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Growth and Performance of F1 Tropically Adapted Beef Cattle Breeds x Angus in Arid Rangeland

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Summary

The objective of this study was to determine the growth patterns and performance ofFI Brahman (Bos indicus)-, Senepol (Bos taurus)-, and Tuli (Sanga)-Angus calves under semiarid south Texas conditions. Four hundred eighty-nine preweaning 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 x 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 Fl 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 Fl calves. Senepol Fl calves were intermediate *(P* < 0.05) between the Brahman and Tuli Fl calves for birth and weaning weight, but had 11 % more (P < 0.05) vigor at birth than the other two crossbreds. Tuli and Senepol Fls 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 Fl Brahman males that were 4.5 kg heavier *(P* < 0.05) than their counterparts. Brahman Fls weaned 19.9 kg heavier *(P* < 0.05) than the average of the other two Fls 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 x year interaction *(P* < 0.003). Brahman Fls were heavier at every measurement both preweaning and postweaning, and appeared to be later maturing and more able to excel under good forage conditions than the other two Fl breed types; Senepol and Tuli Fls were similar *(P* > 0.05) in these respects, but appeared to be more competitive in relative preweaning growth rate to the Brahman Fl calves in years of greater nutritional stress. Because the Brahman Fl females had heavier *(P* < 0.05) weights throughout the experiment, but were later maturing, they had lower reproductive rates than the other two Fl breed types.

Senepol and Tuli Fl 's were earlier maturing, but the Senepol Fl 's had difficulty calving as two year olds, reducing their percent calf crop weaned. As a result, the Tuli Fl's weaned more calf per female exposed, and more calfper 100 kg female exposed than the other Fl breed types. Senepol and Brahman Fl 's were similar in efficiency of production for their first calving opportunity. However, Senepol Fl females weaned less calfper 100 kg female maintained for both the second and third calving opportunities. The Tuli Fl females had the highest efficiency for their 1st and 2nd calving opportunities but were similar to Brahman Fl females by their 3rd calf. Brahman F 1 females had the highest weight of calf per loo kg cow maintained for their third calf.

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Introduction

Senepol cattle have been reported to be adapted to tropical and subtropical conditions. Because genotype x environment interactions have been shown to be important, it is unclear the conditions that are critical to their adaptation (Butts et al., 1971; Bertrand et al., 1985; Holloway et al., 1994). 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 production systems for Senepol cattle is the determination of their 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 in arid, subtropical rangeland in south Texas and the production performance as brood females. 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 U.S. and Nebraska, ranging from hot, humid conditions (Overton, Texas (Browning et al., 1995), Brooksville, Florida (Chase et al., 2000), and Tifton, Georgia (Baker, 1996)) to semi-arid conditions (El Reno, Oklahoma; Clay Center, Nebraska (Cundiff et al., 1998), and McGregor, Texas (Herring et al., 1996)), and to arid conditions (Uvalde, Texas (Holloway et al.,1998), and Las Cruces, New Mexico (Winder and Bailey, 1995)). Because these experiments were designed to be similar in calving season and sires employed, inferences are drawn concerning genotype x environment interactions. Because the experiment at Brooksville, Florida (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.

Materials and Methods

Angus Dams

Four hundred eighty-nine preweaning growth records were collected for calves out of Angus cows over a 4 yr period and include 168 Brahman *(Bas indicus),* 154 Senepol *(Bas taurus)* and 167 Tuli (Sanga)- sired calves. Number of calves was 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 falls 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 PGF2α. (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 over-story of shrubs that inhibited free movement of animals over the landscape {Holloway et al., 1993). Although the 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 three awn *(Aristida wrightii),* and bristlegrass *(Seteria leucopila).* Prominent forb species were common ragweed *(Ambrosia artemisifolia),* 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 l00 kg animal **BW.** Cattle were provided free access to trace mineralized salt[1].

F 1 Females

The F 1 females were maintained in one herd postweaning and exposed to Hereford bulls for 90 days in the spring as yearlings (April 15 to July 15). The same breeding schedule and Hereford bulls were utilized in each of the subsequent years through their third reproductive cycle. The first calves born to the Fl females were in 1994. Birth date, weight and calving difficulty score (1 = live and vigorous, 2 = weak or assisted birth, and 3 = dead) were collected only for the first calf, each year after that only weaning data which included weight, body condition score (1 = thin, 9 = fat, Long, et al., 1979) and frame (1 = small, 9 = large, expanded scale from Lowman et al., 1976) were collected in the fall of each year. Pregnancy was determined by palpation of the fetus per rectum between 90 and 175 d after breeding. Male calves were left intact. Calves were weaned in October of each year at about 7 mo of age. All Fl females were weighed, condition scored and frame scored in the fall at weaning. Fl females palpated open were not removed from the herd. After their first calf all the F 1 females were maintained in the same pasture. In September of 1996 all the Fl females were moved to a new ranch located at Cline, Texas (20 miles N 77° W of the city ofUvalde, and 18 miles S 84° E

[1]Trace mineralized salt composition: 33% NaCl, 11% Ca, 8% P, 1.9% Mg, 1.3% K, .4% Mn, .5% Zn, .8% Fe, .1% Cu, 1,564,000 ill/kg of vitamin A, and 1,100 ill/kg of vitamin D3.

of the city of Bracketville). This ranch is classified as extensively managed "mixed- brush" rangeland characterized by relatively sparse herbage with an over-story of shrubs that inhibited free movement of animals over the landscape, similar to the Rio Grande Experimental Ranch as described above.

Statistical Analysis

Least square means for the performance response variables were computed using GLM of SAS (SAS Inst. Inc., Cary, N.C.). The model for birth weight and birth date was: $\hat{Y}$=sex, yr, breed of sire, age of dam, breed of sire x yr. The model for other calf growth variables was $\hat{Y}$=day of age, sex, yr, breed of sire, age of dam, breed of sire x yr. Preliminary analyses for all variables included all interactions of calf sex and other main effects. None of these interactions were important (P> .05), and these terms were omitted from the final models. Statistical differences between means were determined with t-tests (Steel and Tome, 1980). Calf vigor at birth and impact of breed of calf on subsequent reproduction were analyzed by the chi-square statistic through the CA TMOD procedure of SAS. The model: $\hat{Y}$=yr, age of dam, breed of sire was used for calf vigor; and $\hat{Y}$=yr 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 x breed of sire interaction ($P < 0.07$) for birth weight (Table 2), the Fl 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, Texas; Brooksville, Florida; Tifton, Georgia; El Reno, Oklahoma; and Clay Center, Nebraska showed similar birth weight advantages for Brahman-sired calves. We detected only weak evidence ($P = 0.12$, Table 3) for a sex of calf x 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 Senopol and 2.5 kg for Tuli Fl males, Table 3). Browning et al. (1996), 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.

Proportion of calves born alive and vigorous is presented in Table 4. A higher percentage ($P < 0.05$) of Senepol Fl calves were born alive and vigorous (85.7%) followed by Tuli crosses (71.0%) with the Brahman crosses having the lowest percentage ($P < 0.05$,62.5%). A higher percentage ($P < 0.05$) of the Brahman Fl calves were also born dead (5.4% as compared with 0 and 0.4% for Senepol and Tuli crossbreds respectively). Percentage of calves born that were weaned; however, was similar ($P > 0.10$) for the three crossbreds, although the Brahman F 1 calves tended to wean a lower percent of those born than the other two breeds (93.9% compared with 99.4% for Senepol Fl and 97.7% for Tuli Fl calves). Notter et al., (1978) reported dystocia problems with young *Bas taurus* females calving Fl *Bas indicus-sired* calves.

Weaning Characteristics

Year significantly affected weaning weight and frame score (P < .05) and tended to affect (P < 0.10) preweaning gain. Calves weaned in the year of lowest rainfall (1993) had 11.7 kg less (*P* < 0.05) weaning weight, .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 5,7 and 8). The year of the heaviest weaning weight and preweaning gain (*P* < 0.05); however, was in 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 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 .25 units lower BCS (*P* < 0.05, Table 6), had 1.75 units higher frame scores (*P* < 0.05, Table 7), and gained .04 kg/d faster prior to weaning (P < 0.05, Table 8) than Senepol or Tuli crossbred calves. Senepol and Tuli F1s were generally similar (P > 0.05) for these variables although the Senepol F1s 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 F1s 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 x 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 x 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 female calves for Brahman crossbreds than other breeds studied. The interaction of breed of sire x sex was not important (*P* > 0.20) for weaning characteristics in this study.

Breed of sire x year interactions were detected for weaning weight (*P* < 0.003, Table 5), BCS (*P* < 0.0001, Table 6), and preweaning **ADG** (P < 0.04, Table 8), but not frame score (*P* > 0.20, Table 7). In the year of the highest rainfall (1994, Table 1), Brahman F1 calves had the greatest advantage in weaning weight and preweaning **ADG** over the other crossbred calves (19.9 kg and .08 kg/d, Tables 5 and 8, respectively). This was also the only year that they exhibited comparable BCS to the other F1s (*P* > 0.10, Table 6). These observations agree with comparisons with Chase et al. (2000) indicating that the Senepol and Tuli crossbreds are more competitive in growth traits compared to Brahman crossbreds under low nutrition conditions. Trends in BCS and frame scores indicated that the breed of sire x 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 8).

Preweaning and Postweaning Growth of developing heifers

Developing heifer preweaning growth is shown in Table 9. Postweaning growth is shown in Table 10. As shown in Tables 2,3,5,6,7, and 8 for the calf crop, Brahman cross females retained as brood females were heavier ($P < 0.05$) than the other two breed crosses at birth, and weaning. They had greater ($P < 0.05$) frame sizes and less ($P < 0.05$) condition than the other breed crosses. Senepol crosses were generally intermediate for these variables. Although Brahman cross females had greater ($P < 0.05$) daily gain preweaning, the other two breed crosses were similar ($P < 0.05$, Table 9). Postweaning, Brahman cross females were heavier ($P < 0.05$) and grew faster ($P < 0.05$) than the other two breed crosses, with the Tuli crossbreds being intermediate (Table 10). These results indicate that Brahman crosses were later maturing and Senepol crosses were earlier maturing than Tuli crosses.

Performance of First Calf Females

Hereford crossbred calves out of first parity Senepol x Angus females were heavier at birth ($P < 0.05$) than calves out of the other crosses (Table 11). Weanling calves out of Brahman cross females were heavier ($P < 0.05$), grew at a faster ($P < 0.05$) rate prior to weaning, had more ($P < 0.05$) condition, and greater ($P < 0.05$) frame sizes than calves out of the other two crossbreds. Calves out of Tuli cross females were intermediate ($P < 0.05$) for these variables.

Reproductive Performance and Efficiency

Senepol and Tuli primiparous crossbred females had 12.0 and 12.5% respectively greater (Table 12) reproductive rates than Brahman crossbred females resulting in 4.5 and 11.7% more calves being born respectively. Senepol crossbred females had 7.5% more calving difficulty than Brahman cross females, and 7.2% more than Tuli cross females. As a result, the weight weaned per female exposed and weight weaned per 100 kg of female exposed was greatest for Tuli crossbreds (37.9 kg calf weaned/100 kg cow exposed) and least for Senepol crossbreds (27.1 kg calf weaned/100 kg cow exposed). For weight weaned per 100 kg of female exposed, Brahman crosses were intermediate (30.2 kg calf weaned/100 kg cow exposed, Table 12).

Reproductive rate and efficiency improved for all the F1 females having their second calving opportunity (Table 13). Senepol crossbred females had the lowest efficiency of weight weaned per 100 kg of cow exposed (29.6%) compared to the other 2 crossbred females (35.4% for Brahman and 41.3% for Tuli crossbreeds). The Senepol crossbred females were intermediate for fall weight maintained (Table 13) with Tuli crosses being only 9 kg less while Brahman crosses were 43 kg heavier. Brahman crossbred females had calves with the heaviest weaning weights compared to either Senepol or Tuli crossbred females (221 vs 194 and 205 kg, respectively). The heavier weaning weights of the calves from Brahman crosses resulted in the highest weaning weight per cow exposed (149) but were not enough to offset the higher cow weight maintained. Therefore Tuli crosses were the most efficient in terms of calf weaned per 100 kg of cow maintained (41.3 kg calf weaned per 100 kg cow maintained).

Reproductive performance and efficiency continued to increase for all of the F1 females having their third calving opportunity (Table 14). As was the case for their second calf, Senepol crossbreds had the lowest efficiency (37.5 kg calf weaned per 100 kg cow maintained) compared to the other F1 crossbred females (43.1 for Brahman and 42.7 for Tuli crossbreeds). Brahman crossbred females had calves that were heavier at weaning compared to either Senepol or Tuli crossbred females (251 kg vs 223 and 228, respectively). Due to a slightly lower percent weaned than the other F1 crosses, weaned weight per cow exposed was lowest for Senepol F1 females (164 kg vs 208 for Brahman and 182 for Tuli). Brahman and Tuli F1 females were similar in efficiency of calf weaned per 100 kg of cow maintained (43.1 and 42.7 kg calf weaned per 100 kg cow maintained respectively) even though Brahman F1 females were 57 kg heavier in the fall.

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

[a] Season of calf growth (April through October)
[b] Maximum temperature during season of calf growth.
[c] Minimum temperature during season of calf growth.

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

	Breed of sire			
Year	Brahman	Senepol	Tuli	Mean
1992	40.0 ± .90[e]	37.4 ± 1.08[g]	35.2 ± .90[ghi]	37.5 ± .64[b]
1993	36.3 ± .96[g]	32.8 ± .84[hi]	31.6 ± .94	33.6 ± .60[c]
1994	39.5 ± .91[e]	37.0 ± .77[g]	33.6 ± .74[hi]	36.7 ± .48[b]
1995	42.4 ± .63[f]	37.2 ± .73[g]	33.9 ± .71[i]	37.8 ± .48[b]
Mean	39.5 ± .43[b]	36.1 ± .43[c]	33.6 ± .42[d]	36.8 ± .22

[a] Least square means ± SE from model: Birth weight=sex (*P* < 0.0001), year (*P* < 0.0001), breed of sire (*P* < 0.0001), age of dam (*P* < 0.0023), sire x 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 x year sub-cell means with different superscripts differ (*P* < 0.05) according to a t test.

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

	Breed of sire			
Sex	Brahman	Senepol	Tuli	Mean
Female	37.2 ± .54[e]	34.7 ± .58[f]	32.5 ± .57	34.8 ± .35[b]
Male	41.7 ± .58	37.4 ± .58[e]	35.0 ± .55[f]	38.1 ± .36[c]
Mean	39.5 ± .42[b]	36.1 ± .42[c]	33.8 ± .42[d]	36.8 ± .22

[a] Least square means ± SE from model: Birth weight=sex (*P* < 0.0001), year (*P* < 0.0001), breed of sire (*P* < 0.0001), age of dam (*P* < 0.0023), sire x year (*P* < 0.0659), sex x 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 x 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)

	Breed of sire			
Age of dam	Brahman	Senepol	Tuli	Mean
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)

[abc]Main effects (percentage born live and vigorous) with different superscript 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]

	Breed of sire			
Year	Brahman	Senepol	Tuli	Mean
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

[a] Least square means ± SE from 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 x 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 x year sub-cell means with different superscripts differ (*P* < 0.05) according to a t test.

Table 6. **BCS** at weaning adjusted for age at weaning for calves born in different years[a]

	Breed of sire			
Year	Brahman	Senepol	Tuli	Mean
1992	3.8 ± .14[e]	4.6 ± .17[fh]	4.1 ± .14[ei]	4.1 ± .10[b]
1993	4.3 ± .15[fghi]	4.4 ± .13f[gi]	4.6 ± .14[fh]	4.4 ± .09[c]
1994	4.6 ± .14[fh]	4.4 ± .12[fi]	4.7 ± .11[fh]	4.6 ± .08[c]
1995	4.1 ± .11[gi]	4.6 ± .11[fh]	4.5 ± .11[f]	4.4 ± .08[c]
Mean	4.2 ± .07[b]	4.5 ± .07[c]	4.5 ± .06[c]	4.4 ± .03

[a] Least square means ± SE from 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 x 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 x year sub-cell means with different superscripts differ (*P* < 0.05) according to a t test.

Table 7. Frame score at weaning adjusted for age at weaning for calves born in different years[a]

Year	Breed of Sire			
	Brahman	Senepol	Tuli	Mean
1992	6.5 ± .15[d]	4.5 ± .18[f]	4.5 ± .15[f]	5.2 ± .11[b]
1993	5.9 ± .16[e]	4.1 ± .14[g]	4.4 ± .15[fg]	4.8 ± .10[c]
1994	6.2 ± .15[de]	4.6 ± .13[f]	4.6 ± .12[f]	5.1 ± .08[b]
1995	6.2 ± .12[de]	4.3 ± .12[fg]	4.4 ± .12[fg]	5.0 ± .08[bc]
Mean	6.2 ± .07[b]	4.4 ± .07[c]	4.5 ± .07[c]	5.0 ± .03

[a] Least square means ± SE from model: Frame score=day of age ($P < 0.0001$), sex ($P < .03$), year ($P < 0.005$), breed of sire ($P < 0.0001$), age of dam ($P < 0.06$), sire x 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 x year sub-cell means with different superscripts differ ($P < 0.05$) according to a t test.

Table 8. Preweaning average daily gain (kg/d) adjusted for age at weaning for calves born in different years[a]

Year	Breed of sire			
	Brahman	Senepol	Tuli	Mean
1992	.75 ± .019[dfg]	.75 ± .022[dfg]	.71 ± .019[fg]	.74 ± .013[b]
1993	.75 ± .020[dfg]	.72 ± .017[fg]	.71 ± .020[fg]	.72 ± .013[c]
1994	.78 ± .018[d]	.68 ± .016[g]	.72 ± .015[g]	.73 ± .010[c]
1995	.85 ± .014[e]	.83 ± .015[e]	.78 ± .015[d]	.82 ± .010[c]
Mean	.78 ± .009[b]	.75 ± .009[c]	.73 ± .009[c]	.76 ± .004

[a] Least square means ± SE from 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 x 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 x year sub-cell means with different superscripts differ ($P < 0.05$) according to a t test.

Table 9. Preweaning growth of heifers retained as brood females.

	Breed of sire		
Variable	Brahman	Senepol	Tuli
Number of calves	91	74	84
Birth weight, kg[a]	39.0 ± .52	36.1 ± .49	34.0 ± .51
Birth date[a,c]	12308.4 ± 2.06[d]	12308.6 ± 1.94[e]	12305.0 ± 1.97[e]
Weaning weight, kg[b]	197.8 ± 2.54	184.8 ± 2.28[d]	181.5 ± 2.42[d]
Condition score at weaning[b]	4.29 ± .082[d]	4.41 ± .074[de]	4.54 ± .078[e]
Frame score at weaning[b]	6.18 ± .090	4.38 ± .080[d]	4.56 ± .085[d]
Total preweaning gain, kg[b]	71.7 ± 1.05	67.4 ± .94[d]	67.1 ± 1.04[d]
Preweaning daily gain, kg/d[b]	.36 ± .005	.33 ± .005[d]	.33 ± .005[d]

[a]Least square means from the model: $\hat{Y}$=sex of calf, year of birth, sire of dam, age of dam, sire of dam x year of birth, sire of dam x sex of calf, sire of dam x age of dam.
[b]Least square means from the model: $\hat{Y}$ = Preweaning day of age, sex of calf, year of birth, sire of dam, age of dam, sire of dam x year of birth, sire of dam x sex of calf, sire of dam x age of dam, preweaning day of age x sire of dam, preweaning day of age x age of dam.
[c]Date is a SAS (Statistical Analysis System) date value which is number of days from January 1, 1960.
[d,e] Breed of sire means with different superscripts differ ($P < 0.05$) according to a t test.

Table 10. Postweaning growth of brood females.[a]

Variable	Brahman	Breed of sire Senepol	Tuli
Number of females	91	74	84
Postweaning gain, kg	24.3 ± 1.90[c]	18.5 ± 1.94[d]	22.0 ± 1.86[cd]
Postweaning daily gain, kg/d	.17 ± .012[c]	.13 ± .012[d]	.16 ± .012[cd]
Yearling gain, kg	41.9 ± 1.44[c]	35.6 ± 1.48	39.7 ± 1.42[c]
Yearling daily gain, kg/d	.12 ± .004[c]	.10 ± .004	.11 ± .004[c]
Weight in spring, kg	250.4 ±4.21	218.8 ± 5.14	237.3 ± 4.79
Condition score in spring	4.84 ± .096[c]	4.61 ± .117[c]	4.86 ± .109[c]
Frame score in spring	5.92 ± .126	4.23 ± .154[c]	4.35 ± .143[c]
Weight in fall, kg	337.0 ± 6.00	302.2 ± 7.09[c]	304.9 ± 6.50[c]
Condition score in fall	5.19 ± .076[c]	4.87 ± .093[d]	5.01 ± .087[cd]
Frame score in fall	6.55 ± .009	4.74 ± .121[c]	4.78 .113[c]

[a]Least square means from the model: $\hat{Y}$ = Postweaning day of age, year of birth, sire of dam, age of dam, sire of dam x year of birth, sire of dam x age of dam.
[b]Least square means from the model: $\hat{Y}$ = Year of birth, pregnancy status, sire of dam, sire of dam x year of birth, sire of dam x pregnancy status, year of birth x pregnancy status.
[cd] Breed of sire means with different superscripts differ (*P* < 0.05) according to a t test.

Table 11. Performance of Hereford-sired calves from first calf females.

Variable	Brahman	Breed of sire Senepol	Tuli
Number of calves	46	37	53
Birth weight, kg[a]	35.6 ± 1.13[cd]	37.4 ± 0.98[c]	34.8 ± 0.86[c]
Birth date[ab]	12865.4 ± 7.38[d]	12876.3 ± 6.31[c]	12859.7 ± 5.59[d]
Weaning weight, kg[a]	201.8 ± 8.6	163.8 ± 7.8	183.5 ± 6.6
Condition score at weaning[a]	4.87 ± .206[c]	4.24 ± .189[d]	4.59 ± .160[cd]
Frame score at weaning[a]	5.67 ± .267	4.23 ± .242	4.73 ± .207
Preweaning daily gain, kg/d[a]	.85 ± .031	.66 ± .028[d]	.71 ± .024[d]
Preweaning gain, kg[a]	163.3 ± 8.70	124.0 ± 8.08	147.2 ± 6.76

[a]Least square means from the model: $\hat{Y}$ = Calf sex, year of birth, survivability code, sire of dam, sire of dam x year of birth, sire of dam x calf sex.
[b]Date is a SAS (Statistical Analysis System) date value which is number of days from January 1, 1960.
[cd] Breed of sire means with different superscripts differ (*P* < 0.05) according to a t test.

Table 12. Reproductive performance of F1 females for their first calf.

Variable	Breed of sire		
	Brahman	Senepol	Tuli
Number of brood females	91	74	84
Number of offspring	46	37	53
Percent pregnant[a]	63.7	75.7	76.2
Percent born[b]	55.0	59.5	66.7
Percent having calving difficulty[c]	8.7	16.2	9.5
Percent weaned[d]	50.5	50.0	63.1
Weight weaned per cow exposed, kg	101.9	81.9	115.8
Efficiency, kg calf/100 kg cow exposed	30.2	27.1	37.9

[a]Percent of females exposed to a bull that were palpated pregnant in the fall.
[b]Percent of females exposed that calved.
[c]Percent of females that had difficult births (calving difficulty score of 2 or 3 (calving difficulty: 1 = live and vigorous, 2 = weak or assisted birth, 3 = dead).
[d]Percent of females exposed that weaned a calf.

Table 13. Reproductive performance of F1 females for their second calf.

Variable	Breed of sire		
	Brahman	Senepol	Tuli
Number of brood females	86	66	78
Number of offspring	58	38	52
Percent weaned[a]	67.4	57.6	74.3
Brood female weight in the fall, kg	421	378	369
Weaning weight of the calves, kg	221	194	205
Weight weaned per cow exposed, kg[b]	149	112	152
Efficiency, kg calf/100 kg cow	35.4	29.6	41.3

[a]Percent of females exposed to a bull that weaned a calf in the fall.
[b] Weight weaned per cow exposed = weaning weight x percent weaned.
[c] Efficiency = weight weaned per cow exposed/brood female weight in the fall.

Table 14. Reproductive performance of F1 females for their third calf.

Variable	Breed of sire		
	Brahman	Senepol	Tuli
Number of brood females	88	65	79
Number of offspring	73	48	63
Percent weaned[a]	83.0	73.8	79.7
Brood female weight in the fall, kg	483	439	426
Weaning weight of the calves, kg	251	223	228
Weight weaned per cow exposed, kg[b]	208	164	182
Efficiency, kg calf/100 kg cow	43.1	37.5	42.7

[a]Percent of females exposed to a bull that weaned a calf in the fall.
[b] Weight weaned per cow exposed = weaning weight x percent weaned.
[c] Efficiency = weight weaned per cow exposed/brood female weight in the fall.

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