

JOURNAL OF ANIMAL SCIENCE

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J Anim Sci 1996. 74:955-964.

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Evaluation of F₁ Calves Sired by Brahman, Boran, and Tuli Bulls for Birth, Growth, Size, and Carcass Characteristics

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ABSTRACT: Birth (n = 308), weaning (n = 291), feedlot and carcass (n = 142), and yearling heifer traits (n = 139) were evaluated in F₁ calves sired by Brahman (BR), Boran (BO), and Tuli (TU) bulls and born to multiparous Hereford and Angus cows. Calves sired by BR were heaviest ($P < .05$) at birth and largest ($P < .05$) for cannon bone length. Tuli crosses were smaller ($P < .05$) for birth weight and cannon bone length than BR and BO crosses. No significant differences were observed for gestation length among sire breeds. Brahman crosses had larger ($P < .05$) weaning weight, hip height, and preweaning ADG than calves sired by BO and TU. Similar trends were observed for feedlot traits. Carcasses of BR crosses were heavier ($P < .05$) and had less ($P < .05$) internal fat than those of BO and TU crosses. Tuli

crosses averaged greater ($P < .05$) skeletal maturity than BO crosses. Tuli crosses averaged greater marbling ($P < .05$) than BR crosses and less ($P < .05$) Warner-Bratzler shear force than BO crosses. No differences were observed in longissimus muscle area, fat thickness, or yield grade among sire breeds. Heifers sired by BR were heaviest ($P < .05$) and tallest ($P < .05$) at yearling measurement. Brahman F₁ heifers had larger ($P < .05$) pelvic height and pelvic area, due to larger skeletal frame size, than BO and TU F₁ heifers. These results indicate large differences in growth and skeletal size exist among calves sired by these three breeds. Several important differences also exist for carcass quality traits, but not for carcass yield traits, among these three breeds.

Key Words: Tropical Cattle, Size, Growth, Carcass, Pelvic Area

J. Anim. Sci. 1996. 74:955-964

Introduction

Tropically adapted cattle, specifically Brahman, have been important to the U.S. beef industry for many years, especially in regions where stresses from heat (Cartwright, 1980) and parasites (Turner, 1980) may limit productivity in many *Bos taurus* breeds. Brahman-*Bos taurus* F₁ cows have proven to be very productive in regard to fertility, milk production, and longevity (Cartwright et al., 1964; Franke, 1980; Bailey, 1991). However, high percentage Brahman (*Bos indicus*) cattle tend to have delayed age of puberty (Plasse et al., 1968; Cartwright, 1980), lower vigor of newborn calves (Reynolds et al., 1980), less intramuscular fat (Huffman et al., 1990; Whipple et al., 1990), and less tender beef (Crouse et al., 1989; Wheeler et al., 1990; Shackelford et al., 1991a) compared with many *Bos taurus* breeds.

The inability of the Brahman-*Bos taurus* F₁ cow to produce a replacement of equal productivity has been a severe production limitation, which has led to interest in other sources of tropically adapted cattle such as the Boran and Tuli breeds of Africa that might possibly exhibit high levels of heterosis when crossed with both Brahman and with *Bos taurus* breeds (Vercoe and Frisch, 1992).

Studies conducted within Africa have shown both Boran and Tuli cattle to be very fertile and productive for maternal traits (Maule, 1973; Trail et al., 1977; Gregory et al., 1985); however, information about these two African breeds is scarce for growth ability and carcass characteristics. This project was designed to evaluate F₁ calves sired by Brahman, Boran, and Tuli bulls for birth, growth, size, and carcass traits.

Materials and Methods

General Procedures

Multiparous Angus and Hereford cows were bred by AI to Brahman, Boran, and Tuli bulls in 1991 and 1992 at the Texas A&M University Research Center

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Received August 8, 1995.

Accepted January 16, 1996.

(TAES), McGregor. Calves included in this study were born in 1992 and 1993. Calves born in 1992 were sired by 5 Tuli, 4 Boran, and 10 Brahman bulls; calves born in 1993 were sired by 9 Tuli, 8 Boran, and 15 Brahman bulls. All bulls that sired calves in 1992 were also used to sire calves in 1993. Semen from available Tuli and Boran bulls was purchased and imported from Australia. These African bulls were considered to be typical individuals of their respective breeds (J. E. Frisch, personal communication). Semen from Brahman bulls was obtained from commercial breeding services and purebred breeders in the United States. These Brahman sires were considered to be representative of young herd sire prospects of the American Brahman breed of the early 1990s.

Calves were born in the spring calving seasons. Each calf was weighed and ear-tagged for identification within 48 h after birth; additionally, cannon bone length was measured on one rear leg of each calf. Each calf received a subjective score for calf vigor, calving ease, and nursing ability. Sex of calf, dam identification, birth date, and gestation length were also recorded at birth. Age of dams ranged from 3 to 22 yr; however, due to small sub-class numbers, cows that were 13 yr or greater were pooled into a single age of dam class for analyses of birth and weaning traits, giving a total of 11 age-of-dam classes.

Calves were dehorned and vaccinated for leptospirosis (5-way), clostridial complex (7-way), and IBR-PI3 at approximately 2 wk of age. Males born in 1992 were castrated at weaning, whereas those born in 1993 were castrated when birth measurements were recorded.

Calves were weaned at approximately 7 mo of age. Weight, hip height (directly over hook bones), and a subjective body condition score on a 1 to 9 scale were recorded for each calf; a score of 1 represented emaciated and 9 represented obese. Each calf also received a booster for leptospirosis and clostridial complex at weaning. Heifers were vaccinated for brucellosis. All calves were confined to pens and given free-choice hay and feed.

After a brief weaning adjustment period, heifers were put on warm-season grass pastures; during winter they grazed small grain pastures. At approximately 12 mo of age heifers were weighed, measured for hip height, and assigned a body condition score. Additionally, internal pelvic height and width were measured per rectum with a Rice Pelvimeter. Pelvic area was simply calculated as the product of internal pelvic height and width.

Steers were fed in the station feedlot after a brief weaning adjustment period until time of slaughter. Steers were given ad libitum access to a growing diet that consisted of ground grain sorghum, cottonseed meal, cottonseed hulls, and vitamin-mineral premix. Steer weight, hip height, and body condition score were evaluated at 28-d intervals throughout the feedlot phase. Final feedlot weight, hip height, and

body condition score were recorded 7 d prior to slaughter. Steers were killed at a commercial packing plant in Waco, TX. Steers born in 1992 were killed at approximately 400 d average age; those born in 1993 were on feed roughly 45 d longer and were killed at approximately 445 d average age. The mean final age of steers across both years was 423 d.

All carcasses were graded 24 h after death by one trained TAES evaluator according to USDA (1989) standards. Two 2.54-cm steaks (first two loin steaks) were removed from the hindquarter sections of the carcasses of the 1992-born calves, whereas one 2.54-cm steak at the 12th rib was removed from carcasses of the 1993-born calves. Steaks were wrapped in plastic and transported on ice to Texas A&M University Department of Animal Science, where they were vacuum-packaged and aged. The two steaks from the 1992-born animals were aged either 7 or 14 d, whereas the single steaks from 1993-born animals were aged 14 d. All steaks were frozen after the aging period. Upon thawing, steaks were cooked to an internal temperature of 70°C on an open-face broiler and allowed to cool to room temperature. Subsequently, 8 to 12 cores (1.27 cm in diameter) were removed from each steak and evaluated for tenderness on a Warner-Bratzler shear machine. Average shear force per steak was calculated and analyzed. The distributions of birth, steer carcass, and yearling heifer records by sire breed and dam breed are presented in Table 1.

Statistical Analysis

Data were analyzed through the mixed linear model procedure of SAS (1992), which uses a Newton-Raphson algorithm of REML (Patterson and Thompson, 1971) to estimate variance components.

Birth traits were weight (**BWT**), cannon bone length (**CBL**), and gestation length (**GEST**). Independent variables included in analyses of birth traits were sire breed, dam breed, age of dam, birth year, and calf sex as fixed effects. The regression on breeding date within breeding year was included to account for the trend of late-born spring calves to be much bigger at birth than early-born spring calves in central Texas.

Weaning traits were weight (**WWT**), hip height (**WHT**), and preweaning gain (**WGN**). Fixed effects included in models were sire breed, calf sex, age of dam, and dam breed-birth year management group. Cows of different breeds were managed separately after they calved in the 2 yr. Although the same group of Hereford and Angus cows were used both years, Angus cows that calved in 1993 were managed separately if they were large or moderate in regard to frame size to better manage nutritional requirements; this gave rise to five dam breed-birth year management groups. The regression on age was included for all weaning trait analyses.

Table 1. Distribution of birth, steer carcass, and yearling heifer records by sire breed and dam breed

	Birth		Steer carcass		Yearling heifer	
	Angus	Hereford	Angus	Hereford	Angus	Hereford
Sire breed						
Brahman	43	57	17	23	23	30
Boran	44	59	26	33	15	20
Tuli	43	62	16	27	23	28
Total	130	178	59	83	61	78

Feedlot traits of steers included final weight (**FWT**), final hip height (**FHT**), and feedlot ADG. Fixed effects included in models were sire breed, dam breed, birth year, and age of dam. The regression on final age within year was also included as a covariate. Due to small numbers in certain age of dam classes, cows 3 and 4 yr old were grouped into a single class. Cows 8, 9, and 10 yr were similarly grouped, as were cows 11 yr and older. These groupings based on similar ages of dams were used in the analyses of carcass traits and yearling heifer traits.

Carcass traits of steers included warm carcass weight (**HCW**), skeletal maturity (**SMAT**), lean muscle maturity (**LMAT**), intramuscular fat (**MARB**), longissimus muscle area (**REA**), 12th rib actual fat thickness (**FT**) and adjusted fat thickness (**AFT**), estimated internal fat (**KPH**), USDA yield grade (**YG**), and Warner-Bratzler shear force (**WBS**). Fixed effects included in the model were the same as for feedlot traits with the exclusion of age of dam. The regression on slaughter age within year was included as a covariate.

Yearling heifer traits were weight (**YWT**), hip height (**YHT**), body condition score (**YCS**), internal pelvic height (**PH**), pelvic width (**PW**), and pelvic area (**PA**). Fixed effects included in models were sire breed, dam breed, birth year, and age of dam. The regression on age within year was included in analyses of weight, hip height, and condition score. For pelvic measures, the regression on age within year and the regression on hip height within year were both investigated as covariates.

Sire within sire breed was included as a random effect for all analyses and was used as the denominator to calculate the *F*-statistic for testing the sire breed effect. Dam within dam breed was included as a random effect only for the birth trait analyses and was used as the denominator in the *F*-tests of the dam breed effect for birth traits. Dam effect was not included in the weaning trait analyses due to confounding of dam and dam breed-birth year management group. Dam within dam breed was not included in analyses of feedlot, carcass, and yearling heifer traits because fewer than 10% of the dams had more than one progeny represented in these data. Dam breed was tested against residual variation for weaning, feedlot, carcass and yearling heifer characters. All

other fixed effects were tested against residual error variation for all traits. Least squares means were calculated for fixed effects included in models and were tested for equality by paired *t*-tests (SAS, 1992).

Results and Discussion

Birth Traits. Breed of sire accounted for variation found among calves for BWT ($P < .001$) and CBL ($P < .001$), but not for GEST. Least squares means for birth traits are presented in Table 2. Brahman-sired calves were heaviest at birth ($44.0 \pm .7$ kg), followed by Boran- ($40.3 \pm .8$ kg) and Tuli-sired calves ($36.4 \pm .8$ kg), respectively. The difference in mean BWT of Brahman- vs Tuli-sired calves was much greater than the 4.3-kg difference in Botswana where calves were born to Tswana dams (Trail et al., 1977) and the 3.4-kg difference in Zimbabwe averaged across several dam breeds (Tawonezvi et al., 1988).

Calves produced by Angus vs Hereford dams and calves born in different years did not differ ($P = .15$) for BWT. Males weighed 4.4 kg more ($P < .001$) at birth than females. The regression on breeding date within breeding year did not account for variation observed in BWT. A sire breed \times calf sex interaction ($P = .07$) was present for BWT. Among Brahman crosses, males weighed 5.9 kg more than heifers, and among Boran crosses, males weighed 4.5 kg more than females. However, among Tuli crosses, bull calves averaged only 2.8 kg heavier than heifers. This is consistent with other reports (Cartwright et al., 1964; Comerford et al., 1987; Paschal et al., 1991) of sire breed \times calf sex interactions on birth weight where large sex differences were found in *Bos indicus* \times *Bos taurus* crossbred calves. A dam breed \times birth year interaction was also present ($P < .001$) for BWT. Calves born to Angus dams in 1992 averaged 1.9 kg less than those born to Hereford dams; however, calves born to Angus dams in 1993 averaged 2.8 kg heavier. Several cows only produced calves in one year; therefore, this interaction may reflect differences in management groups across years, or possibly differences in breeding values among cows used in different years.

Brahman-sired calves averaged largest for CBL ($31.0 \pm .1$ cm), followed by Boran- ($29.4 \pm .1$ cm) and

Table 2. Least squares means \pm SE of birth traits by sire breed, dam breed, sex of calf, and birth year

Fixed effect	n	Birth wt, kg	Cannon bone length, cm	Gestation length, d
Sire breed				
Brahman	101	44.01 \pm .69 ^a	31.00 \pm .14 ^a	288.6 \pm .9
Boran	104	40.25 \pm .84 ^b	29.44 \pm .14 ^b	289.7 \pm 1.2
Tuli	103	36.36 \pm .80 ^c	28.48 \pm .14 ^c	286.8 \pm 1.1
Dam breed				
Angus	131	40.43 \pm .58	30.08 \pm .12 ^a	288.2 \pm .8
Hereford	177	39.99 \pm .62	29.21 \pm .14 ^b	288.6 \pm .8
Sex of calf				
Female	131	38.01 \pm .58 ^a	29.30 \pm .12 ^a	287.4 \pm .7 ^a
Male	177	42.40 \pm .55 ^b	29.98 \pm .12 ^b	289.3 \pm .7 ^b
Birth year				
1992	156	45.26 \pm 3.39	30.45 \pm .85	290.9 \pm 3.7
1993	152	35.15 \pm 3.50	28.83 \pm .87	285.8 \pm 3.9

^{a,b,c}Means within a column lacking a common superscript differ ($P < .05$).

Tuli-sired calves, respectively ($28.5 \pm .1$ cm), indicating differences in skeletal size at birth. Paschal et al. (1991) reported mean CBL of F₁ Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, Red Brahman-, and Angus-sired calves to be 29.2, 28.9, 30.3, 29.9, 29.4, and 26.7 cm, respectively, when born to Hereford dams. Calves born to Angus cows had larger ($P < .001$) average CBL than those born to Hereford dams. Calves born in 1992 and 1993 did not differ for CBL. Male calves averaged .7 cm longer CBL than heifers. The regression on birth date was not significant for CBL variation.

These sire breeds did not differ in regard to GEST of progeny. There was a trend for calves sired by Boran bulls to have longest mean GEST (289.7 ± 1.2 d), followed by Brahman- ($288.6 \pm .9$ d) and Tuli-sired calves (286.8 ± 1.1 d), respectively. Several authors (Gregory et al., 1979b; Reynolds et al., 1980; Paschal et al., 1991) have reported longer gestation length in *Bos indicus*-*Bos taurus* than in straight-bred *Bos taurus* calves. Paschal et al. (1991) reported mean gestation length in *Bos indicus* \times Hereford F₁ calves to range from 289 to 294 d, whereas Angus \times Hereford F₁ calves averaged 282 d. In the current project, these three sire breeds all seemed to sire calves with longer mean gestation than what is expected in straight-bred *Bos taurus* calves. Calves produced by Angus vs Hereford cows did not differ; additionally, calves born in 1992 vs 1993 did not differ ($P = .50$). Male calves averaged 1.9 d greater ($P < .001$) GEST than females. The regression on breeding date did not account for differences observed in GEST.

Notter et al. (1978) reported the severe degree of dystocia that can occur in F₁ *Bos indicus*-sired calves born to young *Bos taurus* females. Very few calves in this project required assistance at birth; however, most of the cows were of relatively mature size. A total of six calves in 1992 and two in 1993 were given assistance during parturition. Of the six in 1992, three

were Brahman-sired (two in posterior position), two were Boran-sired, and one was Tuli-sired (posterior position). The two requiring assistance in 1993 were Brahman-sired heifers. A total of four calves required assistance to begin nursing their dams; three were Boran-sired and one was Brahman-sired. Gregory et al. (1979b) reported calving difficulty of 13.0% and 9.2% among Brahman- and Sahiwal-sired calves, respectively, born to Angus and Hereford cows that were 4 yr old and greater; contemporary Angus- and Hereford-sired F₁ calves experienced 5.9% calving difficulty.

Weaning Traits. Least-squares means of weaning traits are presented in Table 3. Breed of sire accounted for variation in WWT ($P < .001$), WGN ($P < .001$), and WHT ($P < .001$). Calves sired by Brahman bulls were heavier (234.3 ± 3.4 kg) than Boran- (217.1 ± 3.7 kg) and Tuli-sired calves (209.1 ± 3.5 kg), which did not differ. Maule (1973) reported F₁ Hereford \times Boran steers to average 185 kg for WWT, whereas straightbred Boran steers averaged 175 kg in Zambia. Trail et al. (1977) observed mean WWT to be 195 kg in Brahman \times Tswana F₁ calves and 179 kg for Tuli \times Tswana F₁ calves.

Male calves averaged 14.7 kg heavier WWT than females ($P < .001$). Dams in the 6 yr to 9 yr age range produced the heaviest calves. The regression on age ($P < .001$) was $.77 \pm .11$ kg/d. A sire breed \times age of dam interaction was present ($P = .07$) for WWT. No meaningful trends among sire breed \times age of dam subclass least squares means were apparent.

Brahman-sired calves averaged the most WGN (190.5 ± 3.0 kg), followed by Boran- (176.5 ± 3.3 kg) and Tuli-sired calves (172.3 ± 3.1 kg), which were not significantly different. Male calves averaged 10.8 kg more WGN than females ($P < .01$). The regression of WGN on age ($P < .001$) was $.85 \pm .10$ kg/d. Trends in WGN were similar to those observed for WWT in regard to dam breed-birth year groups and age of dam. An interaction between sire breed and age of dam was

Table 3. Least squares means \pm SE of weaning traits by sire breed, dam type, and sex of calf

Fixed effect	n	Weaning wt, kg	Preweaning gain, kg	Hip height, cm
Sire breed				
Brahman	97	234.3 \pm 3.4 ^b	190.5 \pm 3.0 ^b	115.9 \pm 0.5 ^b
Boran	95	217.1 \pm 3.7 ^c	176.5 \pm 3.3 ^c	110.3 \pm 0.5 ^c
Tuli	99	209.1 \pm 3.5 ^c	172.3 \pm 3.1 ^c	108.7 \pm 0.5 ^d
Dam type ^a				
Angus-92	50	230.7 \pm 3.7 ^b	189.0 \pm 3.4 ^b	111.4 \pm 0.6 ^b
Hereford-92	94	229.2 \pm 3.4 ^b	184.7 \pm 3.1 ^{bc}	111.1 \pm 0.5 ^b
M Angus-93	46	217.3 \pm 4.0 ^c	178.7 \pm 3.7 ^c	111.7 \pm 0.6 ^{bc}
L Angus-93	31	225.4 \pm 4.7 ^{bc}	185.4 \pm 4.4 ^{bc}	113.3 \pm 0.7 ^c
Hereford-93	70	198.3 \pm 3.6 ^d	161.1 \pm 3.3 ^d	110.5 \pm 0.5 ^b
Sex of calf				
Female	141	212.8 \pm 2.9 ^b	174.4 \pm 2.6 ^b	111.1 \pm 0.4 ^b
Male	150	227.5 \pm 2.8 ^c	185.2 \pm 2.5 ^c	112.2 \pm 0.4 ^c

^aAngus-92 = Angus dams calving in 1992, Hereford-92 = Hereford dams calving in 1992, M Angus-93 = medium-frame Angus dams calving in 1993, L Angus-93 = large-frame Angus dams calving in 1993, Hereford-93 = Hereford dams calving in 1993.

^{b,c,d}Means within a column lacking a common superscript differ ($P < .05$).

present ($P = .05$) for WGN with no apparently meaningful trends. Also, an interaction between calf sex and age of dam was present for WGN ($P = .06$). Across age of dam groups male calves averaged more WGN than females, except from cows 12 yr or older.

Brahman-sired calves were the tallest at weaning (115.9 \pm .5 cm), followed by Boran- (110.3 \pm .5 cm) and Tuli-sired calves (108.7 \pm .5 cm), respectively. Male calves averaged 1.1 cm taller than females ($P = .02$). The dam breed-birth year group ($P = .03$) and the age of dam ($P < .01$) effects both accounted for WHT variation. Trends in WHT for these two effects were similar to those observed in WWT and WGN. The regression of WHT on weaning age ($P < .001$) was .09 \pm .02 cm/d.

Feedlot Traits. Sire breed ($P < .001$), dam breed ($P = .05$), and age of dam ($P = .01$) accounted for variation in FWT. A dam breed \times age of dam interaction was also observed ($P = .04$). Least squares

means for feedlot traits are presented in Table 4. Brahman-sired steers were heavier (504.9 \pm 7.2 kg) than Boran- (446.8 \pm 6.7 kg) and Tuli-sired steers (454.3 \pm 7.2 kg), which did not differ. Koch et al. (1982) reported final feedlot weight of F₁ Brahman- and Sahiwal-sired steers to average 477.7 and 445.4 kg, respectively, when adjusted to 445-d basis. Paschal et al. (1995) observed F₁ steers sired by Gray Brahman, Gir, Indu-Brazil, Nellore, and Red Brahman bulls to average 499.7, 471.9, 491.7, 480.1, and 501.0 kg, respectively, for FWT at 504 d mean age.

Steers born to Angus dams averaged 16.3 kg heavier ($P = .05$) than those born to Hereford dams. Cows in the 3-yr to 7-yr age range generally produced the heaviest steers, compared to those born to cows 8 yr and older. In regard to the dam breed \times age of dam interaction, Hereford cows 3 to 4 yr old produced the heaviest steers, and Angus dams 5 to 7 yr old produced the largest steers.

Table 4. Least squares means \pm SE of feedlot traits by sire breed, dam breed, and birth year

Fixed effect	n	Final wt, kg	Feedlot ADG, kg/d	Final hip height, cm
Sire breed				
Brahman	40	504.9 \pm 7.2 ^a	1.33 \pm .03 ^a	135.8 \pm .7 ^a
Boran	59	446.8 \pm 6.7 ^b	1.12 \pm .03 ^b	126.5 \pm .7 ^b
Tuli	43	454.3 \pm 7.2 ^b	1.18 \pm .03 ^b	126.6 \pm .7 ^b
Dam breed				
Angus	59	476.8 \pm 6.2 ^a	1.23 \pm .02	129.9 \pm .6
Hereford	83	460.5 \pm 5.8 ^b	1.19 \pm .03	128.6 \pm .6
Birth year				
1992	74	461.8 \pm 8.8	1.19 \pm .04	128.4 \pm .8
1993	68	475.6 \pm 9.0	1.23 \pm .04	130.1 \pm .8

^{a,b}Means within a column lacking a common superscript differ ($P < .05$).

Table 5. Least squares means \pm SE for carcass quality traits by sire breed, dam breed, and year of birth

Fixed effect	n	Skeletal ^a maturity	Lean ^a maturity	Marbling ^b score	Warner-Bratzler shear force, kg
Sire breed					
Brahman	40	135.7 \pm 2.6 ^{cd}	133.7 \pm 2.6	323.9 \pm 9.3 ^c	3.59 \pm .14 ^{cd}
Boran	59	133.4 \pm 2.6 ^c	137.6 \pm 2.7	344.5 \pm 9.5 ^{cd}	3.76 \pm .14 ^c
Tuli	43	141.5 \pm 2.8 ^d	138.5 \pm 2.8	351.0 \pm 10.3 ^d	3.32 \pm .15 ^d
Dam Breed					
Angus	59	135.5 \pm 2.1	135.7 \pm 2.0	342.6 \pm 7.4	3.43 \pm .12
Hereford	83	138.2 \pm 1.8	137.4 \pm 1.8	337.0 \pm 6.5	3.68 \pm .10
Birth year					
1992	74	135.1 \pm 2.9	135.0 \pm 2.7	344.9 \pm 10.1	3.75 \pm .16
1993	68	138.6 \pm 3.0	138.2 \pm 2.8	344.7 \pm 10.4	3.36 \pm .17

^aMaturity: 100 = A⁰⁰, 200 = B⁰⁰, etc.

^bMarbling: 300 = Slight⁰⁰, 400 = Small⁰⁰, etc.

^{c,d}Means within a column lacking common superscripts differ ($P < .05$).

Sire breed ($P < .001$), dam breed ($P = .08$) and age of dam ($P < .01$) accounted for variation in FHT in steers. A dam breed \times age of dam interaction was also present ($P < .01$). Brahman-sired steers (135.8 \pm .7 cm) were taller than Boran- (126.5 \pm .7 cm) and Tuli-sired steers (126.6 \pm .7 cm), which did not differ. Trends in FHT due to age of dam, and the dam breed \times age of dam interaction, were similar to those observed in FWT.

Sire breed ($P < .001$) and age of dam ($P < .01$) effects accounted for variation observed in feedlot ADG. Brahman-sired steers averaged 1.33 \pm .03 kg/d and had higher ADG than Boran- (1.12 \pm .03 kg/d) and Tuli-sired steers (1.18 \pm .03 kg/d), which did not differ. The ADG observed for Brahman-sired steers was lower than that reported by Paschal et al. (1995) where F₁ Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, and Red Brahman-sired steers averaged 1.60, 1.47, 1.60, 1.50, and 1.57 kg/d, respectively, which is probably the result of feeding calves directly after weaning in the current study. Trend in feedlot ADG of steers due to age of dam was similar to that seen in FWT and FHT. The regressions of FWT, FHT, and

feedlot ADG on final age within slaughter year were not significant.

Carcass Traits. Least squares means are presented in Table 5 for carcass quality traits and Table 6 for carcass yield traits. Tuli-sired carcasses averaged higher for mean SMAT (141.5 \pm 2.8) than Boran-sired carcasses (133.4 \pm 2.6) but were not different from Brahman-sired carcasses (135.7 \pm 2.6). Carcasses did not differ in SMAT due to dam breed or birth year. For LMAT, carcasses did not differ due to sire breed, dam breed, or birth year. A sire breed \times birth year interaction ($P < .01$) was present, however. Among Brahman- and Boran-sired steers, those born in 1993 averaged higher LMAT, but among Tuli-sired steers, those born in 1992 averaged higher LMAT. Steers born in 1993 were approximately 45 d older when killed.

Tuli-sired steers averaged higher ($P = .05$) MARB (351.0 \pm 10.3) than Brahman-sired steers (323.9 \pm 9.3) but did not differ from Boran-sired steers (344.5 \pm 9.5). Koch et al. (1982) reported Sahiwal-sired steers to average slightly greater for MARB than

Table 6. Least squares means \pm SE for carcass yield traits by sire breed, dam breed, and year of birth

Fixed effect	n	Actual fat thickness, cm	Adjusted fat thickness, cm	Kidney pelvic and heart fat, %	Carcass wt, kg	Longissimus muscle area, cm ²	Yield grade
Sire breed							
Brahman	40	1.36 \pm .11	1.36 \pm .10	2.47 \pm .09 ^a	311.4 \pm 4.7 ^a	74.9 \pm 1.4	3.23 \pm .14
Boran	59	1.42 \pm .12	1.39 \pm .11	2.79 \pm .08 ^a	273.2 \pm 4.1 ^b	72.5 \pm 1.4	3.13 \pm .16
Tuli	43	1.28 \pm .12	1.27 \pm .12	2.77 \pm .09 ^b	276.2 \pm 4.7 ^b	74.3 \pm 1.7	2.95 \pm .17
Dam breed							
Angus	59	1.38 \pm .08	1.36 \pm .07	2.74 \pm .07	290.8 \pm 3.8	74.3 \pm 1.1	3.16 \pm .11
Hereford	83	1.32 \pm .07	1.32 \pm .07	2.62 \pm .06	283.1 \pm 3.3	73.5 \pm 1.0	3.05 \pm .10
Birth year							
1992	74	1.16 \pm .10 ^a	1.19 \pm .10	2.79 \pm .10	283.8 \pm 5.3	76.6 \pm 1.4 ^a	2.81 \pm .14 ^a
1993	68	1.54 \pm .11 ^b	1.48 \pm .10	2.57 \pm .10	290.0 \pm 5.7	71.2 \pm 1.5 ^b	3.40 \pm .14 ^b

^{a,b}Means within a column lacking common superscripts differ ($P < .05$).

Brahman-sired steers. Additionally, Paschal et al. (1995) reported no significant differences in MARB of Gray Brahman-, Gir-, Indu-Brazil-, Nellore- and Red Brahman-sired F₁ steers. No differences in MARB were attributed to dam breed or birth year. Tuli-sired carcasses averaged lower ($P = .03$) WBS ($3.32 \pm .15$ kg) than Boran-sired carcasses ($3.76 \pm .14$ kg) but did not differ from Brahman-sired carcasses ($3.59 \pm .14$ kg). Koch et al. (1982) reported WBS to average 4.27 kg for Sahiwal-sired steers and 3.92 kg for Brahman-sired steers, whereas contemporary Angus-Hereford F₁ steers averaged 3.44 kg. Carcasses born to Angus dams required .25 kg less WBS ($P = .07$) than those produced by Hereford dams. Carcasses of steers born in 1992 and 1993 did not differ for WBS.

Shackelford et al. (1991b) reported that threshold levels of consumer dissatisfaction for WBS were 4.6 kg for retail beef and 3.9 kg for food-service beef. Among Brahman-sired steers, 12 (30.0%) were above the 3.9-kg threshold and 3 (7.5%) were above the 4.6-kg threshold. Among Boran-sired steers, 25 (42.4%) were above the 3.9-kg level and 11 (18.6%) were above the 4.6-kg level. Among Tuli-sired steers, 10 (23.3%) were above the 3.9-kg level and 2 (4.7%) were above the 4.6-kg level. These differences were not statistically tested. Koch et al. (1982) reported that 20% of Sahiwal-sired steers and 14% of Brahman-sired steers were deemed unacceptable by taste panel evaluation when these two sire breeds averaged an acceptable tenderness score.

No differences among sire breeds or between dam breeds were observed for FT or AFT. Koch et al. (1982) reported similar FT in Brahman- and Sahiwal-sired F₁ steers when adjusted to weight-constant or age-constant bases. Steers born in 1993 averaged .38 cm more ($P = .02$) FT and .29 cm more ($P = .05$) AFT as a result of being fed approximately 45 d longer than those born the previous year. Brahman-sired steers had less KPH ($2.47 \pm .09\%$) than Boran- ($2.79 \pm .08\%$) and Tuli-sired steers ($2.77 \pm .09\%$). Koch et al. (1982) observed 4.24% actual KPH in Brahman-sired steers and 4.04% in Sahiwal-sired steers. Paschal et al. (1995) reported no differences in estimated KPH among F₁ steers sired by five *Bos indicus* breeds. No differences between dam breeds or between birth years were observed for KPH. A sire breed \times birth year interaction was present ($P = .07$) for KPH. Among steers born in 1992, Tuli crosses possessed the most KPH (3.02%), with Boran crosses intermediate (2.86%) and Brahman crosses the least (2.48%), but among steers born in 1993, Boran crosses had the most KPH (2.73%), with Tuli crosses intermediate (2.52%) and Brahman crosses the least (2.46%).

There were no differences in REA accounted for by sire breed or dam breed even though HCW was significantly heavier for Brahman-sired steers. This trend corresponds to that reported by Koch et al. (1982), who found that REA was similar between

Brahman- and Sahiwal-sired F₁ steers. This is also similar to the findings of Paschal et al. (1995), who reported no significant differences in REA of steers sired by five *Bos indicus* breeds. Steers born in 1992 averaged 5.4 cm² more ($P = .02$) REA than those born in 1993. A sire breed \times birth year interaction was also present ($P = .08$) for REA, as it was for KPH. Among Brahman- and Boran-sired steers, those born in 1992 averaged 6.9 and 7.2 cm², respectively, more REA than those born in 1993. However, among Tuli-sired steers, those born in 1992 averaged 1.7 cm² more than those born in 1993.

In regard to YG, no differences were accounted for by sire breed or dam breed. Steers born in 1993 had a higher ($P = .01$) numerical YG ($3.40 \pm .14$) than those born in 1992 ($2.81 \pm .14$). Sire breeds ranked the same for HCW as for FWT with Brahman-sired carcasses heavier (311.4 ± 4.7 kg) than Boran- (273.2 ± 4.1 kg) and Tuli-sired carcasses (276.2 ± 4.7 kg). Koch et al. (1982) reported Brahman-sired F₁ steers to average 308.2 kg at 445 d; Sahiwal-sired F₁ steers averaged 284.7 kg, and contemporary Angus-Hereford F₁ steers averaged 296.4 kg.

The regressions on slaughter age within year were not significant for carcass traits evaluated, with the exception of REA ($P = .03$). For steers killed in 1993 this regression was $.14 \pm .06$ cm²/d, whereas for steers killed in 1994 this regression was $.05 \pm .06$ cm²/d.

Yearling Heifer Traits. Sire breed accounted for variation seen in YWT ($P < .001$), YHT ($P < .001$), and YCS ($P < .01$) of heifers. Least squares means for yearling heifer traits are presented in Table 7. Brahman-sired heifers (310.7 ± 4.2 kg) averaged heavier YWT than Boran- (286.9 ± 5.6 kg) and Tuli-sired heifers (279.7 ± 4.8 kg). Gregory et al. (1979a) reported that 400-d weights of heifers born to Angus and Hereford dams averaged 349 kg for Brahman-sired heifers and 326 kg for Sahiwal-sired heifers. Long et al. (1979) reported 360-d weights of pasture-reared calves to average 244 kg for Brahman-Angus F₁ heifers and 240 kg for Brahman-Hereford F₁ heifers. Heifers produced by Angus dams were 16.8 kg heavier ($P < .001$) than those produced by Hereford dams.

Heifers born in 1993 averaged 18.2 kg heavier ($P < .001$) YWT than those born in 1992. Age of dam accounted for variation ($P = .01$) seen in YWT of heifers and followed a trend similar to that observed in FWT of steers. A sire breed \times age of dam interaction was present ($P = .04$) for heifer YWT. The heaviest Tuli-sired heifers were born to cows 6 yr old, the heaviest Boran-sired heifers were born to cows 4 yr old, and the heaviest Brahman-sired heifers were born to cows 7 yr old.

Brahman-sired heifers were taller ($125.5 \pm .7$ cm) for YHT than Boran- ($119.2 \pm .9$ cm) and Tuli-sired heifers ($118.8 \pm .8$ cm). Gregory et al. (1979a) reported 550-d hip height averaged 126 cm for

Table 7. Least squares means \pm SE for yearling heifer traits by sire breed, dam breed, and year of measurement

Fixed effect	n	Yearling wt, kg	Hip height, cm	Body condition score	Pelvic width, cm	Pelvic height, cm	Pelvic area, cm ²
Sire breed							
Brahman	53	310.7 \pm 4.2 ^a	125.5 \pm .7 ^a	5.09 \pm .07 ^a	10.94 \pm .16	15.04 \pm .11 ^a	165.55 \pm 3.10 ^a
Boran	35	286.9 \pm 5.6 ^b	119.2 \pm .9 ^b	5.53 \pm .10 ^b	10.60 \pm .22	14.55 \pm .13 ^b	154.73 \pm 4.16 ^b
Tuli	51	279.7 \pm 4.8 ^b	118.0 \pm .8 ^b	5.33 \pm .08 ^b	10.64 \pm .19	14.39 \pm .11 ^b	153.13 \pm 3.61 ^b
Dam breed							
Angus	61	300.8 \pm 3.7 ^a	121.8 \pm .6 ^a	5.37 \pm .06	10.79 \pm .13	14.83 \pm .10 ^a	160.33 \pm 2.70
Hereford	78	284.0 \pm 3.4 ^b	120.0 \pm .6 ^b	5.26 \pm .06	10.67 \pm .13	14.49 \pm .09 ^b	155.27 \pm 2.52
Evaluation yr							
1993	64	283.3 \pm 4.0 ^a	120.4 \pm .7	5.29 \pm .07	10.62 \pm .15	14.52 \pm .11	154.67 \pm 2.98
1994	75	301.5 \pm 3.4 ^b	121.4 \pm .6	5.35 \pm .06	10.83 \pm .13	14.80 \pm .09	160.93 \pm 2.53

^{a,b}Means within a column lacking common superscripts differ ($P < .05$).

Brahman-sired F₁ heifers, while those sired by Sahiwal averaged 122 cm, and contemporary F₁ Angus-Hereford heifers averaged 117 cm. Heifers born to Angus dams were 1.9 cm taller ($P = .01$) than those born to Hereford dams. Long et al. (1979) reported 360-d hip height of Brahman-sired F₁ heifers born to Angus and Hereford dams to be 113 to 114 cm.

Sire breed ($P < .01$) and the regression on age within year ($P < .01$) both accounted for variation observed for YCS of F₁ heifers. Brahman-sired heifers had the lowest YCS (5.09 \pm .07), followed by Tuli (5.33 \pm .08) and Boran-sired heifers (5.53 \pm .10); the difference between Boran and Tuli crossbred heifers approached significance ($P = .10$). The regression on age within evaluation year yielded a coefficient of .004 unit/d for heifers evaluated in 1993, whereas this regression was .013 unit/d for heifers evaluated in 1994. A dam breed \times year interaction was observed ($P = .05$) for YCS. Among heifers born to Angus cows, those evaluated in 1994 had higher YCS, whereas among heifers born to Hereford cows, those evaluated in 1993 averaged higher for YCS.

Sire breed differences were not found for PW. There was a trend for Brahman-sired heifers to have larger PW (10.94 \pm .16 cm) than Boran- (10.60 \pm .22 cm) and Tuli-sired heifers (10.64 \pm .19 cm) when age was included as a covariate. Stewart et al. (1980) reported pubertal PW averaged 9.99 cm for Angus-Brahman F₁ heifers at 399 d, whereas Hereford-Brahman F₁ heifers averaged 10.53 cm at 425 d when all heifers were managed on pasture from weaning to puberty. The regression on age within evaluation year accounted for variation ($P < .001$) observed in PW and yielded coefficients of .026 \pm .008 cm/d for heifers evaluated in 1993 and .016 \pm .007 cm/d for heifers evaluated in 1994. Age of dam also accounted for variation ($P = .02$) in PW. The trend was for cows 6 and 7 yr old to produce heifers with the greatest PW whereas those younger and older produced heifers with smaller PW. A dam breed \times age of dam interaction was present ($P = .08$) for PW. Angus dams

6 yr old produced heifers with larger PW and Hereford dams 7 yr old produced heifers with largest PW.

Differences in PH were observed due to sire breed ($P < .001$) and dam breed ($P = .01$) when the regression on age within evaluation year ($P < .01$) was included in the analyses. Brahman-sired heifers had larger PH (15.04 \pm .11 cm) than Boran- (14.55 \pm .13 cm) and Tuli-sired heifers (14.39 \pm .11 cm), which did not differ. Stewart et al. (1980) reported pubertal PH of pasture-reared heifers averaged 12.79 cm at 399 d among Angus-Brahman F₁ heifers and 13.69 cm at 425 d among Hereford-Brahman F₁ heifers. Heifers produced by Angus cows averaged greater PH (14.83 \pm .10 cm) than those produced by Hereford cows (14.49 \pm .09 cm). The regression on age within evaluation year yielded coefficients of .007 \pm .008 cm/d for heifers evaluated in 1993 and .021 \pm .006 cm/d for heifers evaluated in 1994. Heifers evaluated in 1994 averaged .28 cm greater ($P = .05$) PH than heifers evaluated in 1993.

Variation was observed in PA due to sire breed ($P = .03$), dam breed ($P = .09$), age of dam ($P = .09$), and a dam breed \times age of dam interaction ($P = .05$) when the regression on age within evaluation year ($P < .001$) was included. Brahman-sired heifers averaged greater PA (165.55 \pm 3.10 cm²) than Boran- (154.73 \pm 4.16 cm²) and Tuli-sired heifers (153.13 \pm 3.61 cm²), which did not differ. Stewart et al. (1980) reported pubertal PA for pasture-reared heifers averaged 144.2 cm² among Hereford-Brahman F₁ crosses at 425 d and 272 kg, whereas Angus-Brahman F₁ heifers averaged 127.8 cm² at 399 d and 262 kg. Comerford et al. (1988) reported average yearling PA in Brahman-Polled Hereford heifers of 229.7 cm² at 388.1 kg average YWT, which is much heavier than Brahman-sired heifers in this study (310.7 kg). Heifers produced by Angus dams averaged 5.06 cm² greater PA ($P = .09$) than those produced by Hereford dams. The trend in age of dam differences was similar to that seen for PW, with cows 6 and 7 yr old producing heifers with larger PA than other age classes. The

Literature Cited

trend in age of dam by dam breed combinations was similar to that observed for PW. The regression on age within evaluation year yielded coefficients of $.419 \pm .164$ cm²/d for heifers evaluated in 1993 and $.479 \pm .139$ cm²/d for heifers evaluated in 1994.

When YHT within evaluation year was included as a covariate no differences among sire breeds, dam breeds, or age of dam classes were observed for pelvic measurements. This indicates differences among pelvic measurements for these sire breeds were reflections of skeletal size differences. Morrison et al. (1989) reported Brahman-sired F₁ cows had less dystocia than Chianina-, Maine Anjou-, and Simmental-sired F₁ cows due to a smaller calf birth weight to pelvic area ratio. As a result, differences in skeletal size and pelvic measurements among sire breeds in this study should not necessarily be used to predict dystocia of these types of heifers.

The regression on YHT within evaluation year was an important source of variation for PW ($P < .001$), PH ($P < .001$), and PA ($P < .001$). For PW, the regressions were $.081 \pm .020$ cm/cm for heifers evaluated in 1993 and $.083 \pm .020$ cm/cm for those evaluated in 1994. For PH, the regressions were $.070 \pm .017$ cm/cm for heifers measured in 1993 and $.115 \pm .007$ cm/cm for those evaluated in 1994. For PA, the regressions were $1.91 \pm .388$ cm²/cm for heifers evaluated in 1993 and $2.51 \pm .396$ cm²/cm for heifers evaluated in 1994. Differences between years were observed in PH ($P = .06$) and PA ($P = .06$) when YHT was included as the covariate. Heifers evaluated in 1993 averaged $14.55 \pm .09$ cm PH and 155.00 ± 2.52 cm² PA, whereas those evaluated in 1994 averaged $14.79 \pm .08$ cm PH and 160.97 ± 2.14 cm² PA. This is likely a reflection of the fact that heifers evaluated in 1994 averaged 6 d older at measurement than heifers evaluated in 1993.

Implications

These results showed important differences in size and growth of calves sired by three tropically adapted breeds. Carcass differences were observed for quality traits, but not for yield traits. Brahman-sired calves were larger than those sired by Boran and Tuli at all ages of evaluation, which could represent economic advantages in a weight-based marketing system. The more desirable quality attributes of the Tuli-sired carcasses represent advantages in a value-based marketing system. The smaller birth size of the Tuli-sired calves could be a management advantage, and the smaller size of the Tuli- and Boran-sired females could translate into lower maintenance costs as mature cows. Further research on these cattle is needed to compare the production efficiencies of the crossbred females.

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