires showed no difference in gestation length between males and female calves. These differences caused a significant interaction effect.

Calving Difficulty

Sire breed has been established as a factor affecting calving difficulty in beef cattle (Zaborski et al., 2009). In the present study, offspring derived from Brahman sires had the greatest calving difficulty ($P < 0.001$) when compared with the calving difficulty of other sire breeds (Table 4). Paschal et al. (1991) compared calving difficulty among several *B. indicus* breeds and Angus. Paschal et al. (1991) observed that offspring from Brahman sires had greater calving difficulty compared with progeny from Angus sires. Previously, Gregory et al. (1979) found a similar effect of sire breed when comparing offspring derived from Brahman, Hereford, and Angus sires. This is consistent with results found in the present study. Dams with offspring by Tuli sires had the smallest numerical calving difficulty, but this was not significantly different ($P > 0.05$) from the calving difficulty observed for dams with offspring from Boran and British breed sires. Size and BW of the calf are important factors in calving difficulty (Bennett et al., 2008). In the present study, Brahman calves were the heaviest at birth (Table 5). It is likely that the size of Brahman calves plays an important role in calving difficulty.

Belgian Blue is a double-muscled breed homozygous for an inactive form of the myostatin gene (Kambadur et al., 1997). Calves from Belgian Blue sires in this population were expected to have inherited the inactive form of the myostatin gene from their sires. Progeny from Belgian Blue sires had a numerical, but not significant ($P > 0.05$), increase in calving difficulty (increase of 0.05) when compared with progeny of British breeds. The same difference was also observed by Casas et al. (1999) between animals inheriting 1 and 0 copies of the inactive form of the myostatin gene in a crossbred population with Piedmontese. Further studies would be needed to establish whether this difference is statistically significant.

The larger size and greater BW of male calves is directly associated with increased calving difficulty (Bennett et al., 2008; Zaborski et al., 2009). Offspring from Brahman sires were the heaviest (Table 5) and also had the most difficulty at calving (Table 4). Results from this study are consistent with those of other studies (Smith et al., 1976; Gregory et al., 1978, 1979) establishing that dams with male calves have more calving difficulty than those with females.

The interaction of sire breed × sex for calving difficulty is shown in Table 6. Male progeny from Brahman sires had a greater ($P < 0.05$) calving difficulty score than females derived from this sire breed (difference of

Table 7. Levels of significance, least squares means, and SE for the interaction of dam breed × sex for calving difficulty[1]

Dam breed	Males	Females
Significance	0.034	
Hereford	1.26 ± 0.04^{a}	1.01 ± 0.04^{c}
Angus	1.09 ± 0.03^{b}	1.02 ± 0.03^{c}
MARC III[2]	1.09 ± 0.02^{b}	1.04 ± 0.02^{bc}

[a–c]Means without a common superscript differ ($P < 0.05$).
[1]Calving difficulty scores: 1 = no difficulty to 7 = cesarean birth.
[2]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

Table 8. Levels of significance, least squares means, and SEM for the interaction of sire breed × dam breed for perinatal survival (PS, %) and survival from birth to weaning (SBW, %)

	Dam breed					
	PS			SBW		
Sire breed	Hereford	Angus	MARC III[1]	Hereford	Angus	MARC III
Significance	0.043			0.005		
British	100.0 ± 2[a]	95.8 ± 1.3[a]	98.2 ± 0.9[a]	98.6 ± 2.5[a]	93.7 ± 1.7[a]	97.5 ± 1.1[a]
Brahman	86.3 ± 2.1[b]	96.4 ± 1.3[a]	95.7 ± 1.1[a]	81.3 ± 2.6[b]	95.6 ± 1.7[a]	94.3 ± 1.4[a]
Boran	98.8 ± 2.0[a]	96.9 ± 1.3[a]	97.0 ± 1.1[a]	97.2 ± 2.5[a]	95.6 ± 1.6[a]	96.0 ± 1.4[a]
Tuli	97.2 ± 2.0[a]	97.1 ± 1.3[a]	98.6 ± 1.0[a]	96.9 ± 2.5[a]	95.8 ± 1.6[a]	96.1 ± 1.3[a]
Belgian Blue	95.1 ± 2.2[a]	97.7 ± 1.3[a]	97.5 ± 1.1[a]	93.5 ± 2.7[a]	97.6 ± 1.6[a]	95.8 ± 1.3[a]

[a,b]Within a trait, means without a common superscript differ ($P < 0.05$).

[1]MARC III = one-fourth Hereford, one-fourth Angus, one-fourth Red Poll, and one-fourth Pinzgauer.

0.33). Male offspring from Belgian Blue sires also had an increased ($P < 0.05$) calving difficulty score when compared with female calves (difference of 0.15). Differences between male and female calves for the remaining breeds were nonsignificant ($P > 0.05$). These differences contribute to the significance of the interaction.

Table 7 shows the means for the interaction of dam breed × sex for calving difficulty. Male calves from Hereford cows had an increased ($P < 0.05$) incidence of calving difficulty when compared with female calves from this sire breed (difference of 0.25). The differences in calving difficulty incidence for male and female calves from Angus and MARC III cows were similar ($P > 0.05$; average difference of 0.06).

Unassisted Calving

Calving ease, as reflected by the percentage of unassisted calvings, differed significantly ($P < 0.001$) among sire breeds (Table 4). Progeny of British, Boran, and Tuli sires had the greatest incidence of unassisted calving. Percentage of unassisted calving for progeny from British breed sires was similar to that of progeny from Tuli and Boran sires, which had the most unassisted calving. However, percentage of unassisted calving for offspring from Boran sires was similar to that of progeny from Belgian Blue sires. Offspring from Belgian Blue and Brahman sires had the least unassisted calving. Chase et al. (2000) compared with progeny of Brahman and Tuli sires under subtropical conditions, and they also found that progeny from Brahman sires needed more assistance at calving than did progeny from Tuli sires.

Calves produced by Hereford cows had less unassisted calving than calves born from Angus or MARC III cows. Smith et al. (1976) and Gregory et al. (1978) also found that Hereford cows had more calving difficulty than Angus cows. The calving difficulty of the MARC III cows evaluated in the present study was similar to that of Angus cows.

Female calves had a greater percentage ($P < 0.001$) of unassisted calving than male calves. Birth weight of male calves is an important factor affecting the percentage of unassisted calving, as a reflection of the greater calving difficulty in males (Cundiff et al., 1998).

Perinatal Survival and Survival from Birth to Weaning

A small proportion of stillbirths and calves that died within 72 h were observed (less than 3%). Percentage of perinatal survival was affected by sire breed (Table 4). Progeny of all sire breeds had similar percentages of perinatal survival except for progeny from Brahman sires ($P < 0.001$). Offspring from Brahman sires had a greater perinatal mortality. Riley et al. (2007) found that calves derived from Brahman and Angus had decreased perinatal survival when compared with the perinatal survival of other crosses derived from Brahman and *B. taurus* breeds. Prayaga (2004) found greater perinatal mortality among calves derived from the cross of Brahman sires with Adaptaur (Hereford-Shorthorn) cows. Prayaga (2004) and Riley et al. (2007) attributed the greater perinatal mortality of calves from Brahman sires to the greater birth weight of these calves and their subsequent calving difficulty. These observations are consistent with the results from the present study. However, in Nebraska, the occurrence of cold and wet weather during spring calving takes a greater toll on Brahman and other *B. indicus*-sired calves than on *B. taurus*-sired calves.

Survival of calves from birth to weaning was significantly less in the progeny of Brahman sires than in the progeny of any other sire breed ($P = 0.002$). Most of the mortality in Brahman-sired calves occurred within 72 h after birth. This effect on survival from birth to weaning was also observed by Prayaga (2004) and Riley et al. (2007). Survival of calves was similar among the other sire breeds.

The interaction of sire breed × sex for percentage of perinatal survival is shown in Table 6. Male progeny from Brahman sires had a decreased ($P = 0.045$) percentage of perinatal survival when compared with the perinatal survival of females derived from this sire breed (difference of 5.8%). Differences between male and female calves for the remaining breeds were not significantly different ($P > 0.05$). The decreased percentage of perinatal survival observed in calves from Brahman sires (Table 4) was due to perinatal mortality in male calves. This difference contributed to the significance of the interaction.

Means for the interaction of sire breed × dam breed for percentage of perinatal survival and survival from birth to weaning are shown in Table 8. The decreased percentage of perinatal survival and reduced survival from birth to weaning (86.3 and 81.3%, respectively) of calves from Brahman sires and Hereford cows was responsible for this interaction. Brahman sires and Hereford dams had the greatest calving difficulty, which could have contributed to the decreased survival.

Birth Weight

The effects of sire breed were significant ($P < 0.001$) for birth weight (Table 5). Offspring derived from Brahman sires were heaviest at birth. The lightest calves were produced by Tuli sires. Progeny from British, Boran, and Belgian Blue sires had intermediate birth weights. Paschal et al. (1991) showed that Brahman calves were heavier at birth when compared with Angus calves. Riley et al. (2007) indicated that Brahman-sired calves had heavier birth weights than reciprocal crossbred calves (Angus- and Romosinuano-sired calves with Brahman cows). Brahman-sired male calves were heavier at birth than male calves sired by Romosinuano and Angus. Chase et al. (2000) compared birth weights of calves produced by Brahman and Tuli sires and found that Brahman calves were heavier at birth than Tuli calves. Holloway et al. (2002) indicated a similar pattern, in which offspring from Brahman sires were heavier at birth than progeny from Tuli sires. Browning et al. (1995) found no difference in birth weight among offspring from Angus, Brahman, and Tuli sires. It is possible that a lack of statistical power hampered the ability of the study by Browning et al. (1995) to detect statistical differences for birth weight among offspring of these breeds because a limited number of observations were used. However, numerically, offspring from Brahman cattle were the heaviest at birth, followed by offspring from Angus sires. The lightest calves were produced by Tuli sires in the study by Browning et al. (1995). Birth weights of offspring from Belgian Blue sires were not statistically different from birth weights of offspring from Boran or British breeds. Lunstra and Cundiff (2003) found no difference for birth weight among bulls obtained from Hereford, Angus, and Belgian Blue sires. Calves from Belgian Blue sires were heterozygous for the inactive form of the myostatin allele. Casas et al. (2004) reported that the birth weight of calves derived from Belgian Blue grandsires with 1 copy of the inactive myostatin allele was 42.2 kg. This is similar to the birth weight reported in the present study (42.3 kg). Bidner et al. (2009) indicated that calves produced by Belgian Blue sires were heavier at birth than were the progeny of Angus sires. Results from the present study corroborate results from additional studies indicating that the progeny from Brahman sires are heaviest at birth (Chase et al., 2000).

Calves from MARC III cows were heavier ($P < 0.001$) at birth than progeny from Hereford or Angus cows. No difference in birth weight was observed between calves from Hereford or Angus cows. Smith et al. (1976), Gregory et al. (1978, 1979), and Cundiff et al. (1998) indicated that calves from Hereford cows were heavier at birth than calves from Angus cows. The difference in birth weight for progeny from MARC III cows and Hereford and Angus cows could be explained by retained heterosis in the composite breed (Gregory et al., 1991).

Male calves were heavier ($P < 0.001$) at birth than female calves. The difference between males and females was 4.3 kg. Sex differences have been detected regardless of breed (Bellows et al., 1996; Cundiff et al., 1998; Chase et al., 2000; Holloway et al., 2002; Riley et al., 2007), except for calves by *B. taurus* bulls from Brahman cows. Thallman et al. (1992) reported that among calves sired by Simmental bulls from Brahman cows, female calves were 0.4 ± 0.5 kg heavier at birth than the corresponding male calves. In the study by Thallman et al. (1992), calves were embryos in Holstein recipient cows.

The interaction of sire breed × sex for birth weight is shown in Table 6. This interaction resulted from a significantly greater difference between males and females in the progeny derived from Brahman sires (males − females = 7.5 kg). The difference between sexes for the offspring of Boran sires was 5.9 kg, which also contributed to the significance of this interaction. The difference between males and females for the offspring of British breed, Tuli, and Belgian Blue sires was in the range of 2.2 to 3.1 kg. Chase et al. (2000) found a significant interaction of sire breed × sex in a population that included calves derived from Brahman, Senepol, and Tuli sires. Chase et al. (2000) indicated that heavier male calves from Brahman sires were responsible for this interaction. Cundiff et al. (1998) found this interaction to be significant in Cycle IV of the GPE project. Cundiff et al. (1998) indicated that this interaction was due to the difference between males and females from offspring of Nellore sires. *Bos indicus* sires tend to produce heavier male than female calves relative to the sex difference between *B. taurus* × *B. taurus*.

BW at 200 d, and ADG

Table 5 shows the least squares means for BW at 200 d and for ADG. Sire breed, dam breed, and sex were significant ($P < 0.001$) sources of variation for all traits.

Progeny from Brahman sires were heaviest at 200 d and had the greatest ADG. Progeny from Boran and Tuli sires were the lightest at 200 d, with the smallest

ADG. Offspring from British breeds and Belgian Blue sires were intermediate for these traits. Chase et al. (2000), comparing offspring from Brahman and Tuli sires, found that offspring from Brahman sires were heavier than those from Tuli sires. This is similar to the reports from Herring et al. (1996) and Holloway et al. (2002). Similarly, Chase et al. (2004) found that animals with Brahman maternal grandsires were heavier at weaning than animals from Tuli maternal grandsires. Riley et al. (2007) indicated that calves produced by Brahman sires were heavier at weaning than calves sired by Angus and Romosinuano.

Progeny from Angus cows were heavier at weaning and at 200 d, and they had a faster growth rate. Offspring from Hereford cows were the lightest at weaning and at 200 d, with the slowest growth rate. Calves from MARC III cows were intermediate. Herring et al. (1996) found that calves from Angus cows were heavier at weaning when compared with progeny from Hereford cows. Gregory et al. (1979) indicated that Angus cows produced heavier calves at 200 d when compared with Hereford cows. Results from these studies are similar to those found in the present study.

Male calves are heavier at weaning and at 200 d, with faster growth compared with females. This has been observed previously by Herring et al. (1996), Chase et al. (2000), and Riley et al. (2007).

Data used in the present study are from animals produced at the USMARC between 1992 and 1994. Boran and Tuli are 2 tropically adapted breeds that have not been intensively selected. Therefore, results from this study should remain relevant.

Characterization of the reproduction performance for females produced in this GPE Cycle is needed. Traits associated with the stayability and overall productivity of females also need to be characterized in this population. However, this falls outside the scope of the present study. Further studies are required to fully evaluate these breeds.

Significant differences exist among crossbred progeny derived from British breeds, Brahman, Boran, Tuli, and Belgian Blue sires for birth and weaning traits. Under temperate conditions, offspring from Brahman sires grew faster and were heavier at birth and at weaning. However, Brahman sires produced offspring that required more calving assistance and had the least survival rate. Breed differences can be exploited to optimize performance levels in crosses or in composite populations relatively more quickly than performance can be optimized by intrapopulation selection. Results from the present study would allow producers to make informed decisions if the need arises to optimize performance levels quickly.

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