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Prewaning growth of F₁ tropically adapted beef cattle breeds × Angus and reproductive performance of their Angus dams in arid rangeland¹

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ABSTRACT: The objective of this study was to determine the preweaning performance of F₁ Brahman (*Bos indicus*)-, Senepol (*Bos taurus*)-, and Tuli (Sanga)-Angus calves under semiarid south Texas conditions and to evaluate the reproductive performance of their Angus dams. Four hundred eighty-nine records collected over 4 yr were analyzed. The statistical model for performance traits included the effects of breed of sire, year, sex, age of dam, and breed of sire × year. Year effects were important ($P < 0.05$) for performance traits but could be explained, at least partially, by differences between years in rainfall patterns. Brahman F₁ calves were 13% less ($P < 0.05$) vigorous at birth, 4.7 kg heavier ($P < 0.05$) at birth, 13.5 kg heavier ($P < 0.05$) at weaning, 0.25 units lower ($P < 0.05$) in body condition score (BCS) at weaning, and 1.75 units greater ($P < 0.05$) in frame score (scores of 1 to 9) at weaning than Tuli and Senepol F₁ calves. Senepol F₁ calves were intermediate ($P < 0.05$) between the Brahman and Tuli F₁ calves for birth and weaning weight but had 11% more ($P < 0.05$) vigor at birth than the other two crossbreds. Tuli and Senepol

F₁ were similar ($P > 0.05$) in BCS and frame size at weaning. Males were 3.3 kg heavier ($P = 0.12$) at birth than females, especially for the F₁ Brahman males that were 4.5 kg heavier ($P < 0.05$) than their counterparts. Brahman F₁ weaned 19.9 kg heavier ($P < 0.05$) than the average of the other two F₁ in the year of the greatest rainfall (1994), whereas the average advantage in other years was 11.4 kg. This difference gave rise to a breed of sire × year interaction ($P < 0.003$). Brahman F₁ were heavier at every measurement and appeared to be later-maturing and more able to excel under good forage conditions than the other two F₁ breed types; Senepol and Tuli F₁ were similar ($P > 0.05$) in these respects but appeared to be more competitive in relative growth rate to the Brahman F₁ calves in years of greater nutritional stress. Angus females were observed to have a relatively low reproductive rate and high apparent fetal loss at the first (27.5%) and second (19.2%) compared with the third or later pregnancy (11.2%). Angus females that gave birth to Brahman F₁ calves had 20.1% lower ($P < 0.05$) pregnancy rates in the succeeding year than those that had given birth to the other two breeds.

Key Words: Breeding Methods, Crossbreeding, Performance, Genotype Environment Interaction

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Introduction

The genus *Bos* is adapted to much of the world. Broad adaptation does not result from the ability of individuals to adapt broadly, but from the aggregate adaptation of the genetic diversity of the genus. Aggregate adaptation is evidenced in the abundance of reports indicating the prevalence of genotype × environment interactions (Butts et al., 1971; Bertrand et al., 1985; Holloway et

al., 1994). This indicates that even though the genus is widely adapted, individuals and types within the genus are not widely adapted. The production and economic consequences of mismatching animals with environmental niches can be great (Koger et al., 1975; Tess et al., 1979; Notter et al., 1992). Thus, perhaps, the most fundamental decision in beef production is the type of cattle that should occupy a production niche. The purpose of this experiment was to evaluate crossbred animals derived from three breeds that originated in different tropical environments as to their performance on arid, subtropical rangeland in south Texas and the performance of their Angus dams.

Materials and Methods

Four hundred eighty-nine preweaning growth records were collected for calves out of Angus cows over

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Table 1. Rainfall (mm) and temperature (°C) for the experimental period

| Year | Season ^a | Annual | Max. temp. ^b | Min. temp. ^c |
|------|---------------------|--------|-------------------------|-------------------------|
| 92 | 633 | 791 | 36.5 | 15.1 |
| 93 | 427 | 470 | 38.5 | 11.5 |
| 94 | 724 | 845 | 38.5 | 14.7 |
| 95 | 498 | 632 | 37.6 | 15.8 |
| Mean | 571 | 685 | 37.8 | 14.3 |

^aSeason of calf growth (April through October).

^bMaximum temperature during season of calf growth.

^cMinimum temperature during season of calf growth.

a 4-yr period and include 168 Brahman (*Bos indicus*), 154 Senepol (*Bos taurus*) and 167 Tuli (Sanga)-sired calves. Numbers of calves were distributed uniformly across years and breeds. Angus females were selected from two long-term local herds in south and west Texas. These females were moved at weaning during the autumns of 1990 through 1993 to the Rio Grande Plains Experimental Ranch, Spofford (29° 2' N, 100° 14' W, elevation 260 m, Table 1) operated by the Texas Agricultural Experiment Station, Uvalde. These females have been shown to have at least some heat adaptation (Forbes et al., 1998; Sprinkle et al., 2000). These females were artificially inseminated to 12 Brahman, 9 Senepol, and 7 Tuli bulls that were selected to represent bulls available commercially. All sires were represented in all years of the experiment. Each year, females were stratified according to source and age (no grouping by age was performed) and randomly allotted to breed of sire and sire within breed. Females of all ages and parities were represented in all years of the experiment. They were synchronized by administration of an implant (s.c.) containing norgestomet (6 mg, Merial Ltd., Athens, GA) for 9 d. On the day of implant removal, an injection (i.m.) of PGF_{2α} (25 mg, Lutalyse, Pharmacia and Upjohn, Kalamazoo, MI) was administered. Females were artificially inseminated 56 h after implant removal. Females detected in estrus within 23 d following the timed AI were inseminated approximately 12 h after the onset of estrus. Four Brahman bulls were utilized each year for 60-d "clean-up" periods. Calves were born during February through April of each year from 1992 through 1995. The average calving date was March 23. Calves from "clean-up" bulls were used as experimental units only if they calved during the allotted period. Calves were born from primiparous and multiparous females each year. Angus females were examined for pregnancy, weighed, and scored according to BCS (1 = thin, 9 = fat, Long et al., 1979) and frame (1 = small, 9 = large, expanded scale from Lowman et al., 1976) in the fall of each year. Pregnancy was determined by palpation of the fetus per rectum between 90 and 175 d after breeding. Birth dates and weights and a calf vigor score (1 = live and vigorous, 2 = weak but alive, and 3 = born dead) were recorded each year. Male calves were left intact. Calves were weaned in October

of each year at about 7 mo of age. At weaning, calves were weighed and scored for BCS and frame.

Cattle grazed extensively managed "mixed-brush" rangeland characterized by relatively sparse herbage with an overstory of shrubs that inhibited free movement of animals over the landscape (Holloway et al., 1993). Although cattle on this rangeland at times consume certain shrub species, shrubs do not usually compose much of the diet except during drought conditions (Launchbaugh et al., 1990). Prominent grass species were sideoats grama (*Bouteloua curtipendula*), red grama (*B. trifida*), buffalograss (*Buchloe dactyloides*), curly mesquite (*Helaria belangeri*), pink pappas (*Pappophorum bicolor*), Wrights threeawn (*Aristida wrightii*), and bristlegrass (*Setaria leucopila*). Prominent forb species were common ragweed (*Ambrosia artemisiifolia*) and Texas croton (*Croton texensis*). Prominent shrubs included honey mesquite (*Prosopis glandulosa* var. *glandulosa*) and *Acacia* species including twisted acacia (*A. tortuosa*), blackbrush (*A. rigidula*), and guajillo (*A. berlandieri*). Although herbage allowance was not measured during each year, and growing conditions varied from year to year (as reflected by year to year variation in rainfall, Table 1), in general the herbage allowance was estimated to be in the range of 800 to 1,400 kg DM per 100 kg animal BW. Cattle were provided free access to trace mineralized salt³. Adaptation of heat adapted animals to arid rangelands is only a part of the bigger picture of adaptation to the range of subtropical conditions from humid to arid. Therefore, this experiment was a component of a larger study designed to evaluate three classifications of tropically adapted breeds (*Bos indicus*, Sanga, and tropically adapted *Bos taurus*) across the southeastern United States and Nebraska, ranging from hot, humid conditions (Overton, TX [Browning et al., 1995], Brooksville, FL [Chase et al., 2000], and Tifton, GA [Baker, 1996]) to semi-arid conditions (El Reno, OK; Clay Center, NB [Cundiff et al., 1998] and McGregor, TX [Herring et al., 1996]) to arid conditions (Uvalde, TX [Holloway et al.,

³Trace mineralized salt composition: 33% NaCl, 11% Ca, 8% P, 1.9% Mg, 1.3% K, 0.4% Mn, 0.5% Zn, 0.8% Fe, 0.1% Cu, 1,564,000 IU/kg of vitamin A, and 1,100 IU/kg of vitamin D3.

Table 2. Birth weight (kg) for calves born in different years^a

| Year | Breed of sire | | | Mean |
|------|--------------------------|---------------------------|----------------------------|--------------------------|
| | Brahman | Senepol | Tuli | |
| 1992 | 40.0 ± 0.90 ^e | 37.4 ± 1.08 ^g | 35.2 ± 0.90 ^{ghi} | 37.5 ± 0.64 ^b |
| 1993 | 36.3 ± 0.96 ^g | 32.8 ± 0.84 ^{hi} | 31.6 ± 0.94 | 33.6 ± 0.60 ^c |
| 1994 | 39.5 ± 0.91 ^e | 37.0 ± 0.77 ^g | 33.6 ± 0.74 ^{hi} | 36.7 ± 0.48 ^b |
| 1995 | 42.4 ± 0.63 ^f | 37.2 ± 0.73 ^g | 33.9 ± 0.71 ⁱ | 37.8 ± 0.48 ^b |
| Mean | 39.5 ± 0.43 ^b | 36.1 ± 0.43 ^c | 33.6 ± 0.42 ^d | 36.8 ± 0.22 |

^aLeast squares means ± SE from the following model: Birth weight = sex ($P < 0.0001$), year ($P < 0.0001$), breed of sire ($P < 0.0001$), age of dam ($P < 0.0023$), sire × year ($P < 0.0659$).

^{b,c,d}Main effect means with different superscripts differ ($P < 0.05$) according to a *t*-test.

^{e,f,g,h,i,j}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a *t*-test.

1998] and Las Cruces, NM [Winder and Bailey, 1995]). Because these experiments were designed to be similar in calving season and sires employed, inferences are drawn concerning genotype × environment interactions. Because the experiment at Brooksville, FL (Chase et al., 2000) was the most similar to the one presented here (having the same parent dam breed of Angus, the same sire breeds [Tuli, Senepol, and Brahman], many of the same sires within sire breeds, and the same calving season), direct comparisons will be made as to sire breed performance and the reproductive performance of a temperate breed of cows under humid and arid conditions.

Least squares means for the performance response variables were computed using GLM procedures of SAS (SAS Inst. Inc., Cary, NC). The model for birth weight and birth date was $\hat{Y} = \text{sex, year, breed of sire, age of dam, breed of sire} \times \text{year}$. The model for other calf growth variables was $\hat{Y} = \text{day of age, sex, year, breed of sire, age of dam, breed of sire} \times \text{year}$. Preliminary analyses for all variables included all interactions of calf sex and other main effects. None of these interactions were important ($P > 0.05$), and these terms were omitted from the final models. Statistical differences between means were determined with *t*-tests (Steel and Torrie, 1980). Calf vigor at birth and impact of breed of calf on subsequent reproduction were analyzed by the chi-square statistic through the CATMOD procedure of SAS. The model $\hat{Y} = \text{year, age of dam, breed of sire}$ was used for calf vigor; and $\hat{Y} = \text{year age of dam, breed of sire of previous calf}$ was used for dependent variables characterizing impact of breed of calf on subsequent reproduction (pregnancy exam and calving record).

Results and Discussion

Birth Characteristics

The lowest birth weights (33.6 kg, $P < 0.05$, Table 2) were observed in the year of least rainfall (1993, Table 1). Although there was some evidence for a year × breed of sire interaction ($P < 0.07$) for birth weight (Table 2), the F₁ breeds ranked the same in each year, with Brahman, Senepol, and Tuli crossbred calves weighing

39.5, 36.1, and 33.6 kg, respectively. Results from companion studies in McGregor, and Overton, TX; Brooksville, FL; Tifton, GA; El Reno, OK; and Clay Center, NE showed similar birth weight advantages for Brahman-sired calves. We detected only weak evidence ($P = 0.12$, Table 3) for a sex of calf × sire breed interaction for birth weight in this experiment, in agreement with results reported by Herring et al. (1996). There was a trend, however, for Brahman crossbred male calves to have a greater birth weight advantage over females than in the case of Senepol or Tuli crossbred calves (advantage of 4.5 kg for Brahman, 2.7 kg for Senepol and 2.5 kg for Tuli F₁ males, Table 3). Browning et al. (1995) and Chase et al. (2000) reported greater advantages for Brahman-sired males over females than for Angus- and Tuli-Brahman or Senepol- and Tuli-Angus crossbreds, respectively.

The proportion of calves born alive and vigorous is presented in Table 4. A higher percentage ($P < 0.05$) of Senepol F₁ calves were born alive and vigorous (85.7%), followed by Tuli crosses (71.0%); Brahman crosses had the lowest percentage ($P < 0.05$, 62.5%). A higher percentage ($P < 0.05$) of the Brahman F₁ calves were also born dead (5.4% compared with 0 and 0.4% for Senepol and Tuli crossbreds, respectively). The percentage of calves born that were weaned, however, was similar ($P > 0.10$) for the three crossbreds, although the Brahman F₁ calves tended to wean a lower percentage of those born than the other two breeds (93.9% compared with 99.4% for Senepol F₁ and 97.7% for Tuli F₁ calves). Notter et al. (1978) reported dystocia problems with young *Bos taurus* females calving F₁ *Bos indicus*-sired calves.

Weaning Characteristics

Year affected weaning weight and frame score ($P < 0.05$) and tended to affect ($P < 0.10$) preweaning gain. Calves weaned in the year of lowest rainfall (1993) had a 11.7-kg lower ($P < 0.05$) weaning weight, 0.3 units lower ($P < 0.05$) frame score, and 0.04 kg/d lower ($P < 0.10$) preweaning gain than the average of other years (Tables 5, 6, and 7). The year of the heaviest weaning weight and preweaning gain ($P < 0.05$), however, was

Table 3. Birth weight (kg) for calves of different sexes^a

| Sex | Breed of sire | | | Mean |
|--------|--------------------------|--------------------------|--------------------------|--------------------------|
| | Brahman | Senepol | Tuli | |
| Female | 37.2 ± 0.54 ^e | 34.7 ± 0.58 ^f | 32.5 ± 0.057 | 34.8 ± 0.35 ^b |
| Male | 41.7 ± 0.58 | 37.4 ± 0.58 ^e | 35.0 ± 0.55 ^f | 38.1 ± 0.36 ^c |
| Mean | 39.5 ± 0.42 ^b | 36.1 ± 0.42 ^c | 33.8 ± 0.42 ^d | 36.8 ± 0.22 |

^aLeast squares means ± SE from the following model: Birth weight = sex ($P < 0.0001$), year ($P < 0.0001$), breed of sire ($P < 0.0001$), age of dam ($P < 0.0023$), sire × year ($P < 0.0659$), sex × breed of sire ($P < 0.12$).

^{b,c,d}Main effect means with different superscripts differ ($P < 0.05$) according to a *t*-test.

^{e,f}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a *t*-test.

Table 4. Percentage of calves born live and vigorous (percentage born dead)

| Age of dam | Breed of sire | | | Mean |
|------------|-------------------------|-----------------------|-------------------------|-------------------------|
| | Brahman | Senepol | Tuli | |
| 2 | 77.8 (0) | 100 (0) | 75.0 (0) | 84.3 (0) ^a |
| 3 | 79.8 (4.1) | 80.5 (0) | 91.2 (1.8) | 83.8 (2.0) ^a |
| 4 | 41.5 (4.9) | 76.5 (0) | 52.9 (0) | 57.0 (1.6) ^a |
| 5 | 59.4 (12.5) | 86.4 (0) | 76.7 (0) | 74.2 (4.2) ^a |
| 6 | 55.6 (5.6) | 85.0 (0) | 59.1 (0) | 66.6 (1.9) ^a |
| Mean | 62.5 (5.4) ^a | 85.7 (0) ^b | 71.0 (0.4) ^c | 73.2 (1.9) |

^{a,b,c}Main effects (percentage born live and vigorous) with different superscripts differ ($P < 0.05$) according to a chi-square analysis.

Table 5. Weaning weight (kg) adjusted for age at weaning for calves born in different years^a

| Year | Breed of sire | | | Mean |
|------|----------------------------|----------------------------|----------------------------|----------------------------|
| | Brahman | Senepol | Tuli | |
| 1992 | 192.4 ± 4.19 ^e | 189.0 ± 4.89 ^{eh} | 178.1 ± 4.17 ^{gh} | 186.5 ± 2.98 ^b |
| 1993 | 186.7 ± 4.39 ^{eh} | 176.7 ± 3.81 ^g | 173.6 ± 4.24 ^g | 179.0 ± 2.21 ^c |
| 1994 | 196.4 ± 4.06 ^{ef} | 174.9 ± 3.47 ^g | 178.2 ± 3.36 ^{gh} | 183.2 ± 2.20 ^{bc} |
| 1995 | 211.6 ± 3.21 ^f | 204.2 ± 3.32 ^f | 191.6 ± 3.28 ^e | 202.5 ± 2.27 ^d |
| Mean | 196.8 ± 1.94 ^b | 186.2 ± 1.95 ^c | 180.4 ± 1.89 ^d | 189.9 ± 0.98 |

^aLeast squares means ± SE from the following model: Weaning weight = day of age ($P < 0.0001$), sex ($P < 0.0001$), year ($P < 0.0008$), breed of sire ($P < 0.0001$), age of dam ($P < 0.0001$), sire × year ($P < 0.0029$).

^{b,c,d}Main effect means with different superscripts differ ($P < 0.05$) according to a *t*-test.

^{e,f,g,h}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a *t*-test.

Table 6. Frame score at weaning adjusted for age at weaning for calves born in different years^a

| Year | Breed of sire | | | Mean |
|------|--------------------------|--------------------------|--------------------------|--------------------------|
| | Brahman | Senepol | Tuli | |
| 1992 | 6.5 ± 0.15 ^d | 4.5 ± 0.18 ^f | 4.5 ± 0.15 ^f | 5.2 ± 0.11 ^b |
| 1993 | 5.9 ± 0.16 ^e | 4.1 ± 0.14 ^g | 4.4 ± 0.15 ^{fg} | 4.8 ± 0.10 ^c |
| 1994 | 6.2 ± 0.15 ^{de} | 4.6 ± 0.13 ^f | 4.6 ± 0.12 ^f | 5.1 ± 0.08 ^b |
| 1995 | 6.2 ± 0.12 ^{de} | 4.3 ± 0.12 ^{fg} | 4.4 ± 0.12 ^{fg} | 5.0 ± 0.08 ^{bc} |
| Mean | 6.2 ± 0.07 ^b | 4.4 ± 0.07 ^c | 4.5 ± 0.07 ^c | 5.0 ± 0.03 |

^aLeast squares means ± SE from the following model: Frame score = day of age ($P < 0.0001$), sex ($P < 0.03$), year ($P < 0.005$), breed of sire ($P < 0.0001$), age of dam ($P < 0.06$), sire × year ($P < 0.3$).

^{b,c}Main effect means with different superscripts differ ($P < 0.05$) according to a *t*-test.

^{d,e,f,g}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a *t*-test.

Table 7. Preweaning average daily gain (kg/d) adjusted for age at weaning for calves born in different years^a

| Year | Breed of sire | | | Mean |
|------|-----------------------------|-----------------------------|----------------------------|---------------------------|
| | Brahman | Senepol | Tuli | |
| 1992 | 0.75 ± 0.019 ^{dfg} | 0.75 ± 0.022 ^{dfg} | 0.71 ± 0.019 ^{fg} | 0.74 ± 0.013 ^b |
| 1993 | 0.75 ± 0.020 ^{dfg} | 0.72 ± 0.017 ^{fg} | 0.71 ± 0.020 ^{fg} | 0.72 ± 0.013 ^c |
| 1994 | 0.78 ± 0.018 ^d | 0.68 ± 0.016 ^g | 0.72 ± 0.015 ^g | 0.73 ± 0.010 ^c |
| 1995 | 0.85 ± 0.014 ^e | 0.83 ± 0.015 ^e | 0.78 ± 0.015 ^d | 0.82 ± 0.010 ^c |
| Mean | 0.78 ± 0.009 ^b | 0.75 ± 0.009 ^c | 0.73 ± 0.009 ^c | 0.76 ± 0.004 |

^aLeast squares means ± SE from the following model: Average daily gain = day of age ($P < 0.0001$), sex, year ($P < 0.0001$), breed of sire ($P < 0.0001$), age of dam ($P < 0.0001$), sire × year ($P < 0.07$).

^{b,c}Main effect means with different superscripts differ ($P < 0.05$) according to a t -test.

^{d,e,f,g}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a t -test.

1995, the year of the second-lowest rainfall. Although only 498 mm of rain fell during the preweaning period of 1995, higher than normal rainfall during the previous fall augmented growing conditions for that year so that forage supply was greater than expected from the annual rainfall records (Table 1). In the previous year (1994), 411 mm of the 845 mm of rain fell in September through December, providing excellent soil conditions for grass and forb growth early in 1995. Thus, 1995 was a better forage year than is reflected in the rainfall records for that year, and the forage carry-over effect from the previous year combined with early rains during the spring growing season supported heavier birth and weaning weights than in any other year.

As an average of all years of the experiment, Brahman F₁ calves were 13.5 kg heavier at weaning ($P < 0.05$, Table 5), had 0.25 units lower BCS ($P < 0.05$, Table 8), had 1.75 units higher frame scores ($P < 0.05$, Table 6), and gained 0.04 kg/d faster prior to weaning ($P < 0.05$, Table 7) than Senepol or Tuli crossbred calves. Senepol and Tuli F₁ were generally similar ($P > 0.05$) for these variables, although the Senepol F₁ weaned slightly heavier (5.9 kg, $P < 0.05$, Table 5) than Tuli F₁ calves. This provides evidence that Brahman crossbred calves were later-maturing than the other F₁, which appeared similar in maturation rate. Four reports of research using the same bulls as in this study indicated that under humid to semi-arid conditions, Brahman

crossbred calves were heavier at weaning and appeared later-maturing than Senepol and Tuli crossbred calves (Baker, 1996; Herring et al., 1996; Cundiff et al., 1998). Herring et al. (1996) reported that Brahman × British calves were heavier and taller at the hips at weaning than Boran- and Tuli-crossbred calves. Chase et al. (2000) also reported that Brahman × Angus calves were heavier and taller at weaning than Senepol- and Tuli-Angus calves. Chase et al. (2000) also agreed with our results in that the Tuli- and Senepol-Angus calves were similar in weaning weight and height at hooks. The advantage for Brahman crossbred calves over Senepol and Tuli crossbreds, however, was much greater in the humid subtropics than in the arid conditions of our study (27.3 kg advantage reported by Chase et al. (2000) compared with 13.5 kg in south Texas). This provides some evidence that the relative adaptation to rangeland conditions of the three breeds is more similar than the relative adaptation to humid subtropical conditions. Both Herring et al. (1996) and Chase et al. (2000) reported a larger advantage in weaning weight for male calves than for female calves for Brahman crossbreds than for other breeds studied. The interaction of breed of sire × sex was not important ($P > 0.20$) for weaning characteristics in this study.

Breed of sire × year interactions were detected for weaning weight ($P < 0.003$, Table 5), BCS ($P < 0.0001$, Table 8), and preweaning ADG ($P < 0.04$, Table 7), but

Table 8. Body condition score at weaning adjusted for age at weaning for calves born in different years^a

| Year | Breed of sire | | | Mean |
|------|----------------------------|---------------------------|--------------------------|-------------------------|
| | Brahman | Senepol | Tuli | |
| 1992 | 3.8 ± 0.14 ^e | 4.6 ± 0.17 ^{fh} | 4.1 ± 0.14 ^{ei} | 4.1 ± 0.10 ^b |
| 1993 | 4.3 ± 0.15 ^{fghi} | 4.4 ± 0.13 ^{fgi} | 4.6 ± 0.14 ^{fh} | 4.4 ± 0.09 ^c |
| 1994 | 4.6 ± 0.14 ^{fh} | 4.4 ± 0.12 ^{fi} | 4.7 ± 0.11 ^{fh} | 4.6 ± 0.08 ^c |
| 1995 | 4.1 ± 0.11 ^{gi} | 4.6 ± 0.11 ^{fh} | 4.5 ± 0.11 ^f | 4.4 ± 0.08 ^c |
| Mean | 4.2 ± 0.07 ^b | 4.5 ± 0.07 ^c | 4.5 ± 0.06 ^c | 4.4 ± 0.03 |

^aLeast squares means ± SE from the following model: BCS = day of age ($P < 0.0001$), sex ($P < 0.01$), year ($P < 0.0001$), breed of sire ($P < 0.006$), age of dam ($P < 0.0004$), sire × year ($P < 0.001$).

^{b,c,d}Main effect means with different superscripts differ ($P < 0.05$) according to a t -test.

^{e,f,g,h}Breed of sire × year sub-cell means with different superscripts differ ($P < 0.05$) according to a t -test.

Table 9. Influence of parity on pregnancy success and body condition score (BCS) of Angus females^{ab}

| Parity | Pregnant at exam | | Failed to calve | | Successful calving | |
|--------------------------------|------------------|-------------------------|--------------------|--------------------------|--------------------|-------------------------|
| | n ^e | BCS ^f | n (%) ^d | BCS ^f | n (%) ^e | BCS ^f |
| 1 | 234 | 5.6 ± 0.12 ^h | 60 (25.6) | 5.4 ± 0.21 ^{hi} | 174 (74.4) | 5.7 ± 0.13 ^h |
| 2 | 190 | 5.0 ± 0.16 ⁱ | 31 (15.8) | 5.0 ± 0.29 ⁱ | 159 (84.2) | 4.9 ± 0.13 ^j |
| ≥ 3 | 132 | 4.1 ± 0.26 ^j | 11 (8.3) | 3.4 ± 0.49 ^k | 121 (91.7) | 4.8 ± 0.15 ^j |
| Sum or means ± SE ^g | 556 | 5.2 ± 0.07 ^h | 102 (18.3) | 5.4 ± 0.12 | 454 (81.7) | 5.2 ± 0.05 |

^aLeast squares means from the following model: BCS = parity, calving success, parity × calving success.

^bPregnancy success: chi-square analysis from the following model: calving success = parity ($P < 0.05$).

^cNumber of Angus females declared pregnant.

^dNumber of Angus females not giving birth (percentage of pregnant females).

^eNumber of Angus females giving birth (percentage of pregnant females).

^fBCS (1 to 9, 9 being the fattest).

^gSum of all parities (n) or mean ± SE from the model: BCS = parity, calving season, parity × calving season.

^{h,i,j,k}Means within a column with different superscripts differ ($P < 0.05$) according to a *t*-test or chi square; main effects with different superscripts are different within a row or column.

not frame score ($P > 0.20$, Table 6). In the year of the highest rainfall (1994, Table 1), Brahman F₁ calves had the greatest advantage in weaning weight and pre-weaning ADG over the other crossbred calves (19.9 kg and 0.08 kg/d, Tables 5 and 7, respectively). This was also the only year that they exhibited BCS comparable to those of the other F₁ ($P > 0.10$, Table 8). These observations agree with comparisons with Chase et al. (2000) indicating that the Senepol and Tuli crossbreds are more competitive in growth traits compared with Brahman crossbreds under low nutrition conditions. Trends in BCS and frame scores indicated that the breed of sire × year interaction in weaning weight was the result of complex interactions between forage and growth patterns that were not clearly attributable to either frame or BCS but to some combination of the two. Brahman crossbred calves, however, had consistently larger ($P < 0.05$) frame sizes and tended to have lower BCS than the other two breeds every year ($P < 0.05$, Table 7).

Reproduction of Angus Dams

Of the 933 matings of Angus females employed to produce the F₁ calves in this study, 59.6% were examined pregnant in the fall prior to calving and 81.7% of these pregnancies resulted in live calves born the following spring (Table 9). Thus, as an average of all matings, 18.3% of those declared pregnant by pregnancy exam in the fall failed to calve the next spring. Overall pregnancy and calving rates were below the expected range in that estimates of net calf crop in beef herds in the United States range from 65 to 81% (Bellows et al., 1978). Embryo mortality rate was not measured in this study, but the incidence of embryonic death may have exceeded reported values. Alexander et al. (1995) reported a rate of embryo mortality of 5.8% between 30 and 60 d of gestation in dairy cows (Labernia et al., 1996). Bellows et al. (1978) summarized reproductive performance of beef herds during a 14-yr period and reported that fetal death occurred in

2.8% of the cows during the interval from palpation to the end of gestation, compared with 18.3% in this study. Palpation by slip of the chorioallantois during early gestation (30 to 70 d) may increase the rate of iatrogenic abortion (Abbitt et al., 1978). However, other studies found no conclusive evidence that use of the palpation technique between 30 and 70 d of gestation affected the rate of pregnancy loss (Vallancourt et al., 1979; Labernia et al., 1996). It is unlikely that the high rate of fetal attrition in the present study was affected by palpation per rectum that was performed during the second trimester of gestation because it involved minimal manipulation of the uterus.

A smaller ($P < 0.001$) percentage were declared pregnant and actually calved for those calving at 2 yr of age than for older females (Table 10). Females pregnant for the first time had greater ($P < 0.05$) fetal loss (25.6%) than did females with their second (15.8%) or later pregnancy (8.3%, Table 9). Mature cows had a greater chance of maintaining pregnancy to term. Cattle on these rangelands have been reported to consume shrubs including *Acacia berlandieri*, especially under drought conditions (Launchbaugh et al., 1990). Forbes et al. (1995) reported that these shrub species contain high levels of biologically active phenolic amines. Forbes et al. (1994), Carpenter et al. (1994), and Vera Avila et al. (1996) have reported that these amines influence hypothalamic, pituitary, adrenal, and gonadal function, which may result in interruption of pregnancy. Females would be expected to consume higher proportions of their diet as shrubs during years of least rain. The year with the lowest rain during the grazing season (1995; Table 1) also had the lowest percentage calf crop weaned (59%); the year with the lowest annual rainfall (1993, Table 1) had the second-lowest (65%) compared with the higher rainfall years of 1992 and 1994 (95 and 85%, respectively). Females that were declared non-pregnant in the fall prior to calving had 1.0 units lower ($P < 0.05$) BCS at that time than those that were declared pregnant, regardless of age (Table 10). Also,

Table 10. Reproductive rate of Angus females and success rate of their pregnancies

| Age of dam, yr | Sample size | Pregnant at exam ^a | Successful calving ^b | Apparent fetal loss ^c | Fall BCS ^d | | |
|---|------------------|-------------------------------|---------------------------------|----------------------------------|-------------------------|-------------------------|-------------------------|
| | | | | | Nonpregnant | Pregnant at exam | Successful calving |
| 2 | 123 | 54 (43.9) | 34 (63.0) | 20 (37.0) | 4.7 ± 0.20 | 5.1 ± 0.36 | 5.4 ± 0.28 |
| 3 | 258 | 186 (72.1) | 147 (79.0) | 39 (21.0) | 4.8 ± 0.20 | 4.9 ± 0.28 | 5.2 ± 0.14 |
| 4 | 213 | 137 (64.3) | 109 (79.6) | 28 (20.4) | 4.4 ± 0.19 | 5.1 ± 0.31 | 4.9 ± 0.16 |
| 5 | 143 | 97 (67.8) | 84 (86.6) | 13 (13.4) | 3.7 ± 0.25 | 5.0 ± 0.46 | 5.5 ± 0.18 |
| 6 | 96 | 82 (85.4) | 78 (95.1) | 4 (4.9) | 4.1 ± 0.44 | 6.8 ± 0.83 | 5.3 ± 0.19 |
| Sum ^e or means ± SE ^f | 933 ^e | 556 (59.6) ^g | 452 (81.3) ^h | 104 (18.7) ⁱ | 4.4 ± 0.07 ^g | 5.4 ± 0.12 ^h | 5.3 ± 0.05 ^g |

^aNumber of Angus females declared pregnant in the fall prior to calving (percentage of total number).

^bNumber of Angus females giving birth (percentage of pregnant females).

^cNumber declared pregnant in fall exam – number giving birth in spring (number losing fetuses/number pregnant).

^dBody condition scores (BCS) and frame scores (1 to 9, 9 being the fattest or having the most frame).

^eSum of all parities.

^fMean of all parities ± SE of the following model: $Y \hat{Y} = \text{Year} + \text{parity}$.

^{g,h,i}Main effect means with a different superscript differ ($P < 0.05$) according to a t -test (BCS) or chi square (reproductive rate); main effects with a different superscript are different within a row.

young Angus females (2- and 3-yr-olds) that were diagnosed pregnant but failed to calve tended to have lower ($P < 0.10$) BCS than those that successfully calved. These observations provide some evidence that the females that successfully calved tended to be more adapted to the environment than were those that did not calve, and that those that were declared nonpregnant were the least adapted. This was especially true for the younger females that were the most nutritionally stressed. Angus females that had raised Brahman crossbred calves the previous year were declared to have 15.1% lower pregnant rates by palpation in the fall prior to calving ($P < 0.05$, Table 11) than those that had raised the other two crossbred calves. This advantage had disappeared by the time of calving ($P > 0.20$, Table 11). Although the apparent fetal loss rate during gestation could not be shown to be related to sire breed of the previous calf, a trend existed for less apparent fetal loss for females that had previously raised Brahman calves (10.9% compared with 17.2% and 16.0% for females that had raised Senepol and Tuli crossbred calves previously, $P > 0.20$, Table 11). These results indicate the possibility that at least a portion of the low reproductive rate observed for these Angus

females was due to fetal mortality after pregnancy check in the fall. Also, by inference, the low pregnancy rate detected by palpation the fall prior to calving might have been the result of some embryonic loss prior to palpation. These losses might be the result of consumption of shrubs containing toxins that interrupted pregnancy.

Implications

Brahman (*Bos indicus*) × Angus calves grew faster and were apparently later-maturing than both Senepol (*Bos taurus*) and Tuli (Sanga) F₁ calves in that they were larger, had higher frame sizes, and had more growth potential. Their size advantage and later maturity resulted in problems with lack of vigor at birth, which could be associated with the observed decreased reproduction in their dams. Angus females in their first or second parities could not maintain pregnancy to the extent of mature cows. The size advantage of Brahman F₁ calves tended to be less pronounced as nutritional stress increased. Because of these apparent interactions between growth pattern and nutrition, other implications of their size advantage may be site- and mar-

Table 11. Influence of calf breed on subsequent reproductive performance of Angus females

| Item | Sire breed of previous calf | | | |
|----------------------------------|-----------------------------|------------------------|------------------------|------------------|
| | Brahman | Senepol | Tuli | Senepol and Tuli |
| Sample size | 84 | 96 | 103 | 199 |
| Pregnant at exam ^a | 46 (54.8) ^d | 64 (66.7) ^e | 75 (72.8) ^e | 139 (69.9) |
| Successful calving ^b | 41 (89.1) ^d | 53 (82.8) ^d | 63 (84.0) ^d | 116 (83.5) |
| Apparent fetal loss ^c | 5 (10.9) ^d | 11 (17.2) ^d | 12 (16.0) ^d | 23 (16.6) |

^aNumber of Angus females declared pregnant in the fall prior to calving (percentage of sample).

^bNumber of Angus females giving birth (percentage of those declared pregnant).

^cNumber pregnant at palpation – number that calved (percentage of those declared pregnant by exam that did not calve).

^{d,e}Means within a row with different superscripts differ ($P < 0.05$) according to a chi-square analysis.

ket-specific, being determined by the degree of adaptation to specific environments and the degree to which they can produce beef as desired for the market.

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