COMPARISON OF F1 COWS SIRED BY BRAHMAN, BORAN AND TULI BULLS FOR REPRODUCTIVE, MATERNAL, AND COW LONGEVITY TRAITS

A Thesis

by

ASSALIA HASSIMI MAIGA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Animal Breeding

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Approved by:

Chair of Committee,	James O. Sanders
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ABSTRACT

Comparison of F1 Cows Sired by Brahman, Boran and Tuli Bulls for Reproductive, Maternal, and Cow Longevity Traits. (December 2006)

Assalia Hassimi Maiga, B.S., Université du Mali

Chair of Advisory Committee: Dr. James.O. Sanders

Birth weight (BW) (n =1277) and weaning weight (WW) (n = 1090) of calves, pregnancy rate (PR) (n = 1386), calf crop born (CCB) (n = 1386), calf crop weaned (CCW) (n = 1294), cow's weight at palpation (CW) (n = 1474) and cow body condition score (BCS) (n = 1473) were evaluated from 1994 to 2006 in 143 F1 cows sired by Brahman (B), Boran (Bo) and Tuli (T) bulls and born to Angus and Hereford cows. Mouth scores (MS) (n = 139) were assigned to the remaining cows in 2004 and 2005.

Fixed effects included sire breed of cow, dam breed of cow, and calf's birth year/age of cow; random effects included cow and sire of cow. BW and WW were evaluated using the same model and adding gender for both and age for WW. All two-way interactions were tested for significance. Calf's birth year/age of dam was significant for all traits ($P < 0.05$) except WW. BW for calves out of F1 B, Bo and T bulls were 35.08, 34.76 and 34.87 kg, respectively, and were not different. WW differed ($P < 0.05$) for calves out of F1 B, Bo and T cows (235.87, 221.10 and 208.35 kg, respectively). PR (0.922, 0.955 and 0.936, respectively), CCB (0.881, 0.931, 0.890, respectively), CCW (0.848, 0.898 and 0.869, respectively), did not differ among F1 B, Bo and T cows. CW when cows were 8- or 9-year old were 600.78, 514.63 and 513.14

kg, respectively, for F1 B, Bo and T cows, with those sired by B being heaviest ($P < 0.05$). BCS for B-, Bo- and T-sired cows were 5.23, 5.48 and 5.18, respectively, with F1 Bo cows having highest scores. Higher MS ($P < 0.05$) were assigned to Bo and B-sired cows (0.95 and 0.94, respectively) compared to T-sired cows (0.78), when both broken and solid incisors were scored 1, and smooth scored 0. When both smooth and broken were scored 0, and solid were scored 1, higher scores were assigned to B- (0.53) compared to T-sired cows (0.24), the Bo-sired cows being intermediate. Higher reproductive rates were found for Boran-sired cows, but Brahman-sired cows weaned heavier calves.

DEDICATION

To my parents late Hassimi and Weyboncana who instilled in me love for livestock, for all encouragements and sacrifices.

To my uncle Ousmane for all support, motivation and encouragement.

To all my brothers and sisters just to mention few Safiatou, Mahamadou, Aboubacar, for serving as role models and showing the road to success.

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To all my fellow graduate students, faculty and staff of the Animal Science department, especially those in the Animal Breeding section, thank your help, hospitality and friendship.

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INTRODUCTION

Breed differences in performance characteristics are an important genetic resource for improving efficiency of beef production (Cundiff et al., 2000).

Crossbreeding is one of the major management techniques available for commercial beef cattle producers attempting to increase efficiency of production (McCarter et al., 1990), and diverse breeds are required to exploit heterosis and complementarity through crossbreeding and composite populations to match genetic potential with diverse markets, feed resources and climates (Cundiff et al., 2000).

Preliminary results from the germplasm evaluation at the U.S. Meat Animal Research Center (MARC) indicated that no single breed excels in all traits of importance to beef production (Cundiff et al., 2000).

The Brahman (American Zebu) has made a significant contribution to the cattle industry in the South and Southeastern United States. The ability of Brahman and its crosses to adapt to the hot and humid conditions of the Gulf coast region and generally to tolerate cattle pests that were troublesome to other breeds led to interest in its exploitation (Franke, 1980). Moreover, the F1 female is fertile, easy calving and produces heavy calves at weaning (Sanders et al., 2005). Crossbreeding research has consistently documented higher levels of heterosis or hybrid vigor in *Bos indicus x Bos taurus* cows compared to *Bos taurus x Bos taurus* cows, and the F1 Brahman cow is the standard of comparison in the South (Chase et al., 2004).

This thesis follows the style of *Journal of Animal Science*.

However, heavy birth weights and the resulting calving difficulty place some limits on the efficiency of producing Brahman-sired F1 calves (Sanders, 1980). High percentage Brahman (*Bos indicus*) cattle tend to have delayed age of puberty and lower calf vigor (Cartwright, 1980; Reynolds et al., 1980). The inability of Brahman-*Bos taurus* F1 cows to produce a replacement of equal productivity has been a severe limitation for their exploitation (Vercoe and Frisch, 1992). Moreover, feeder cattle phenotypically of Brahman influence (gray/striped/red color, excessive ear length, hump size, and sheath area) are discounted because of unfavorable carcass attributes, especially tenderness (Thrift and Thrift, 2005). These antagonisms and discounts have sparked interest in considering other breeds that have evolved in the tropics as an alternative source of tropically adapted germplasm for crossbreeding or composite breeding programs (Cundiff, 2005).

As a result of embryo transfer technology, a number of tropically adapted breeds have been introduced into the United States, including Nellore from Brazil, Tuli originating in Zimbabwe (sampled via semen from Australia), Boran originally developed as a beef breed in Kenya but sampled via semen from Australia, Bonsmara from South Africa, and Romosinuano originally developed in Colombia but sampled from Venezuela (Cundiff, 2005).

The Tuli, is a Sanga (neck humped) type of cattle developed in the 1940's using foundation cattle considered to be the most productive type selected from indigenous Tswana cattle in Zimbabwe (Hetzel, 1988).

The Boran, is a pure Zebu breed (*Bos indicus*, humped) of cattle, that evolved in Southern Ethiopia and is believed to have been developed for milk and meat production under stressful conditions (Cundiff et al., 2000).

Reproductive traits have been long reported as among the most economically important traits in commercial beef cattle operations (Olson et al., 1990), body condition at the time of parturition is likely the most important factor affecting subsequent net calf-crop in mature beef cows (Morrison et al., 1999), and reproductive life span has an important influence on profitability of commercial beef operations (Bailey, 1991).

The objective of this study was to evaluate F1 cows sired by bulls of the Brahman, Boran and Tuli breeds in order to compare these three tropically adapted breeds for traits that represent reproductive and maternal performance and cow longevity.

LITERATURE REVIEW

The importance of crossbreeding in beef cattle

All breeds manifest superiority in some of the economically important traits, but no breed can boast excellence in all traits. One of the most powerful tools available to cattle producers to improve the efficiency of production in a herd is crossbreeding (Chapman and ZoBell, 2004).

Crossbreeding allows for utilization of heterosis and combining of desired characteristics in commercial cattle that would not be present in any parent breed alone (Cundiff, 1979). However, successful crossbreeding requires the choice of appropriate breed combinations for the environment and production management system (Koger, 1980). There are three benefits of crossbreeding over restriction to a single breed (straightbreeding) - heterosis, breed combination, and complementarity (Hammack, 1998).

Heterosis is measured as performance of crossbred progeny compared to the average of purebred parental breeds. Heterosis is usually positive. It is highest in the progeny of least related parents. For instance, there is greater heterosis in crossing the genetically dissimilar Hereford and Brahman breeds than in crossing the more similar Hereford and Angus (Hammack, 1998). Heterosis is highest in fitness traits such as fertility, livability, and longevity. It is intermediate in milk production, weight gain, feed efficiency, and body size. It is lowest in carcass traits. Heterosis is highest in factors affecting efficiency in dams (Hammack, 1998).

Hammack (1998) explained the advantages from breed combination as the benefits merely from combining breeds with different characteristics to produce a superior package.

The difference between complementarity and combination is that complementarity continually uses a particular genetic type of female and a different type of sire in a particular breeding system (Hammack, 1998).

Cartwright (1970) defined complementarity as the advantage of a cross over another cross or a purebred resulting from the manner in which two or more characters combine or complement each other. Complementarity has both a genetic and an environmental component. Moreover, Fitzhugh et al. (1975) defined complementarity as the cumulative effect on the phenotype of the production unit due to interactions among phenotypes of the production unit components, sire, dam and produce. The authors pointed out that complementarity is a characteristic of breeding systems, not of individual animals.

One extreme crossbreeding example that demonstrates breed differences and complementarity is Jerseys bull crossed onto Angus cows to produce medium frame, high milking F1 females (Chapman and ZoBell, 2004). These were then crossed with Charolais bulls to produce terminal calves. The Jersey provided the genes for milk production and marbling ability; the Angus, the genes for carcass quality; and the Charolais, the genes for superior growth.

Bos indicus / _Bos taurus_ crossbreds and their impact in the beef industry

Today, crosses of Brahman with the British beef breeds are well known for their cow productivity and efficiency in the Southern United States (Riley et al., 2001a). Crossbreeding research has consistently documented higher levels of heterosis or hybrid vigor in *Bos indicus* x *Bos taurus* cows compared to *Bos taurus x Bos taurus* cows, and the F1 Brahman cow is the standard of comparison in the South (Chase et al., 2005). Peacock et al. (1979) discussed the variation of hybrid vigor levels with breed combinations, as demonstrated by heterosis levels of 12% for weaning weight in Brahman-Angus crosses but only 2% in Angus-Charolais crosses.

Thrift and Thrift (2003) indicated that Brahman x *Bos taurus* cows express longevity due to calving ease and resistance to ectoparasites (horn flies, mosquitoes, ticks), endoparasites (gastrointestinal helminthes), eye disorders (infectious bovine keratoconjunctivitis, ocular squamous cell carcinoma), metabolic disorders (grass tetany) and dentition deterioration.

Franke (1980) reviewed the experiments with Brahman, British and Brahman x British crosses and concluded that reproductive traits were significantly improved in F1 Brahman x British cows. Calving rate, calf survival, and weaning rate were increased by 10, 5, and 12.5%, respectively, due to hybrid vigor. Calf weight at weaning was also increased by nearly 32 kg in calves born to Brahman x British F1 cows.

In the southern United States, the major niche for Brahman cattle is in crossbreeding programs that, in addition to taking advantage of heterosis, combine the tropical adaptation of the Brahman with more desirable carcass qualities and reproductive efficiency of temperately adapted *Bos taurus* breeds. However, cattle buyers often discount feeder calves phenotypically of Brahman influence (Hammond et al., 1998).

The price discounts for Brahman-influenced steers and surplus heifers are based on the perception that phenotypic characteristics such as gray/striped/red color and excessive ear length, hump size, and sheath area are indicators of the following : 1) high percentage Brahman inheritance (Thrift and Thrift, 2005), 2) associated cold stress when finished during the winter months (Boyles and Riley, 1991), and 3) unfavorable carcass attributes, especially marbling (Herring et al., 1996).

High percentage Brahman (*Bos indicus*) cattle tend to have delayed age of puberty and lower calf vigor (Cartwright, 1980; Reynolds et al., 1980). The inability of Brahman-*Bos taurus* F1 cows to produce a replacement of equal productivity has been a severe limitation which has led to the interest of other sources of tropically adapted cattle (Vercoe and Frisch, 1992). Development of replacement heifers is also critical to the economic efficiency of a beef cattle operation. In the context of matching cow size to the environment, it is important to consider sire selection for use on the cowherd because in most instances heifer calves will be selected as herd replacements (Chase et al., 2005). As discussed by Hammond et al. (1998), in order for alternative sire breeds to be useful in crossbreeding programs in the warm areas of the United States, their crosses must display heat tolerance similar to that of Brahman crosses; this is particularly important in replacement heifers.

Genotype by environment interaction and adaptation

An important component of efficient beef production is the optimal compatibility between the cattle and their environment. This is particularly important in stressful environments such as the subtropics and tropics. Environment, however, is not simply related to geography or climate (temperature, humidity), it also includes nutrition (forages, minerals, supplements) and disease and the endemic pest load (Chase et al., 2005), as well as associated management inputs.

Differences between Zebu and European breeds that can affect their compatibility with different environments are variation in heat and cold tolerance; reproduction, parturition and lactation; growth and maturation rates; temperament and intelligence; and combining ability and complementarity (Cartwright, 1980).

A classic example of genetic by environment interaction for reproductive traits was provided by Koger et al. (1979). The authors reported results from a study where Hereford cattle from Florida (Line 6) were exchanged with Hereford cattle from Montana (Line 1). Mean pregnancy rates in Montana for Herefords of Montana and Florida origin were 81% and 83%, respectively. However, pregnancy rates in Florida for Herefords of Montana and Florida origin were 64% and 86%, respectively. Mean weaning rates in Montana were 73% and 76% and in Florida were 59% and 80%, respectively.

Crossbreeding in beef cattle has been widely used to achieve improvements in beef production. The appropriate choice of breeds in crossbreeding depends upon the additive genetic merit of the breeds involved and heterosis resulting from the crossing of these breeds, relative to the production environment.

Olson et al. (1991) reported genotype by environmental interaction in crossbred *Bos taurus* heifers and *Bos indicus* x *Bos taurus* heifers that were born and weaned in Nebraska, and one-half were then raised in Nebraska and the other one-half in Florida. Overall there was a 9% higher pregnancy rate in Nebraska than Florida, and crossbred *Bos indicus* x *Bos taurus cows* had a 3.8% higher pregnancy rate than crossbred *Bos taurus* cows. However, the advantages in pregnancy rate of Zebu crossbred dams were much larger in Florida (5.8%) than it was in Nebraska (1.8%). Weaning weights were 15.6 kg heavier in Nebraska than Florida, and calves from crossbred *Bos indicus* x *Bos taurus* cows were 24.9 kg heavier than calves from crossbred *Bos* taurus cows. However, weaning weights of calves were heavier from crossbred *Bos taurus* cows in Nebraska than in Florida, whereas weaning weights were similar for calves from crossbred *Bos indicus* cows in Nebraska and Florida. The researchers also reported that calf weaning weight per cow exposed was 160 kg and 208.2 kg for crossbred *Bos taurus* and crossbred *Bos indicus* x *Bos taurus* cows in Florida, respectively, and 200.2 kg and 215.8 kg in Nebraska, respectively.

Hot, humid conditions during the summer months in subtropical and temperate environments and during much of the year throughout the tropics depress reproductive and growth performance of heat susceptible breeds of beef cattle. (Gaughan et al., 1999).

Ferrell and Jenkins (1998) inferred that because *Bos indicus* breeds such as Boran and Brahman are often used in environments that produce excessive heat loads, they tend to perform well in restrictive nutritional environments.

In subtropical, tropical, and temperate regions where hot, humid conditions impede or reduce productivity and performance, improvements may be seen by the introduction of a tropically adapted *Bos taurus* breed, such as the Tuli, into a crossbreeding program (Gaughan et al., 1999). The authors conducted experiments to evaluate the heat tolerance of Hereford, Brahman, Hereford x Brahman, Hereford × Boran, and Hereford x Tuli. The results showed that purebred Brahman had significantly lower rectal temperature and respiration rates than the other genotypes. Boran and Tuli crosses had rectal temperature (39.5 C) that were intermediate to those of Brahman (39.0 C) and Hereford x Brahman (40.0 C). The Hereford genotype had the greatest rectal temperature at 40.3 C.

Discussion of the sire breeds of the cows involved in the study

The Brahman breed

The Brahman (American Zebu) has made a significant contribution in the South and Southeastern United States. The ability of Brahman and its crosses to adapt to the hot and humid conditions of the Gulf coast region and generally to tolerate cattle pests that were troublesome to other breeds led to interest in its exploitation (Franke ,1980; Turner, 1980). The greater genetic divergence of Brahman inheritance relative to *Bos taurus* breeds offers heterotic (hybrid vigor) advantages when used in crossbreeding systems. This has resulted in the majority of commercial beef cattle herds in the southern United States being composed of crossbred cows with some degree of Brahman inheritance with British, Continental, and possibly dairy breeding (Franke, 1980).

The American Brahman is the result of upgrading by the breeding of various strains of Zebu males to cows typical of the Gulf coast region during the early 1900's. The American Brahman was developed in the U.S. from four major *Bos indicus* breeds imported from India and Brazil. Typical Gray Brahman cattle are primarily a mixture of Guzerat and Nellore, while the Red Brahman are primarily a mixture of Gir and Indu-Brazil with some Guzerat influence (Sanders, 1980). Cartwright (1980) reported the Brahman's main feature to be its ability to withstand extreme tropical climates and to tolerate low quality feed during periods of food shortage in some areas as well as excelling in crossbreeding programs.

The Brahman is classified under the genus and species *Bos indicus*, and has its origin in harsh climates and is well adapted to the rigors of tropical agriculture (Peacock et al., 1977). The Brahman is unique in the U.S. cattle industry because it exists almost solely for crossbreeding. The real value is in the crossbred cow. The F1 female is fertile, easy calving and produces heavy calves at weaning. For calves out of Hereford cows, Sanders et al. (2005) reported heavier weaning weights of both F1 Gray and Red Brahman-sired calves over the Angus and three *Bos indicus* breeds (Gir, Indu-Brazil and Nellore). The authors also reported heavier final weight in steers and palpation weight of both Gray and Red Brahman-sired cows compared to the Angus and the other *Bos indicus* breeds.

Brahman straightbred cows have usually been found to have a lower calving percentage, calf survival and weaning rate than other contemporary straightbreds, although they have been reported to be superior or competitive in some studies (Franke, 1980). Heavy birth weights and the resulting calving difficulty place some limits on the efficiency of producing Brahman-sired F1 calves (Sanders, 1980). High percentage Brahman (*Bos indicus*) cattle tend to have delayed age of puberty and lower calf vigor (Cartwright, 1980; Reynolds et al., 1980). As stated previously, the inability of Brahman-*Bos taurus* F1 cows to produce a replacement of equal productivity has been a severe limitation which has led to the 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 *Bos taurus* (Vercoe and Frisch, 1992).

The Boran breed

The Boran is a Zebu (shoulder humped) breed that originated from southern Ethiopia, Northern Kenya and Somalia and is believed to have been developed for milk and meat production under stressful tropical conditions (Cundiff et al., 2000). Genetics studies at the International Livestock Research Institute (ILRI) have shown that the genetic composition of the Kenyan Boran is unique. As discussed by Hanotte et al. (2000), at ILRI, the Boran breed contains three different genetic influences. Other than the Zebu influence (predominant), there are influences from both the near East European *Bos taurus* as well as distinct influence from native African *Bos taurus*. Frisch et al. (1997), establishing a classification of the Southern African Sanga and East African shorthorned Zebu using DNA markers, suggested that the Boran breed is an admixture of African taurine and Asian indicine breeds. The Boran breed is considered to be a standard of comparison of beef production in East Africa (Trail and Gregory, 1981). The value of the Boran for beef production has been investigated in crossbreeding studies at the U.S. Meat Animal Research Center (MARC) at Clay Center, Nebraska and Texas A&M University Experiment Station at McGregor. Preliminary results from the cattle germplasm evaluation program at MARC, as reported by Cundiff (2005), showed higher calf crop born and higher calf crop weaned of the Boran-sired cows compared to the Brahman and Tuli-sired cows. The higher reproductive rates of Boran-sired cows compared to those sired by Brahman and Tuli, as reported by Ducoing Watty (2002), indicate the benefits of Boran-sired cows when it comes to cow efficiency. In an attempt to analyze the incisor condition, as an indicator of cow longevity, Cunningham (2005) found the Boran F1 cows to have less incisor deterioration than the Brahman and the Tuli F1s. As discussed by Herring et al. (1996), the smaller size of Boran-sired females could be translated into lower maintenance costs as mature cows.

The Tuli breed

The Tuli is a Sanga type of breed that was developed relatively recently in a research program initiated in the 1940’s using foundation cattle considered to be the most productive type selected from indigenous Tswana cattle in Zimbabwe (Cundiff et al., 2000). Sanga cattle are indigenous to Africa and possess a hump located on the neck as compared to over the shoulder (Epstein and Mason, 1971). Investigating the origin of African cattle, cytogenetics studies at the Y-chromosome level by Meyer (1984) showed that Sanga possess the typical submetacentric taurine Y-chromosome (Hanotte et al., 2000). The chromosomal morphology of the Sanga suggests that they are more genetically similar to the *Bos taurus* breeds than to the *Bos indicus* breeds. Based on the low frequency of Brahman-specific alleles in the Tuli, the absence of an acrocentric Y-chromosome, and allele frequencies closely aligned with those of European breeds, Frisch et al. (1997) suggested Sanga to be classified as *Bos taurus*.

Some studies have reported the performance values from the Tuli breed. In a study by Trail et al. (1977) comparing Tuli, Tswana and Africander cattle under the prevailing conditions of Botswana, the Tuli cattle recorded the highest fertility, the lowest calf mortality and the highest cow productivity at weaning and the heaviest calves at 18 months. In Zimbabwe, Tuli-sired calves exhibited preweaning performance comparable to that of British-sired breeds (Tawonezvi et al., 1988). In an earlier phase of the current study, Herring et al. (1996) reported more desirable quality attributes of the Tuli-sired carcasses and smaller birth size of the Tuli-sired calves compared to Boran and Brahman crosses. Holloway (2002) stated the most significant results of the F1 cows sired by Tuli to be the pounds of calves weaned per pound of cows exposed. The Tuli cross cows weaned 75% more pound of calf per cow exposed than Brahman, 53% more than Angus and 21% more than Senepol crosses.

Review of traits to be analyzed

Cow weight

Cow weight is an index of mature size and maintenance requirements, providing that environmental constraints on growth do not affect breeds differently, i.e. that all breeds are similarly adapted to the environment (Hetzel, 1998).

Trail and Gregory (1981) in a study of comparison of the *Bos indicus* breeds of Boran and Sahiwal in Kenya reported similar mature weights from 7 to 9 years old (414, 418 kg respectively) of the cows of the two breeds, even though the Boran heifers were 26 kg heavier at 660 days than were the Sahiwal heifers. The authors explained the probable reason for the inconsistency relating to 660-day weight of heifers and mature cows by the fact that the cows ranged from 3/4 to 15/16 Sahiwal, whereas the heifers ranged from 7/8 to 31/32 Sahiwal. The Sahiwals were graded up by the use of pedigree Sahiwal sires on a foundation female population of Boran crosses with Red Poll and Hereford breeds. They reached the conclusion that, on the basis of the heifer weights at 660 days, the Boran breed probably transmitted higher effects for growth rate, and probably has heavier mature weights than the Sahiwal breed.

Hetzel (1998) reviewing breed evaluations conducted in East and Southern Africa reported that Tuli straightbred cows (400 kg) were heavier than Boran straightbred cows (375 kg), but lighter than Brahman straightbred cows (446 kg). Both Tuli and Brahman were evaluated in Botswana, whereas Boran was evaluated in Zambia.

McCarter et al. (1991), comparing cow weight in 3-, 4- and 5-year old crossbred cows with different proportions of Brahman out of Angus or Hereford, and Angus-Hereford and Hereford-Angus cows, reported adjusted means of 478 and 482 kg respectively in F1 Brahman-Angus and Brahman-Hereford cows, similar to those of F1 Angus-Hereford cows (467 kg), smaller than those of Hereford-Angus cows (498 kg), but greater than those having 1/4 Brahman blood (445 kg).

Demeke et al. (2004), estimating the genetic parameters for Boran, Friesian, and crosses of Friesian and Jersey with the Boran cattle in Ethiopia, found that only Friesian crosses had a significantly heavier body weight by 64 kg than the Boran (304 kg).

Ducoing Watty (2002), as well as Cunningham (2005), in earlier phases of the current study, reported significantly heavier weight for Brahman-sired cows compared to Boran and Tuli-sired cows. Both authors reported significant effects of year/age of cow and sire breed of cow by dam breed (Angus or Hereford) of cow on cow weight.

Also, in an early phase of this study, Herring et al. (1996) observed that the Brahman-sired yearling heifers were significantly heavier than those sired by Boran and Tuli, and the yearling heifers born in 1993 were heavier than those born in 1992.

Cow body condition score

Body condition scores (BCS) are numbers used to suggest the relative fatness or body composition of the cow. The scale most commonly used ranges from 1 to 9, with a score of 1 representing very thin body condition and a score of 9 representing extreme fatness (Herd and Sprott, 1986).

Morrison et al. (1999) found that body condition score (BCS) at the time of parturition is likely the most important factor affecting subsequent net calf-crop in mature beef cows, and a BCS of 5 at calving is critical to ensure acceptable postpartum reproduction in multiparous cows.

Holloway et al. (2002) evaluating crossbred animals derived from Brahman, Senepol and Tuli bulls, observed that females that were diagnosed non-pregnant in the fall prior to calving had 1.0 unit lower BCS at that time than those that were diagnosed pregnant, regardless of age, and young Angus females (2- and 3-yr-olds) that were diagnosed pregnant but failed to calve tended to have lower BCS than those that successfully calved.

DeRouen et al. (1994), in a study aimed to determine the relative importance of prepartum body condition and body condition at calving on postpartum reproduction of first-calf cows, reported a significant effect of BCS at calving on pregnancy rates and days to pregnancy. The authors found that pregnancy rates of cows with BCS 6 and 7 (87.0 and 90.7%) at calving were higher than those of cows with BCS 4 and 5 (64.9 and 71.4%). Cows in moderate to high body condition (BCS $\geq$ 5) at calving were found to have shorter postpartum intervals than thin cows (BCS 4); and BCS 6 and 7 cows had the shortest intervals (74 and 76 days).

Rae et al. (1993), in a study examining the relationship between the body condition score at pregnancy and the pregnancy rate in the subsequent year in commercial beef herds in Florida, found that groups of cows having body condition scores of $\leq$ 3, 4 and $\geq$ 5 had pregnancy of rates of 31, 60 and 89%, respectively.

In an earlier phase of the present study, Herring et al. (1996) reported the effect of sire breed on the variation of the body condition score of F1 heifers. Brahman-sired heifers had the lowest body condition score (5.09) followed by Tuli- (5.33) and Boran-sired heifers (5.53) with significant differences between both Brahman- and Boran-sired heifers, and Brahman- and Tuli-sired heifers; but the difference was not significant between Boran- and Tuli-sired heifers.

Also in an earlier phase of this study, Cunningham (2005) reported higher scores of body condition assigned to Boran-sired (5.5) compared to Brahman- and Tuli-sired females (5.3 and 5.1 respectively), with significant differences among the sire breeds, when these F1 cows were 9 and 10 years of age.

Cow longevity

Productive longevity may be defined as the age at which a cow dies or is culled because she presumably is incapable of weaning another live calf due to physical weakness or subfertility (Rohrer et al., 1988).

In beef production systems, the longevity of breeding stock has a substantial effect on economic efficiency. Increasing the longevity of females reduces annual production costs associated with raising replacement heifers, increases the number of high producing mature cows, and reduces the number of cows that are culled involuntarily (Rogers et al., 2004).

Cows with greater longevity allow the breeder to be more selective when choosing replacement females. While this will result in increased generation intervals, the herd will contain a larger proportion of mature cows that usually have higher percentages of calf crop weaned, wean heavier calves and have lower total energy requirements. Therefore, increased longevity can reduce production costs and increase pounds of calves sold per cow per year (Rohrer et al., 1988).

The productive life of a cow is limited by physical soundness as she ages. The wear and loss of incisors often affect a cow's ability to harvest forage and adequately maintain body condition (Riley et al., 2001b). Nunez-Dominguez et al. (1991) stated that cows with unsound mouths may require more eating time, especially under range conditions, and thus may not meet their full nutritional requirements for optimum body condition and resistance to diseases or injuries.

In this study by Nunez-Dominguez et al. (1991), aimed to estimate the average breed and heterosis effects on longevity of cows including straightbreds and all possible reciprocal crosses of the Hereford, Angus and Shorthorn breeds, crossbred cows lived longer than straightbreds by 1.36 years, corresponding to a heterosis of 16.2%, and 11% more straightbreds than crossbred died before reaching 12 years of age.

Rohrer et al. (1988), in a long term (14 years) study of the productive longevity of beef cows involving a five-breed diallel mating design including Angus, Brahman, Hereford, Holstein and Jersey, reported that Brahman crossbred cows had the longest productive lives of the cattle studied. The authors indicated that the Brahman cows lived longer because they tended to be more structurally sound and had fewer mammary problems than other breeds; but the Brahman cows had lower reproductive rates.

Nunez-Dominguez et al. (1991) reported the advantage of aged crossbred over straightbred cows for size and condition of incisors. In this study, the authors found that more straightbred (7.1%) than crossbred (1.7%) cows were culled for emaciation, because straightbreds had shorter teeth and more missing teeth than crossbreds. The authors found a significant effect of breed group on the size of incisor teeth for every pair and for the whole mouth indicating that differences in additive and (or) breed effects exist for tooth size. In regard to this, all reciprocal crosses except the Angus-Shorthorn had higher sum of teeth sizes in the whole mouth compared to the straighbred Angus, Hereford and Shorthorn. For the condition of teeth, the proportion of normal teeth were reported to be lower for straightbred (85.9%) than for crossbred (89.1%) cows due in part to the high frequency of missing teeth for Hereford (24%) compared with 3 to 7% for the other groups. However, 7.1% of crossbred cows had broken, loose, plus broken and loose teeth compared to the 5% of the straightbred cows.

Bailey (1991), assessing the reproductive lifespan of *Bos taurus and Bos indicus* x *Bos taurus* breeds, observed that Brahman crosses and Angus x Hereford were above the average of other breeds representing Hereford, Red Poll, their reciprocal crosses and Angus x Charolais cows in all three measures of reproductive span including number of mating seasons per dam, lifetime total number of full-term calves born dead or alive, and lifetime total number of calves weaned per dam.

Riley et al. (2001b) analyzed mouth scores of 14-year old F1 cows sired by Angus, Gray and Red Brahman, Gir, Indu-Brazil and Nellore bulls out of Hereford in two different models using binary traits. In the first model (where smooth mouths were assigned a value of 0 and broken or solid assigned a value of 1), Angus-sired cows had a significantly lower mouth score than the other F1 sire breed groups. No significant differences were observed among *Bos indicus* crossbreds using this model. In the second model (where both smooth and broken mouths were assigned a value of 0, and solid mouths assigned a value of 1), no significant differences were noted among any of the breed groups, but the Angus-sired cows had the lowest mouth scores.

Cunningham (2005) used similar models to those of Riley et al. (2001b). In the first model Boran crosses averaged the highest score (1.0) followed by Brahman crosses (0.96), significantly higher than the Tuli crosses (0.76). In the second model, the same rankings were observed, with scores of 0.67, 0.55 and 0.28 respectively, with the Boran and the Brahman crosses having higher values than the Tuli crosses.

Pregnancy rate

Peacock et al. (1979), at the Ona center in Florida reported breed of sire effects on pregnancy rates. Pregnancy rates by breed of sire were 82.3%, 79.1%, and 74.4%, respectively, for Brahman-, Charolais-, and Angus-sired cows. The pregnancy rates by breed of dam were almost identical with rates 78.8%, 78.3%, and 78.6%, respectively, for cows out of Brahman, Charolais and Angus. In contrast, Crockett et al. (1978), reported pregnancy rates of Angus cows to be 88%, as compared to 72% for Brahman cows in Southern Florida (Belle Glade).

In a comparative study involving various *Bos indicus* breeds and Angus as F1 cows out of Hereford dams, Riley et al. (2001a) found a significant interaction of the sire breed of cow by age interaction on pregnancy rate. The rate for Nellore crossbreds was the highest, followed by that for Gray Brahman, Gir, Red Brahman, Indu-Brazil, and Angus crossbred cows (97.0, 96.4, 96.0, 93.8, 91.0, and 87.4%, respectively). The authors found the pregnancy rate for Angus-sired to be significantly lower than that for Nellore, Gray Brahman and Gir crossbred cows. They noted a tendency that pregnancy rates appeared to be lower and (or) to fluctuate between ages after 10 year of age, and that Angus and Indu-Brazil pregnancy rate decreased the most as the females aged.

Holloway et al. (2002) reported that the pregnancy rates of Angus cows that had raised Brahman crossbred calves (54.8%) were significantly lower than those that had raised Senepol (66.7%) and Tuli (72.8%) crossbred calves.

Ducoing Watty (2002) analyzed the pregnancy rate obtained from 1994 to 2001 for the F1 cows of the present project using 3 different models. In the first model, the sire breed, dam breed and birth year / age of cow were included. In the second model, the lactation status at weaning time of the cow was added to the first model. The third model consisted of the first model plus the cow condition at weaning time, as a covariate, nested within the sire breed of cow. The effect of sire breed of dam was only marginally important in models 1 and 3 with the Boran-sired cows having the highest values followed by the Brahman- and Tuli-sired cows, whereas no significant differences were observed in model 2. However the dam of cow breed was significant in model 2 only, with cows out of Hereford dams having higher value (0.955) than those out of Angus dams (0.905). The birth year of calf / age of cow effect was significant in all the 3 models.

In the analysis of Cunningham (2005), sire breed of cow was not a significant source of variation for any of the 3 models. However birth year / age of dam was an important source of variation in all 3 models. Lactation status and cow condition score nested in year / age were significant in the second and third models, respectively.

Calf crop born

Calving rate is defined as the proportion of cows exposed to breeding that give birth to a calf (Williams et al., 1990).

Peacock et al. (1977) reported birth rates for straightbred Angus (A), Brahman (B), and Charolais (C) cows to be 75.3%, 89.9% and 79.7%, respectively, while B x A and B x C cows had pregnancy rates of 92.4 and 82.5%, respectively. The advantage for the crossbred cows was 17.1% for Brahman bulls on Angus cows over the straightbred Angus cows and 2.8% for Brahman bulls on Charolais cows over the straightbred Charolais.

Franke (1980) reviewing breed and heterosis effects of American Zebu cattle, reported that first-cross Brahman British cows showed positive levels of heterosis for calving rates with estimates ranging from 4.4 to 18.8%.

Williams et al. (1991), studying genetic effects for reproductive traits, reported the Brahman additive genetic effect to be negative (-9.5), while the direct heterosis for F1 Angus-Brahman, Brahman-Charolais and Brahman-Hereford were 5.8, 3.9 and 3.1, respectively. The authors reported negative maternal additive estimates of -1.3 for Brahman, whereas the estimates of maternal heterotic effects were positive with estimates of 12.9, 12.5 and 20.35, respectively.

Riley et al. (2001a), evaluating F1 cows sired by Angus and several *Bos indicus* breeds and out of Hereford dams, found that the crossbred Angus cows had the lowest adjusted calf crop born of 86.7, and that cows sired by Gray Brahman, Gir, Indu-Brazil, Nellore and Red Brahman had rates of 95.6, 94.6, 92.8, 97.1, 92.7, respectively. No differences were noted among the means of *Bos indicus* sire breeds. Within ages, they observed differences among *Bos indicus* sire breed means only in the older cow age groups. These differences were associated with fluctuations; and the breed that was higher at one age tended to be lower at the next age.

Williams et al. (1990), in a comparison of rotational crossbreeding systems and breed combinations involving Angus, Brahman, Charolais and Hereford for reproductive traits over generations, found that three and four-breed rotation cows had similar calving rate of 86.9 and 85.0% respectively. Straightbred cows had a lower calving rate (73.1%) than two-breed (83.3%) and three- and four-breed rotation cows. These authors observed that the differences among mating systems were fairly consistent across generations. There was a variation in calving rates for individual straightbreds and two-, three- and four-breed rotation combinations by generation. The authors attributed the differences among generations to differences in genetic potential and in environmental trends.

Trail et al. (1985), comparing Exotic x Boran crosses to Boran straightbred females, observed that Angus x Boran and Red Poll x Boran crossbred dams had an average increase of 27% in calving rate over the purebred Boran dams.

Ducoing Watty (2002) evaluating the F1 cows of the present study, reported adjusted means for calf crop born of 0.863, 0.927 0.890, respectively for Brahman-, Boran and Tuli-sired cows, without significant differences between them.

In a comparative study, Hetzel (1988) found calving rates of Brahman, Tuli and Boran straightbreds to be 72, 75 and 87% respectively. Both Brahman and Tuli were evaluated in Botswana, whereas the Boran was evaluated in Zambia.

Moyo (1995), comparing the productivity of beef breeds in Zimbabwe, found similar calving rates for Tuli (72%) and Brahman (71%), which were higher than those of Charolais (67%) and Sussex (59%) straightbred cows.

Cundiff et al. (2000) evaluating F1 cows by Brahman, Tuli, and Boran sires for reproductive and maternal performance at the U.S. Meat Animal Research Center, found mean values for calf crop born of 76.6, 90.3, and 86.1% respectively during their first calving. In the second calving season, the authors reported means of 92.8, 91.8, and 93.1% respectively for the above-mentioned cows.

Birth weight

Birth weight is an important measure to consider in beef cattle management systems. Extreme birth weights can cause large production problems and economic losses for beef producers. Heavy birth weights are often associated with dystocia which can cause calf loss, cow loss, reduced calf performance and reduced cow fertility. Low birth weight can reduce calf vigor ending up with early calf mortality or reduced calf performance (Roberson et al., 1986).

Paschal et al. (1991) stated that because of the close association between birth weight and dystocia and the threshold nature of dystocia, breeds with a large difference between sexes for birth weight can experience higher frequencies of dystocia than would be expected from the average birth weight for the breed. That is, due to the threshold nature of dystocia (calves below a certain size experience little or no dystocia), large sex differences in birth weight can result in a larger fraction of the bull calves being above the threshold. When Brahman bulls are mated to *Bos taurus* females, dystocia can be a problem (Koger, 1980).

Birth weight is the result of the genetic growth potential of the fetus responding to the maternal uterine environment throughout gestation (Bellows et al., 1993). It is well documented that *Bos indicus* influence in the cow is associated with lower birth weights. Ferrell (1991) found a lower uterine blood flow in Brahman than in Charolais dams.

Bellows et al. (1993) observed placental differences between F1 *Bos taurus* and F1 *Bos indicus* heifers. Heifers were slaughtered at an average of 231 days of gestation. Total conceptus weight was lower and placental weight was higher for F1 Brahman heifers than for the *Bos taurus* heifers. All fetuses were sired by Angus bulls.

The lower birth weight for calves out of *Bos indicus* cows holds even for recipient cows. In a study where four types of embryo (Hereford, Brahman, Brahman-sired F1 and Hereford-sired F1calves) were transferred to two types of recipients cows (Hereford and Brahman), Baker (1990) found Brahman recipient effect on birth weight relative to Hereford for the four calf breed types to be -2.72, -4.99, -2.72 and 1.82 kg respectively for Brahman, Brahman-Hereford, Hereford-Brahman and Hereford calves. Brahman-sired F1 calves on average were 8.39 kg heavier than the Hereford-sired F1 calves. Also, Brahman-Hereford calves were 7.39 kg heavier than the Hereford-Brahman calves when both were produced from Brahman recipients, whereas when Hereford recipients were used, the Brahman-Hereford embryo transfer calves were 11.88 kg heavier than the Hereford-Brahman calves.

Gill et al. (2005) investigated reciprocal differences in birth weight in calves that were 3/4 Angus–1/4 Brahman (or Nellore) or 3/4 Brahman–1/4 Angus, all born to 1/2 Brahman-1/2 British recipient dams. Among Angus backcross calves with F1 sires, male calves with AB sires and A (Angus) dams were 8 kg heavier than female calves of this cross, while BA-sired male calves out of A dams averaged only 2 kg heavier than females of that cross. Angus backcross calves with F1 dams exhibited no significant difference in birth weight between male and female calves. There was no significant difference between male and female B backcross calves from F1 sires. However, 3/4 B male calves were 4.4 kg and 4.7 kg heavier than female calves when the dam was AB and BA, respectively. In the analysis within sex of reciprocal crosses, AB x A male calves averaged 8.1 kg heavier than A x AB male calves, and BA x A male calves were only 2.5 kg heavier than A x BA male calves. The F1-sired female calves were only 1.5 heavier than A-sired females. *Bos indicus* x AB males averaged 7 kg heavier than AB x B males calves, and B x BA male calves averaged 5.8 kg heavier than BA x B male calves. Among female calves, all reciprocal differences (none of them significant) were in the same direction as those in the male calves.

Thallman et al. (1992) discussed the fact that Brahman cows tend to produce small calves at birth, regardless of bull breed, even in embryo transfer calves. They concluded that *Bos taurus* cows, when bred to Brahman bulls produce calves about 6.80 kg heavier than those produced when Brahman cows are bred to bulls of a *Bos taurus* breed. They found the differences in birth weight to be proportional to the amount of Brahman in the respective parent (that is, the more Brahman in the cow, the lighter the calf, and the more Brahman in the bull, the heavier the calf). The authors reported a sire breed by sex of calf interaction; when Brahman bulls were bred to *Bos taurus* cows, the bull calves were about 5.44 kg or more heavier than the heifer calves; the difference between the sexes was relatively small (1 kg or less) when *Bos taurus* bulls were bred to Brahman females.

Likewise, Trail et al. (1982) evaluating the Boran and Red Poll breeds; found Boran-sired calves to be 2.4 kg heavier than those sired by Red Poll bulls. They also found crossbred calves out of Boran dams to be 3.6 kg lighter than those out of Red Poll cows.

Roberson et al. (1986) reported large effects of dam breed type on birth weight. For the breed types Brahman, Hereford and various Brahman-Hereford crosses, Brahman dams produced the lightest calves at birth, the crossbred cows were intermediate and calves born to Hereford dams were the heaviest within the sire breed evaluated. By estimating direct and maternal effects in these breeds on birth weight, they found that the direct genetic effect of Brahman was greater (4.6 kg) than that of Hereford and the maternal genetic effect of the Brahman was smaller (7.5 kg) than that of Hereford.

Moreover, Elzo et al. (1990), investigating genetic effects in Brahman and Brahman x Angus crossbreds found a negative additive effect (-2.71 kg) for Brahman dams and a positive additive effect (2.99 kg) for Brahman sires.

Cundiff et al. (2000) reported significant differences between the birth weight averages of 46.6, 43.4, 38.9 and 41 kg of calves sired respectively by Brahman, Boran, Tuli and Angus bulls. However, the birth weight of the calves out of these F1 females mated to Red Poll bulls were 34.2, 33.3 and 34 kg, respectively, for the calves out of cows produced by Brahman, Boran and Tuli bulls. When these F1 females were mated to purebred Charolais and F1 Belgian bulls to produce their second and subsequent calves, Cundiff et al. (2000) reported means of 37.3, 37.1 and 38.4 kg, respectively, for the calves out of cows born to Brahman, Boran and Tuli bulls.

In a review, involving Brahman and non-Zebu tropically adapted (Tuli, Senepol) sires, Thrift (1997) reported that the average birth weight of calves sired by Brahman exceeded that of calves sired by Tuli and Senepol by 6 and 3 kg respectively.

Herring et al. (1996) evaluating F1 calves sired by Brahman, Boran and Tuli in an earlier phase of this study found significant differences among calves for birth weight ($P < 0.001$). Calves by Brahman bulls were the heaviest at birth (44.01 kg) followed by those by Boran (40.25 kg) and Tuli bulls (36.36 kg) respectively. A sex effect was present ($P < 0.001$); with male calves (42.40 kg) weighing 4.4 kg more at birth than female calves. A sire breed by gender interaction ($P < 0.07$) was found for birth weight. Among Brahman crosses, males weighed 5.9 kg more than heifers; among Boran crosses, males weighed 4.5 kg more than females; and among Tuli-sired calves, male calves were only 2.8 kg heavier than heifer calves. Dam breed by birth year interaction ($P < 0.001$) was present. Calves born to Angus dams in 1992 were 1.9 kg lighter than those born to Hereford dams; however, calves born to Angus dams in 1993 were 2.8 kg heavier. The authors attributed the significant interaction to the differences in management groups across years, or possibly the difference in breeding values among cows used in different years.

Also in an earlier phase of the current study, Ducoing Watty (2002) evaluating the F1 cows, found no differences for birth weight among calves out of Brahman- (35.53), Boran- (34.78) and Tuli-sired cows (35.49). The calf sex was important ($P < 0.001$), with male calves (36.34 kg) being 2.16 kg heavier than the female calves.

Similarly, Cunningham (2005), also in an earlier phase of the current study, found no significant sire breed of cow effect and observed the same rankings as those reported by Ducoing Watty (2002). Heifer calves (34.33 kg) were significantly lighter ($P < 0.001$) by 2.43 kg than bull calves. Dam breed of dam by sex of calf interaction was also important ($P = 0.004$). The bull calves out of cows born to Angus dams (37.09 kg) were 3.18 kg heavier than the heifer calves (33.91 kg); but the bull calves out of cows born to Hereford dam (36.43 kg) were only 1.68 kg heavier than the heifer calves (34.75 kg).

Dam age effects on birth weight have been reported. Roberson et al. (1986) found that birth weight increased with dam age up to 7 years of age and declined gradually for older dams. Similarly, McCarter et al. (1991) reported significant increases in birth weight as the effect of the increase of dam age from 3 to 5 years.

Buchanan and Frahm (2005) evaluating calves with various proportions of Brahman in Oklahoma reported significant differences in birth weight. Calves with

Angus and Hereford dams that were 0, 1/4 and 1/2 Brahman weighed 33.84, 35.24 and 37.60 kg, respectively, at birth.

Calf crop weaned

Weaning rate is a measure of realized net reproductive performance of the herd. Under most situations it is the most important trait influencing economy of beef cattle production (Crockett et al., 1978). Calf crop weaned is totally determined by calf crop born and calf survival Peacock et al. (1977).

Peacock et al. (1977) found the weaning rates for straightbreds to be 67.2, 81.6, and 75.7%, respectively for the Angus (A), Brahman (B), and Charolais (C) breeds. For the crossbred matings, weaning rates were 77.7 and 79.9% for BxA and BxC matings and 89.4% and 84.1% for F1 B x A and B xC cows respectively. The advantage in percentage units for crossbred matings over the average of straightbred parent breeds was 3.3% for B x A, 1.2% for B x C, 15% for F1 BA cows, and 5.4% for F1 BC cows. Heterosis estimates for weaning rates were 20.2% for F1 BA cows and 6.9% for F1 BC cows, as percentages of the midparent averages.

Franke (1980), in a review of breed and heterosis effects of American Zebu cattle, observed that first-cross Brahman British cows showed positive levels of heterosis for weaning rates with estimates ranging from 7.1 to 21.2%.

Williams et al. (1990), in a study of comparison of rotational crossbreeding systems and breed combinations involving Angus, Brahman, Charolais and Hereford for reproductive traits over generations, found that three- and four-breed rotation cows had similar and higher weaning rates (81.5 and 80.8%) than two-breed rotation (77.1%) and straightbred (65.5%) cows. Two-breed rotation cows had a significantly higher weaning rate than straightbred cows. As for calving rate, there was variation in weaning rates for individual straightbreds and two-, three- and four-breed rotation combinations by generation.

In a comparative study, Hetzel (1988) found weaning rates of straightbred Brahman, Tuli and Boran to be 63, 68 and 82% respectively. Both Brahman and Tuli were evaluated in Botswana, while Boran was evaluated in Zambia.

Riley et al. (2001a) evaluating F1 cows sired by Angus and several *Bos indicus* breeds and out of Hereford cows, found that Nellore crossbred cows had the highest calf crop weaned (96.1%), higher than that of Red Brahman, Angus, and Indu-Brazil crossbreds (86.0, 83.3, and 81.0% respectively), but not significantly different than those of cows sired by Gray Brahman and Gir (88.4 and 91.5% respectively).

Cunningham (2005) observed that Boran-sired cows weaned more calves (8.87%) than the Tuli- and Brahman-sired cows (85.7% and 8.34%, respectively), without significant differences. Likewise Ducoing Watty (2002) found adjusted rates of 80.8%, 87.4% and 83.7%, respectively, for Brahman-, Boran- and Tuli-sired F1 cows.

Weaning weight

Weaning weight of calves is a measure of production and reflects the genotype of both sire and dam, plus the maternal influence of the dam (Peacock et al., 1977). According to Roberson et al. (1986), weaning weight is important for cow-calf producers because it measures their primary product. It is a composite character composed of birth weight and preweaning gain, and it is a function of the direct additive component, direct heterosis (non-additive), maternal additive and maternal heterosis components. Sanders (1994) stated that weaning weight is of importance to the beef industry because for many producers it represents the sale weight, and, even if calves are kept after weaning, weight at weaning could have major impacts on efficiency and profits.

Herring et al. (1996) reported Brahman-sired calves (234.3 kg) to be heavier than Boran (217.1 kg) and Tuli-sired calves (209.1 kg), which did not differ ($P > 0.05$) . Male calves averaged 14.7 kg heavier at weaning than females. Dams in the 6 yr to 9 years of age range produced the heaviest calves.

Franke (1980), in a review, found backcross calves from F1 Brahman-Hereford sires and straightbred Brahman and Hereford cows to be 9.3% heavier than straightbred calves at weaning, while backcross calves out of F1 Brahman-Hereford cows weighed 18.8% more than straightbred calves. The difference was attributed to the maternal heterosis of the F1 cow.

Roberson et al. (1986) reported similar average weaning weights for purebred Brahman (135.8 kg) and Hereford (133.6 kg); while F1 Brahman-Hereford calves (144.2 kg) were 21 kg lighter at weaning than F1 Hereford-Brahman calves (165.2 kg). This happened even though F1 calves out of Hereford cows outweighed by 7.5 kg those out of Brahman cows at birth. They attributed the differences in weaning weight for F1 calves to the higher milk production of the Brahman cow, as compared to the Hereford cow.

Riley et al. (2001a) comparing calves born to F1 *Bos indicus* x Hereford and Angus x Hereford cows in central Texas found a sex of calf by sire breed of cow interaction on weaning weight. Steer calves from Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, and Red Brahman-sired F1 cows had adjusted weaning weights that were 20.2, 19.0, 14.7, 18, and 16.1 kg heavier than those of heifer calves born to these *Bos-indicus*-sired F1 cows, respectively. Steers calves from Angus-sired cows had an adjusted weaning weight that was 8.2 kg heavier than that of heifers.

McCarter et al. (1991) reported that as dam age increased from 3 to 5 years, the weaning weight of the calves increased from 226 to 237 kg.

Buchanan and Frahm (2005) observed an increase in weaning weight of the calves as the proportion of the Brahman in the sire increased. They reported average adjusted weaning weight of 206, 228 and 237 kg respectively for calves with Angus and Hereford dams that were 0, 1/4, and 1/2 Brahman.

Throughout this literature review, the F1 calves sired by *Bos indicus* bulls and out of *Bos taurus* cows tended to be heavier at birth, and averaged heavier weight at weaning, as compared to the F1 calves out of *Bos taurus* x *Bos taurus* crossbred cows. Brahman x *Bos taurus* crosses lived longer, and averaged higher reproductive rates as compared to *Bos taurus* x *Bos taurus* cows.

MATERIAL AND METHODS

One hundred and forty three F1 Brahman-Hereford, Brahman-Angus, Boran-Hereford, Boran-Angus, Tuli-Hereford and Tuli-Angus cows born in 1992 (n = 66) and 1993 (n = 77) at the Texas A&M Research Center at McGregor were evaluated for maternal and reproductive characters. The Center is located at latitude 31º 44” N, longitude -97º 41” W at an elevation of 212m. The averages for maximum and minimum temperatures are 25.6º C and 13.5º C with extreme temperatures of 44.4 and -13.5º C. The average for annual precipitation is 910.75 mm. The highest rainfall amounts were recorded in 1992 (1075 mm) and 2004 (1346 mm). The lowest rainfall amounts were recorded in 1995 (747 mm), 1999 (710 mm) and 2005 (592 mm)

The semen of 9 Tuli, 7 Boran and 16 Brahman bulls was used to breed by artificial insemination multiparous Angus and Hereford cows. Boran and Tuli semen was imported from Australia, and semen from Brahman bulls considered to be representative of the breed in the early 1990’s was obtained from purebred breeders and commercial breeding services.

The cows evaluated were pastured on coastal Bermuda grass and other warm season grasses during spring, summer, and fall. During winter, they were fed with hay and supplemented with protein.

As heifers, the females were bred to Angus bulls in 1993 and 1994. In 1994, 2 year-old cows born in 1992 were bred to Brangus bulls. In the following years, cows were bred to Brangus in 1995, F1 Hereford-Brahman in 1996, F1 Brahman-Angus in 1997, F1 Angus-Brahman in 1998, 3/8 Nellore-5/8 Angus in 1999, F1 Nellore-Angus in

2000, 3/8 Nellore-5/8 Angus in 2001 and 2002 and Angus bulls in 2003, 2004, and 2005. Cows calved from approximately February 20 to April 15 each year. Calves born out of these F1 cows and heifers from 1994 to 2006 were evaluated. Each calf was weighed and tagged for identification within 48 h of birth and received a subjective score for calf vigor, calving ease and nursing success. Information about gender of the calf and dam identification was recorded at birth. Male calves were castrated when birth measures were recorded. Calves were weaned at approximately seven months of age in October or November. At weaning, calves were weighed and assigned a body condition score and heifer calves vaccinated for brucellosis. At weaning, cows were palpated for pregnancy diagnosis, weighed and body condition scores were assigned.

Herring et al (1996) reported birth, weaning and postweaning performance of the animals that were evaluated in this study as well as the carcass characteristics of the steers. Ducoing Watty (2002) analyzed the maternal and reproductive performance of these F1 females as 7 or 8 year-olds and included traits such as cow weight, pregnancy rate, calf crop born, birth weight, calving ease, nursing success, calf vigor, calf survival rate, calf crop weaned and weaning weight in his study. Cunningham (2005) analyzed performance of these cows as 11 or 12 years olds, for traits such as cow weight, cow condition score, pregnancy rate, calf crop born, birth weight, calf crop weaned, weaning weight and cow longevity.

Calf crop born, calf crop weaned and pregnancy rate were evaluated in the F1 cows as binary traits using least squares analysis. For analyses of pregnancy, calf crop born, and calf crop weaned, cows that were diagnosed as open through palpation, those that did not calve and those that did not wean a calf during a given year were assigned a value of zero for the respective trait. Pregnant cows, those that calved, and those that weaned a calf during a given year were assigned a value of one, respectively.

The variables considered in this study were analyzed by the mixed model procedure of SAS.

Birth weight (n = 1227) and weaning weight (n = 1090) were evaluated using model components of sire breed of dam, dam breed of dam, calf birth year/age of dam and calf's gender as fixed effect, dam's sire within sire breed and dam within dam's sire within sire breed as random effects using least squares analysis. Weaning age of calf was included in the weaning weight model as a covariate.

Pregnancy rate (n = 1379), calf crop born (n =1356) and calf crop weaned (n = 1294) were evaluated using a model that included sire breed of dam, dam breed of dam and calf birth year/age of dam as fixed effects and dam's sire within sire breed and dam within dam's sire within sire breed as random effects.

Cow weight (n = 1474) and cow body condition score (n = 1473) were evaluated using as model components sire breed of dam, dam breed of dam and year/age of dam as fixed effects and dam's sire within sire breed and dam within dam's sire within sire breed as random effects.

All possible two-way interactions between the main effects were tested for significance, and those with P-value equal or less than 0.25 were included in the final model.

Mouth scores (n = 139), as a measure of cow longevity, were analyzed using two different models. The first method of analysis consisted of assigning a value of zero to smooth mouthed cows and a value of one to all females having a broken or solid mouth. In the second model, a value zero was assigned to all smooth and broken mouthed cows and a value of one was assigned to solid mouths. Incisor condition was analyzed as a binary trait with a model including the fixed effects of sire of cow breed and dam of cow breed. Sire of dam within sire breed of dam and dam within sire of dam within sire breed of dam were used as random effects.

For all analyses, sire of cow within sire breed of cow was used as the error term to test sire breed of cow differences.

RESULTS AND DISCUSSIONS

Cow weight and body condition score

The least squares means and standard errors for cow weight obtained from1993 to 2005 in the Brahman-, Boran-, and Tuli-sired F1 cows by sire breed of cow and calf's birth year/age of cow are presented in Table 1.

The sire breed of the cow effect was significant ($P < 0.001$) with the Brahman-sired cows having a heavier adjusted mean (522.95 kg) than those sired by Boran and Tuli bulls (456.51 kg and 450.50 kg respectively). Note that these averages across the lifetime of the females including the weights as yearling heifers. These observations agree with those reported by Herring et al. (1996) on these females as yearling heifers.

Trail et al. (1981) reported mature weights of 414 kg for 7 to 9-year old Boran cows in Kenya. Hetzel (1998) reported a difference in cow weight between straightbred Brahman (446 kg), Boran (375 kg) and Tuli (400 kg) cows in East and Southern Africa. The Boran was evaluated in Zambia, while both Brahman and Tuli were evaluated in Botswana. Note that the straight Tuli cows were heavier than the straight Boran cows, whereas in the present study, the F1 Tuli-sired cows were lighter than the Boran-sired F1 cows. Demeke et al. (2004) reported mature weight of 304 kg in purebred Boran, significantly lighter (by 64 kg) than Friesian-Boran crossbred cows.

The least squares means and standard errors for cow weight by the interaction of sire breed of cow x dam breed of cow are listed in Table 2 and illustrated by Figure 1. This interaction was important ($P = 0.044$). Note in Figure 1 that in both Brahman- and

Boran-sired cows, those out of Angus dams (533.68 and 462.61 kg, respectively) had heavier adjusted means than their Hereford counterparts (512. 22 and 450 kg, respectively, for Brahman- and Boran-sired cows). By contrast, in Tuli-sired cows, those born to Hereford dams (457.02 kg) were heavier than those out of Angus dams (444.78 kg). Note that the Brahman-sired females, regardless of dam breed, were significantly heavier than those sired either by Boran or Tuli bulls.

McCarter et al. (1991) reported adjusted values of 478 and 482 kg, respectively, in F1 Brahman-Angus and Brahman-Hereford cows, which reflect the opposite trend of the present study, however in their study, the cows were only 3-, 4- and 5-year old.

Birth year of calf / age of cow effect was significant ($P < 0.001$). The pattern for this variable is illustrated by Figure 2. As yearlings, the adjusted values were different between the 1992- and the 1993-born heifers, with those born in 1993 being heavier (305.88 kg) than those born in 1992 (277.13 kg). However, as two-year old heifers, in 1995 and from 1998 to 2005, within the same year, no differences were observed between the 2 groups of cows. Ducoing Watty (2002) observed the same trend between the 2 groups of cow from 1998 to 2001.

Sire breed of cow x year / age of cow interaction was also significant ($P < 0.001$) in explaining the variability in cow weight. The trends for this interaction of the cows born in1992 and 1993 are given in Figures 3 and 4 respectively. Within the same year, in both groups, Brahman-sired females had higher adjusted means than the Boran-and Tuli-sired females. The largest values were observed in 2004, regardless of birth group and sire of cow breed.

Table 1. Least squares means (LSM) and standard errors (SE) for cow weight by sire breed of cow, and calf's birth year/age of cow.

	LSM ± SE, kg	n
Sire breed of cow		
Brahman	522.96[a] ± 5.86	564
Boran	456.52[b] ± 7.88	381
Tuli	450.91[b] ± 6.78	529
Calf's birth year/age of dam		
1993/1[d]	277.13 ± 6.47	66
1994/1[d]	305.88 ± 5.86	77
1994/2[e]	388.01 ± 6.47	66
1995/2[e]	387.11 ± 5.84	77
1995/3[f]	387.22 ± 6.47	66
1996/3	427.41 ± 5.86	75
1996/4	488.92 ± 6.49	65
1997/4	423.83 ± 5.92	73
1997/5	470.77 ± 6.53	64
1998/5	504.38 ± 5.97	71
1998/6	514.05 ± 6.57	62
1999/6	480.25 ± 6.01	70
1999/7	487.49 ± 6.57	62
2000/7	541.97 ± 6.05	67
2000/8	543.72 ± 6.68	57
2001/8	478.34 ± 6.26	58
2001/9	475.72 ± 6.90	48
2002/9	512.73 ± 6.34	54
2002/10	512.53 ± 7.02	45
2003/10	549.42 ± 6.36	53
2003/11	537.99 ± 7.02	45
2004/11	569.81 ± 6.53	47
2004/12	558.96 ± 7.22	39
2005/12	553.27 ± 6.83	39
2005/13	542.97 ± 7.90	28

[a, b] Least squares means in the same column without common superscript differ ($P < 0.05$).

[d] Values for 1993/1 and 1994/1 were obtained from weights taken as yearling heifers in spring of the respective year (1993 and 1994).

[e] Values for 1994/2 and 1995/2 were obtained from weights taken at palpation time when heifers were 1.5-year old (1993 and 1994, respectively).

[f] Values for 1995/3 to 2005/13 were obtained from weights measured at palpation time in the fall of the previous year (e.g., 1995/3 refers to the weight in the fall of 1994, when the cows were about 2.5-year old).

Table 2. Least squares means (LSM) and standard errors (SE) for cow weight by sire breed of cow by dam breed of cow interaction.

	LSM ± SE, kg	n
Brahman x Angus	$533.69^{a} \pm 7.99$	243
Brahman x Hereford	$512.23^{b} \pm 7.18$	321
Boran x Angus	$462.62^{bc} \pm 10.89$	158
Boran x Hereford	$450.42^{c} \pm 9.47$	223
Tuli x Angus	$444.78^{c} \pm 8.80$	232
Tuli x Hereford	$457.03^{c} \pm 7.90$	297

[a, b, c] Least squares means in the same column without common superscript differ ($P < 0.05$).

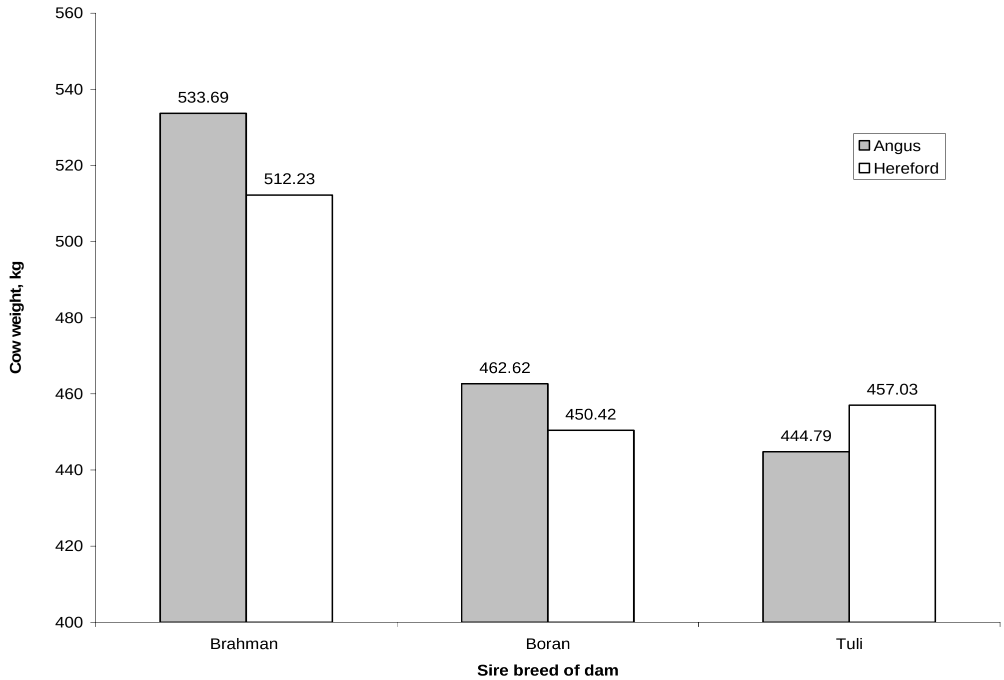

Figure 1. Least squares means for cow weight by sire breed of cow x dam breed of cow interaction

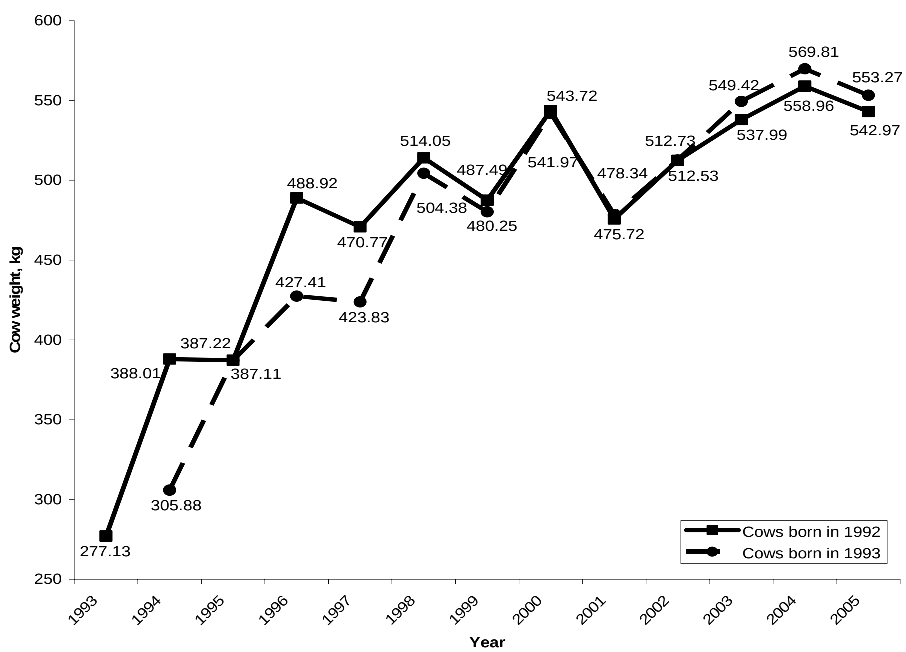

Figure 2. Least squares means for cow weight by year in cows born in 1992 and 1993

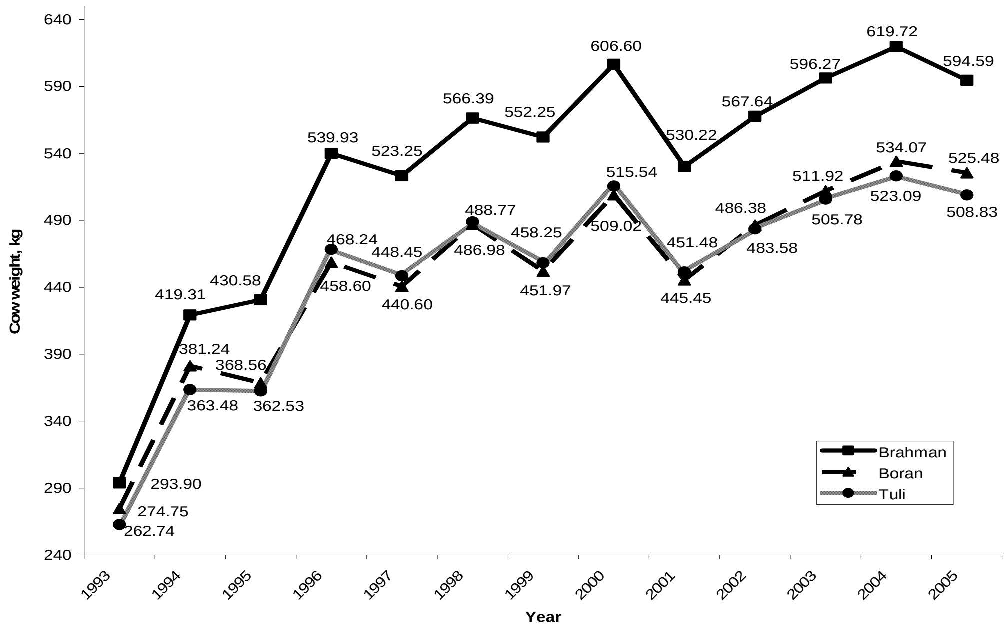

Figure 3. Least squares means for cow weight by sire breed of cow x year / age of cow interaction in cows born in 1992

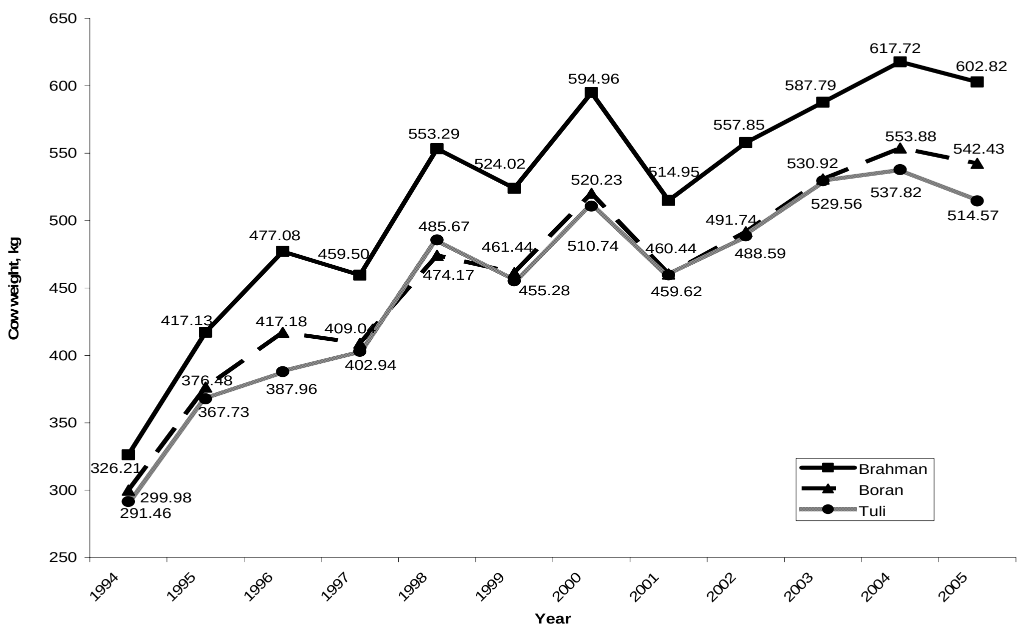

Figure 4. Least squares means for cow weight by sire breed of cow x year / age of cow interaction in cows born in 1993

The least square means and standards errors for cow weight and body condition score of the F1 cows sired by Brahman, Boran and Tuli bulls in the fall of 2000 are listed in Table 3. As 7 and 8-year olds, the Brahman-sired cows (600.78 kg) were heavier ($P < 0.05$) than the Boran-and Tuli-sired cows (514.63 and 513.10 kg, respectively). At these same ages, the Boran-sired cows were assigned higher ($P < 0.05$) body condition scores (6.19) than the Brahman- and Tuli-sired cows (5.89 and 5.63, respectively).

Table 3. Least squares means (LSM) and standard errors (SE) for cow weight at palpation and cow body condition score by sire breed of cow in the fall of 2000, when the cows born in 1992 were eight and those born in 1993 were seven years of age.

	Cow weight	Cow body condition score	
	LSM ± SE, kg	LSM ± SE	n
Brahman	$600.78^{a} \pm 9.60$	$5.89^{b} \pm 0.13$	49
Boran	$514.63^{b} \pm 12.64$	$6.19^{a} \pm 0.17$	31
Tuli	$513.10^{b} \pm 10.57$	$5.63^{b} \pm 0.14$	44

$^{a, b}$ Least squares means in the same column without common superscript differ ($P < 0.05$).

The estimates and standard errors for cow body condition score by sire breed of cow, and by calf's birth year / age of cow are presented in Table 4.

The paternal breed of cow accounted for variation ($P < 0.001$) observed in body condition score. Boran-sired cows were assigned significantly higher scores (5.48) than the Brahman- and Tuli-sired cows (5.23 and 5.18 respectively). In an earlier report of this study, Herring et al. (1996) reported the lowest condition for Brahman-sired heifers (5.09) followed by Tuli- (5.33) and Boran-sired heifers (5.53), but the Boran- and Tuli-sired heifers were not significantly different.

Cunningham (2005) reported higher scores of body condition assigned to Boran-sired cows (5.5) compared to Brahman- and Tuli-sired females (5.3 and 5.1, respectively), with significant differences among the sire breeds, when these F1 cows were 9 and 10 years of age.

Year / age of dam was an important source of variation (P < 0.001) on body condition score. The highest scores were assigned in 2000 to the group of cows born in 1992 when they were 8-year old, while the lowest score was assigned in 1997 to the group of cows born in 1993 when they were 4-year old.

However, the sire breed of cow by year/age of cow interaction was not significant (P < 0.420); the adjusted means are given in Figures 5 and 6, respectively, for the groups of cows born in 1992 and 1993. Nonetheless, in the group of cows born in 1992, across years, the Boran-sired cows were assigned higher scores than the Brahman- and Tuli-sired cows, except for the years 2001 and 2004, when the Boran-sired cows were lower than cows by both these breeds of sire. In the groups of cows born in 1993, the Boran-sired F1 cows were always assigned higher scores than Brahman and Tuli-sired cows.

Table 4. Least squares means (LSM) and standard errors (SE) for cow condition score by sire breed of cow and calf's birth year/age of cow.

	LSM ± SE, kg	n
Sire breed of cow		
Brahman	5.23[b] ± 0.05	565
Boran	5.48[a] ± 0.05	382
Tuli	5.18[b] ± 0.05	526
Calf's birth year/age of cow		
1993/1[d]	5.18 ± 0.08	66
1994/1[d]	5.40 ± 0.08	77
1994/2[e]	5.65 ± 0.08	66
1995/2[e]	5.03 ± 0.08	77
1995/3[f]	4.91 ± 0.08	66
1996/3	5.22 ± 0.08	75
1996/4	5.80 ± 0.08	65
1997/4	4.51 ± 0.08	71
1997/5	5.19 ± 0.08	64
1998/5	5.58 ± 0.08	71
1998/6	5.77 ± 0.08	62
1999/6	5.13 ± 0.08	70
1999/7	5.24 ± 0.08	62
2000/7	5.76 ± 0.08	67
2000/8	6.02 ± 0.09	57
2001/8	4.83 ± 0.09	58
2001/9	4.89 ± 0.10	48
2002/9	5.05 ± 0.10	54
2002/10	4.85 ± 0.09	45
2003/10	5.43 ± 0.09	53
2003/11	5.22 ± 0.10	45
2004/11	5.42 ± 0.10	47
2004/12	5.40 ± 0.11	39
2005/12	5.81 ± 0.65	40
2005/13	5.15 ± 0.46	28

[a, b] Least squares means in the same column without common superscript differ ($P < 0.05$).
[d] Values for 1993/1 and 1994/1 were obtained from body condition scored as yearling heifers in spring of the respective year (1993 and 1994).
[e] Values for 1994/2 and 1995/2 were obtained from body condition scored at palpation time from two-year old heifers in the fall of the previous year (1993, 1994).
[f] Values for 1995/3 to 2005/13 were obtained from body condition scored at palpation time in the fall of the previous year.

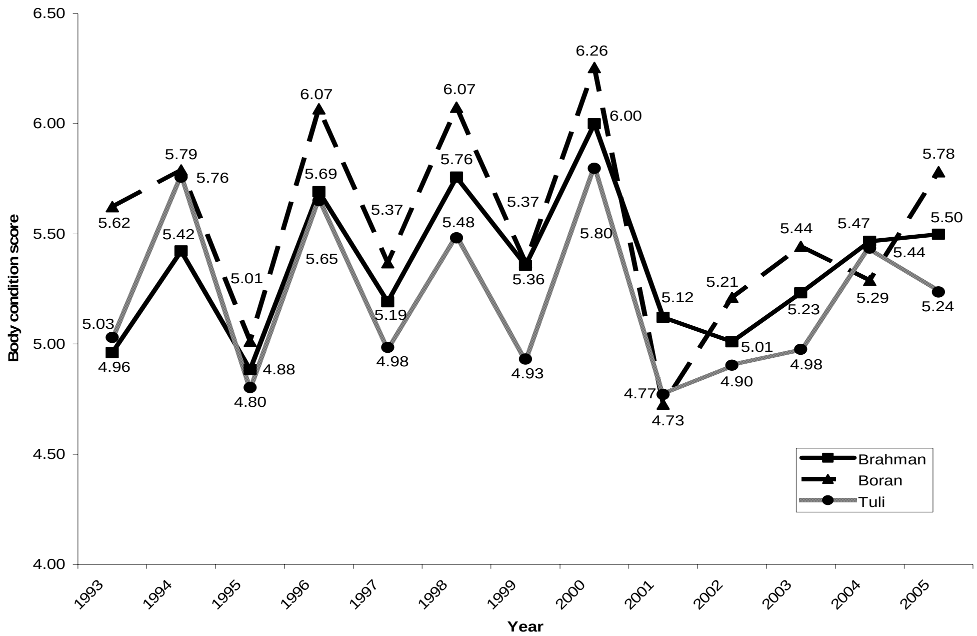

Figure 5. Least squares means for cow body condition score by sire breed of cow x year/age of dam interaction in cows born in 1992

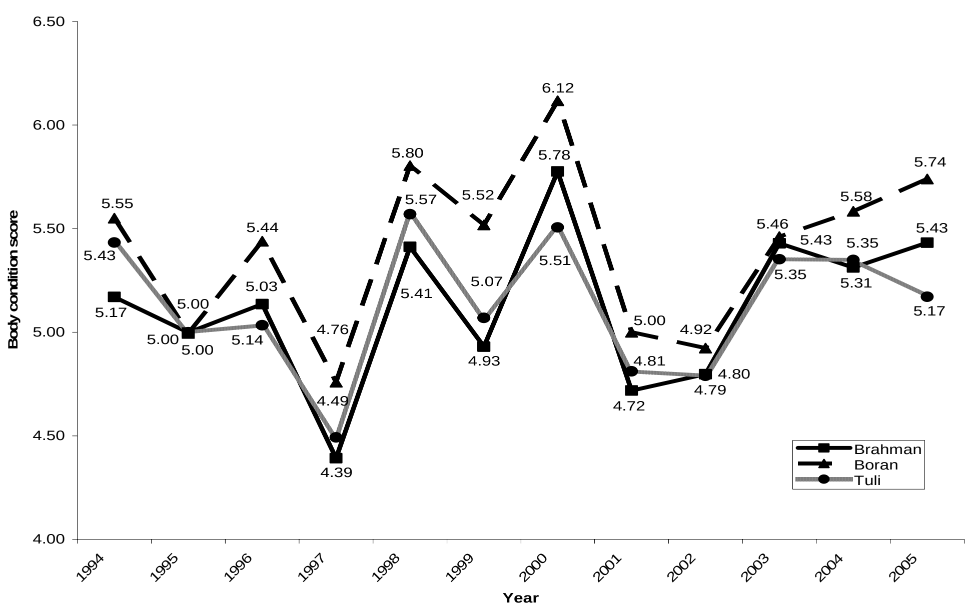

Figure 6. Least squares means for cow body condition score by sire breed of cow x year/age of dam interaction in cows born in 1993

Mouth scores

The results from the 2 analyses of mouth scores by sire of cow breed, calf's birth year / age of cow, and their interaction are presented in Table 5.

In the first model, smooth mouths were assigned a value of 0 and broken or solid a value of 1. Cows sired by Tuli bulls (0.78) had lower mouth scores (P = 0.020) than those sired by Brahman and Boran bulls (0.94 and 0.95, respectively).

Calf's birth year / age of cow affected (P = 0.048) mouth scores. Cows born in 1993 averaged similar mouth scores across the two years, not statistically different from those born in 1992. On the other hand, cows born in 1992 were assigned different scores across the two years, with the 13-year old cows averaging higher adjusted values (1.01) than the 12 year-old cows (0.78).

In the second model, where both smooth and broken were assigned a value of 0 and solid a value of 1, Brahman crosses averaged significantly (P = 0.052) higher mouth scores (0.53) than Tuli crosses (0.24); Boran crosses (0.34) were intermediate.

The effect of birth year / age of cow was also an important (P < 0.001) influence on mouth scores. In 2004, both groups of cows were scored the same value (0.51), which was significantly higher than what the 12-year old cows scored in 2005, while the 13-year old cows were intermediate.

The sire of cow breed by calf's birth year / age of cow interaction was also an important (P = 0.026) effect. In 2004, the highest score was assigned to the 12-year old Boran-sired cows, while in 2005 the lowest score were assigned to the 13-year old

Boran- sired cows (i.e., the same cows); note that the scoring system differed between the two years.

Riley et al. (2001b) analyzed mouth scores of 14-year old F1 cows sired by Angus, Gray and Red Brahman, Gir, Indu-Brazil and Nellore bulls out of Hereford dams using the above-mentioned two different models. In the first model, Angus-sired cows had a significantly lower mouth score than the other F1 sire breed groups. The authors found no significant differences among *Bos indicus* crossbreds using this model. In the second model, no significant differences were noted among any of the breed groups, but the Angus-sired cows had the lowest mouth scores.

Cunningham (2005) analyzed the first mouth scores of the F1 cows of the present study, when they were 11 and 12 years of age. In the first model, Boran crosses averaged the highest score (1.0) followed by Brahman crosses (0.96) significantly higher than the Tuli crosses (0.76). In the second model, the same rankings were observed; with scores of 0.67, 0.55 and 0.28 respectively assigned, with the Boran and the Brahman crosses having significantly higher values than the Tuli crosses.

Table 5. Least squares means (LSM) and standard errors (SE) for mouth scores by sire breed of dam, calf's birth year/age of dam and their interaction according to the two alternative models.

	Model 1[d] LSM ± SE	n	Model 2[e] LSM ± SE	n
Sire breed of dam				
Brahman	0.94[a] ± 0.04	45	0.53[a] ± 0.08	52
Boran	0.95[a] ± 0.05	40	0.39[ab] ± 0.09	40
Tuli	0.78[b] ± 0.05	47	0.24[b] ± 0.09	47
Calf's birth year/age of dam				
2004/11	0.88[ab] ± 0.05	41	0.51 [a]± 0.07	41
2004/12	0.78[b] ± 0.06	28	0.51[a] ± 0.09	29
2005/12	0.89[ab] ± 0.05	42	0.23[b] ± 0.07	42
2005/13	1.01[a] ± 0.06	28	0.30[ab] ± 0.09	27
Sire breed of cow by calf's birth year/age of dam				
Bx2004/11	0.95 ± 0.08	16	0.63[ab] ± 0.11	16
Bx2004/12	0.88 ± 0.10	10	0.50[ab] ± 0.14	10
Bx2005/12	0.95± 0.08	16	0.44[ab] ± 0.11	16
Bx2005/13	0.98 ± 0.10	10	0.56[ab] ± 0.14	10
Box2004/11	0.87 ± 0.10	10	0.57[ab] ± 0.15	10
Box2004/12	0.93 ± 0.10	10	0.75[a] ± 0.14	11
Box2005/12	0.97 ± 0.10	10	0.17[bc] ± 0.15	10
Box2005/13	1.04 ± 0.10	10	0.05[c] ± 0.15	9
Tx2004/11	0.80 ± 0.08	15	0.34[b] ± 0.12	15
Tx2004/12	0.52 ± 0.11	8	0.28[bc] ± 0.16	8
Tx2005/12	0.76 ± 0.08	16	0.07[c] ± 0.11	16
Tx2005/13	1.02 ± 0.11	8	0.28[bc] ± 0.16	8

[a, b, c] Least squares means in the same column without common superscript differ ($P < 0.05$).

[d] Analyzed as a binary trait, where smooth = 0 and broken or solid = 1.

[e] Analyzed as a binary trait, where smooth or broken = 0 and solid = 1.

Pregnancy rate

The estimates, standard errors and sample sizes for pregnancy rates obtained for the calving years 1994 to 2006 in the Brahman-, Boran- and Tuli-sired F1 cows by paternal breed and birth year / age of dam breed are presented in Table 6.

The effect of sire of cow breed was not significant (P = 0.229). Nonetheless, the Boran-sired females had the highest adjusted mean (0.955) followed by the Tuli- and Brahman-sired females (0.936 and 0.922 respectively). The same trend was observed by Ducoing Watty (2002) and Cunningham (2005) in previous studies on the F1 cows of the current study.

Birth year / age of dam was significant (P < 0.001) in explaining the variation in pregnancy rate. In Figure 7, note that cows born in 1992 showed a significant decrease in pregnancy in their second season (0.591) as compared to the first season (0.940). The cows born in 1993 had adjusted values of 0.899 and 0.949 respectively in their first and second seasons, and then showed a decrease in their third season (0.784). These results are consistent with those obtained by Cunningham (2005) who observed no difference among the paternal breed of cows while the birth year of calf / age of dam was significant. The differences in pattern between the 2 groups of cows, as illustrated by figure 7 are probably the result of the different management practices and the environment influence across the years.

Table 6. Least squares means (LSM) and standard errors (SE) for pregnancy rate by sire breed of dam and calf's birth year/age of dam.

	LSM ± SE	n
Sire breed of dam		
Brahman	0.922 ± 0.012	527
Boran	0.955 ± 0.015	367
Tuli	0.936 ± 0.013	492
Calf's birth year/age of dam		
1994/2[a]	0.940 ± 0.030	66
1995/2[a]	0.899 ± 0.028	77
1995/3	0.591 ± 0.031	66
1996/3	0.949 ± 0.028	75
1996/4	0.831 ± 0.030	65
1997/4	0.784 ± 0.029	73
1997/5	0.938 ± 0.031	64
1998/5	0.989 ± 0.029	71
1998/6	0.952 ± 0.031	62
1999/6	0.989 ± 0.029	70
1999/7	0.984 ± 0.031	62
2000/7	0.944 ± 0.030	68
2000/8	0.949 ± 0.032	58
2001/8	0.967 ± 0.032	57
2001/9	0.978 ± 0.035	48
2002/9	0.964 ± 0.033	55
2002/10	0.977 ± 0.037	45
2003/10	1.001 ± 0.034	53
2003/11	0.955 ± 0.037	45
2004/11	0.979 ± 0.036	47
2004/12	0.895 ± 0.039	39
2005/12	0.999 ± 0.038	41
2005/13	0.996 ± 0.045	30
2006/13	0.997 ± 0.045	29
2006/14	0.996 ± 0.055	20

[a] Values for 1994/2 and 1995/2 refer to pregnancy rates for calving as 2-year old in 1994, based on palpation in the fall of 1993 and 1994, respectively.

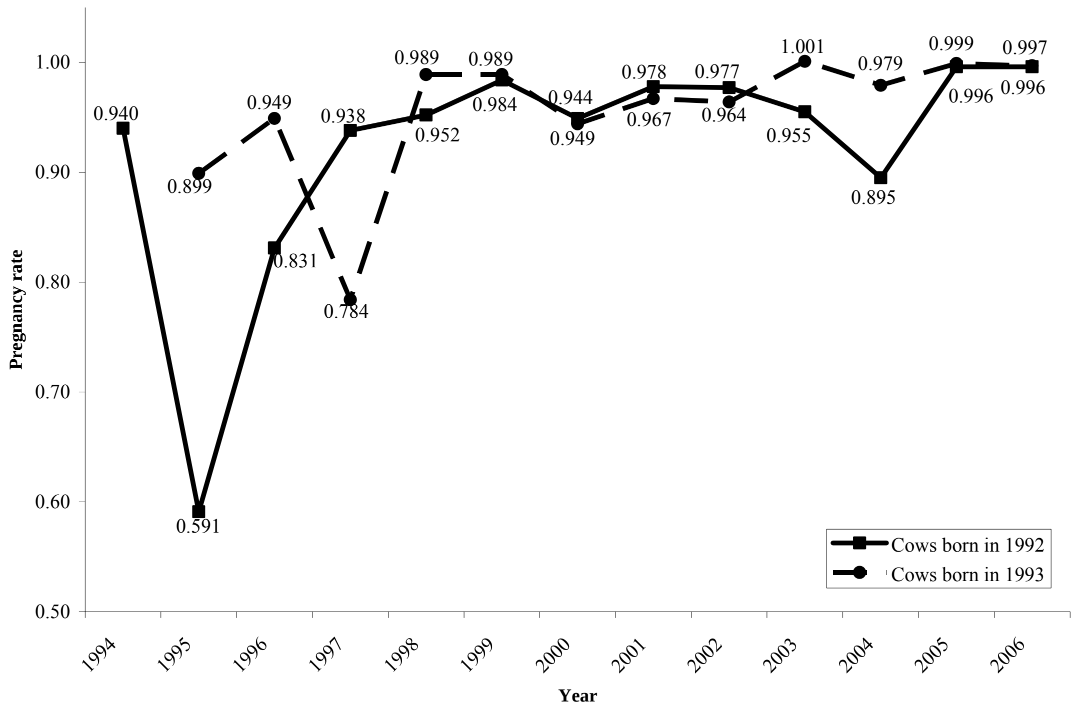

Figure 7. Least squares means for pregnancy rate by year in cows born in 1992 and 1993

Calf crop born

Least squares means and standards errors for calf crop born for F1 cows through 14 years of age by sire breed of cow and birth year / age of cow are presented in Table 7.

The sire breed of cow was not a significant source of variation (P = 0.071) on rate of calf crop born. As expected, calf crop born followed the same trend as for pregnancy rate, with the Boran-sired cows having the highest value (0.931) followed by the Tuli- and Brahman-sired cows (0.890 and 0.881, respectively). Ducoing Watty (2002), evaluating the F1 cows of the present study, observed the same ranking among the sire of cow breed, without significant differences (P = 0.064) among these F1 cows.

However in East and Southern Africa, Hetzel (1988) found calving rate of straightbred Brahman, Tuli and Boran cows to be 72, 75 and 87%, respectively. Both Brahman and Tuli were evaluated in Botswana, while the Boran was evaluated in Zambia. Moyo (1995) reported calving rates in purebred Tuli (72%) and Brahman (71%) in Zimbabwe.

Birth year of calf / age of cow affected significantly ($P < 0.001$) the calf crop born. The pattern of the adjusted means for this effect is given in Figure 8. Again, calf crop born closely followed the pattern of pregnancy rate. Cows born in 1992 showed a significant drop in rate of calf crop born during their second parity (0.579) compared to their first parity (0.942) and then increased gradually until 1998 before fluctuating across years until 2006. The cows born in 1993 had mean values of 0.875 and 0.911, respectively, in their first and second calving seasons, dropped to 0.731 in 1997, increased to 0.977 the following year, and then fluctuated across years up to 2006.

Cundiff et al. (2000) evaluating F1 cows by Brahman, Tuli, and Boran sires found means for calf crop born of 76.6, 90.3, and 86.1% respectively during their first calving season. In the second calving, the authors reported means of 92.8, 91.8, and 93.1 respectively for the crossbred cows being investigated.

Table 7. Least squares means (LSM) and standard errors (SE) for calf crop born by sire breed of dam and calf's birth year/age of dam.

	LSM ± SE	n
Sire breed of dam		
Brahman	0.881 ± 0.014	527
Boran	0.931 ± 0.017	367
Tuli	0.890 ± 0.015	492
Calf's birth year/age of dam		
1994/2	0.942 ± 0.037	66
1995/2	0.875 ± 0.034	77
1995/3	0.579 ± 0.037	66
1996/3	0.911 ± 0.035	75
1996/4	0.726 ± 0.037	65
1997/4	0.731 ± 0.035	73
1997/5	0.925 ± 0.037	64
1998/5	0.977 ± 0.036	71
1998/6	0.954 ± 0.038	62
1999/6	0.948 ± 0.036	70
1999/7	0.922 ± 0.038	62
2000/7	0.828 ± 0.036	68
2000/8	0.863 ± 0.039	58
2001/8	0.967 ± 0.040	57
2001/9	0.934 ± 0.043	48
2002/9	0.946 ± 0.040	55
2002/10	0.952 ± 0.045	45
2003/10	0.963 ± 0.041	53
2003/11	0.885 ± 0.045	45
2004/11	0.935 ± 0.044	47
2004/12	0.788 ± 0.048	39
2005/12	0.997 ± 0.047	41
2005/13	0.987 ± 0.055	30
2006/13	0.995 ± 0.056	29
2006/14	0.987 ± 0.067	20

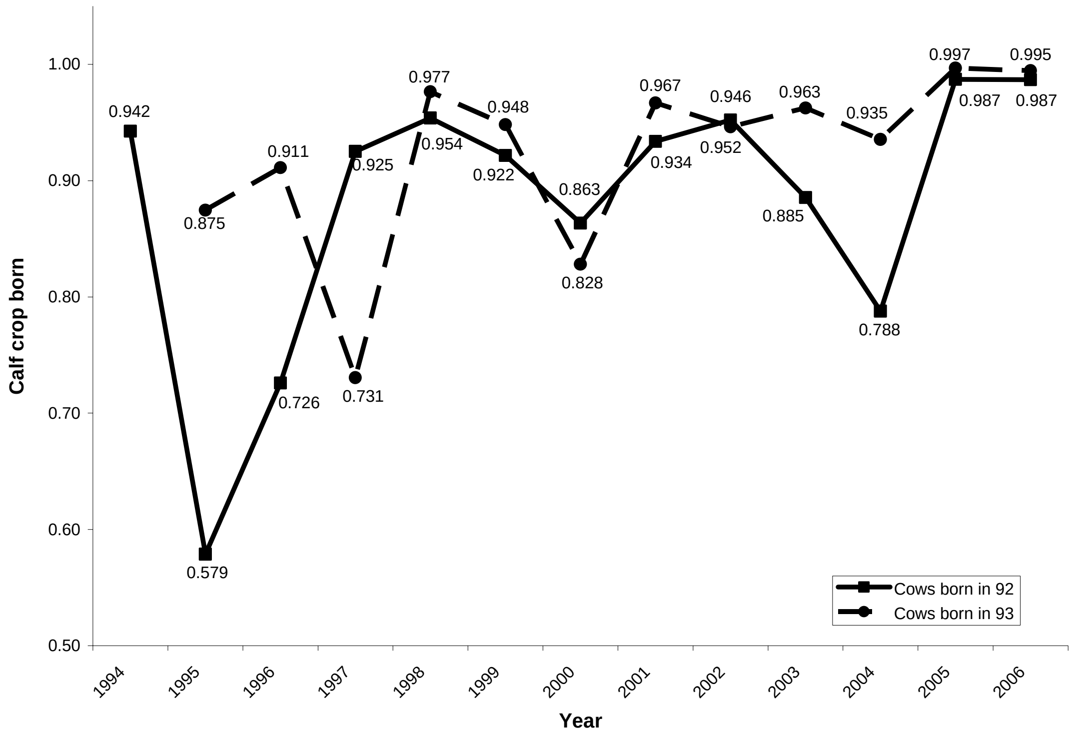

Figure 8. Least squares means for calf crop born by year in cows born in 1992 and 1993

Birth weight

The birth weight least squares means by sire breed of dam, calf's gender and calf's birth year / age of dam are summarized in Table 8.

The sire breed of the cow was not important (P = 0.888) for birth weight. Nevertheless, calves born to Brahman-sired cows showed higher adjusted mean (35.08 kg) than those out of Tuli- (34.87 kg) and Boran-sired cows (34.76 kg). The same rankings were observed by Ducoing Watty (2002) with adjusted means of 35.53, 35.49 and 34.78 kg, respectively, as 8- and 9-year old cows. Cunningham (2005) reported similar adjusted values of 35.66, 35.38 and 35.59 kg, respectively, for calves out of Brahman-, Tuli- and Boran-sired cows at 11 and 12 years of age. Cundiff et al. (2000) found average birth weight of calves out of two-year old F1 females mated to Red Poll bulls to be 34.2, 33.3 and 34 kg, respectively, for the calves out of cows born to Brahman, Boran and Tuli bulls. When these F1 females were mated to purebred Charolais and F1 Belgian Blue bulls, the means were 37.3, 37.1 and 38.4 kg, respectively, for the calves out of cows born to Brahman, Boran and Tuli bulls. However the adjusted means of calves born to Brahman-, Boran- and Tuli-sired cows of the present study were lower than those obtained by Herring et al. (1996) in the F1 calves (44.01, 40.25 and 36.36 kg for the Brahman-, Boran- and Tuli-sired calves, respectively). Cundiff et al. (2000) reported means of 46.6, 43.4, and 38.9 kg, respectively for F1 calves by these sire breed with significant differences between them. Thrift (1997) reported F1 calves born to Brahman sires to exceed by 6 kg those born to Tuli sires.

Table 8. Least squares means (LSM) and standards errors (SE) for birth weight by sire breed of dam, calf's gender and calf's birth year / age of dam.

	LSM ± SE, kg	n
Sire breed of dam		
Brahman	35.08 ± 0.40	457
Boran	34.76 ± 0.55	337
Tuli	34.88 ± 0.47	433
Calf's gender		
Female	33.77[a] ± 0.31	616
Male	36.05[b] ± 0.31	611
Calf's birth year / age of dam		
1994/2	30.87 ± 0.62	62
1995/2	30.16 ± 0.57	66
1995/3	34.03 ± 0.74	38
1996/3	34.28 ± 0.57	67
1996/4	35.49 ± 0.69	47
1997/4	34.23 ± 0.64	51
1997/5	34.99 ± 0.64	58
1998/5	37.17 ± 0.57	68
1998/6	36.35 ± 0.64	59
1999/6	36.75 ± 0.58	66
1999/7	36.24 ± 0.65	57
2000/7	36.33 ± 0.62	56
2000/8	36.15 ± 0.68	50
2001/8	38.46 ± 0.62	56
2001/9	38.22 ± 0.73	45
2002/9	35.18 ± 0.64	52
2002/10	34.39 ± 0.73	43
2003/10	37.70 ± 0.64	51
2003/11	35.41 ± 0.75	40
2004/11	36.64 ± 0.68	44
2004/12	35.90 ± 0.83	31
2005/12	34.79 ± 0.71	41
2005/13	32.81 ± 0.85	30
2006/13	31.37 ± 0.83	29
2006/14	28.78 ± 0.99	30

[a, b] Least squares means in the same column without common superscript differ ($P < 0.05$).

The calf's gender effect was significant (P < 0.001) in affecting birth weight, with bull calves (36.05 kg) weighing 2.28 kg more than heifer calves (33.77 kg). These results coincide with those by Ducoing Watty (2002), who observed that male calves were 2.16 kg heavier than female calves and those by Cunningham (2005) who found male calves to be 2.43 kg heavier than female calves, the difference being significant in both cases. Furthermore, Herring et al. (1996) observed a larger difference (4.4 kg) between male (42.4 kg) and female Brahman-, Boran-, and Tuli-sired calves.

The adjusted means for birth weight for the interaction of dam breed of dam by calf's gender are listed in Table 9. This interaction was involved (P < 0.001) in explaining the variation in birth weight. Female calves born to cows out of Angus dams (33.21 kg) were significantly lighter than the female calves born to cows out of Hereford dams (34.32 kg), which in turn were significantly lighter than the male calves out of dams born to both Angus and Hereford cows (36.41 and 35.68 kg, respectively). The pattern of this interaction presented in Figure 9 showed that the bull calves born to cows out of Angus dams (36.41 kg) were 3.20 kg heavier than the heifer calves (33.21 kg), whereas the bull calves born out of cows born to Hereford dam (35.68 kg) were only 1.36 kg heavier than the heifer calves (34.32 kg). Similarly in the analysis of Cunningham (2005), the bull calves out of cows born to Angus dam (37.09 kg) were 3.18 kg heavier than the heifer calves (33.91 kg); while the bull calves out of cows born to Hereford dam (36.43 kg) were only 1.68 kg heavier than the heifer calves (34.75 kg).

The calf birth year / age of dam was also an important ($P < 0.001$) influence on birth weight, and the pattern is presented in Figure 10. In both groups of cows, the adjusted means for birth weight were the lowest for the first-calf heifers at two years of age (except in 2006 in the 1992-born cows), then the means increased at a decreasing rate before peaking in 2001 when the 1992 and 1993 born cows were 9 and 8-year old, respectively, with means of 38.22 and 38.46 kg, after which they decreased gradually. Note that the calves born after 2003 were sired by Angus bulls while those born from 1996 to 2003 were sired by *Bos indicus* influenced bulls. This observation is consistent with the findings of Roberson et al. (1986) who observed that birth weight increased as the result of the increase of dam age up to 7 years of age and declined gradually for older dams and those by McCarter et al. (1991) who reported significant increases in birth weight as the effect of the increase of dam age from 3 to 5 years.

A significant interaction (P = 0.003) between dam breed of dam and calf's birth year / age of dam was found and is illustrated in Figures 11 and 12, respectively, for the groups of cows born in 1992 and 1993. In the group of cows born in 1992, the lowest adjusted means in calves born to cows out of both Angus and Hereford dams (29.46 and 28.10 kg, respectively) were observed in 2006 when the F1 cows were 14-years old, whereas the peak was observed in 2001when the F1 cows were 9 year-old in calves born to cows out of both Angus and Hereford dams (38.21 and 38.23 kg, respectively). In the group of cows born in 1993, the lowest values were observed in 2006 for calves out of cows that were out of Angus dams (28.63 kg) and in 1995 for calves born to cows out of Hereford dams (30.15 kg) similar to those of calves born to cows out of Angus dams the same year (30.17 kg). Note that sire of calf was partially confounded with year of calf's birth.

Table 9. Least squares means (LSM) and standards errors (SE) for birth weight by dam breed of dam by calf's gender interaction.

	LSM ± SE, kg	n
Female x Angus	$33.21^{a} \pm 0.41$	280
Male x Angus	$36.41^{c} \pm 0.41$	255
Female x Hereford	$34.32^{b} \pm 0.36$	336
Male x Hereford	$35.68^{c} \pm 0.36$	356

$^{a, b, c}$ Least squares means in the same column without common superscript differ ($P < 0.05$).

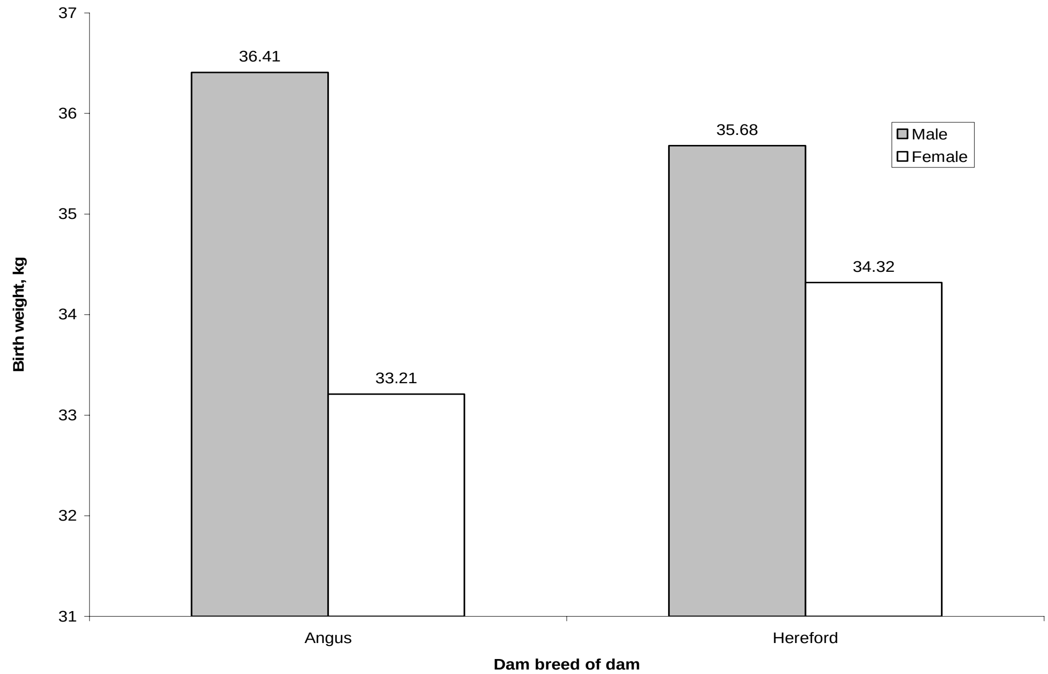

Figure 9. Least squares means for birth weight by dam breed of dam x gender of calf interaction

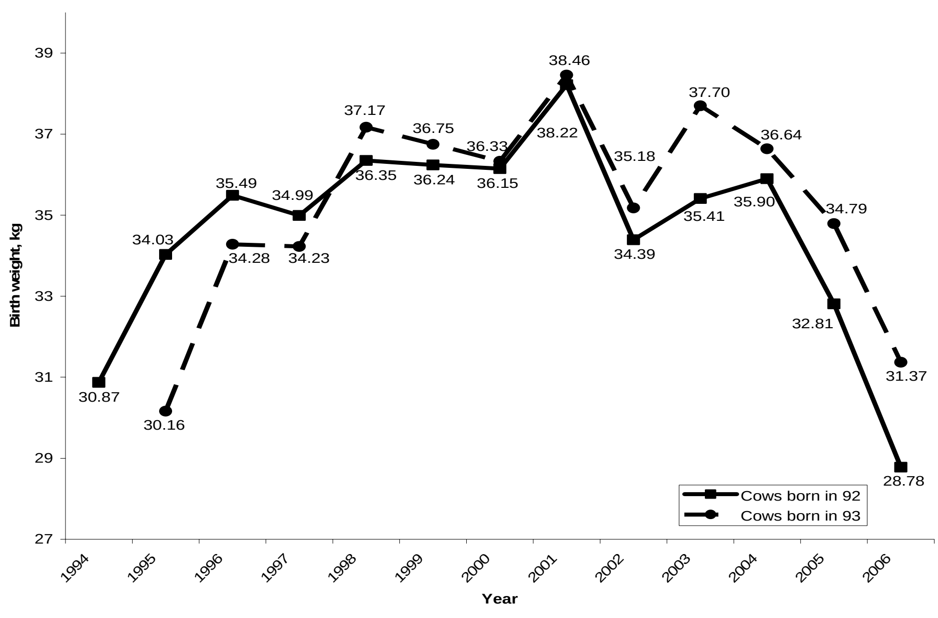

Figure 10. Least squares means for birth weight by year in cows born in 1992 and 1993

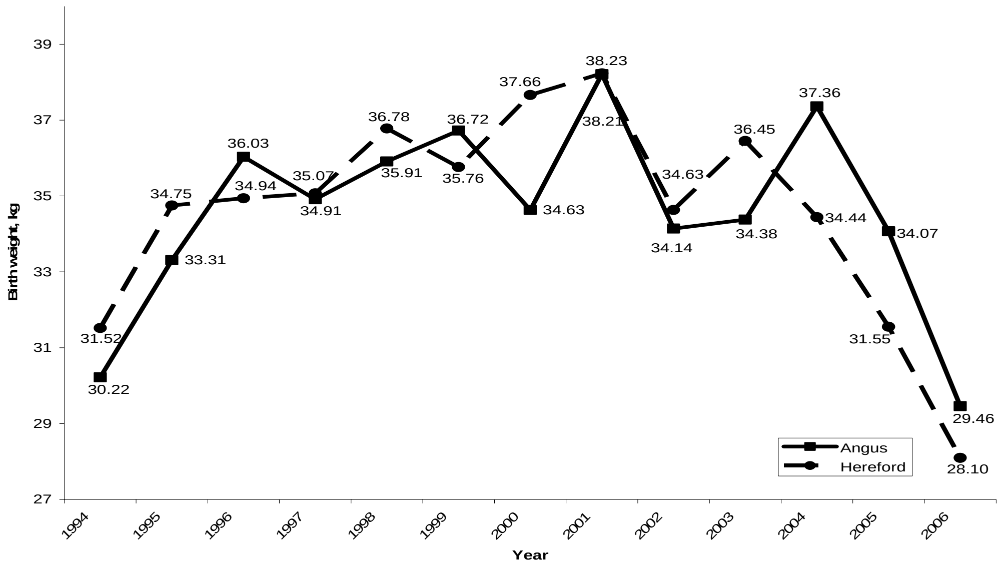

Figure 11. Least squares means for birth weight by dam breed of dam x birth year of calf / age of cow interaction in cows born in 1992

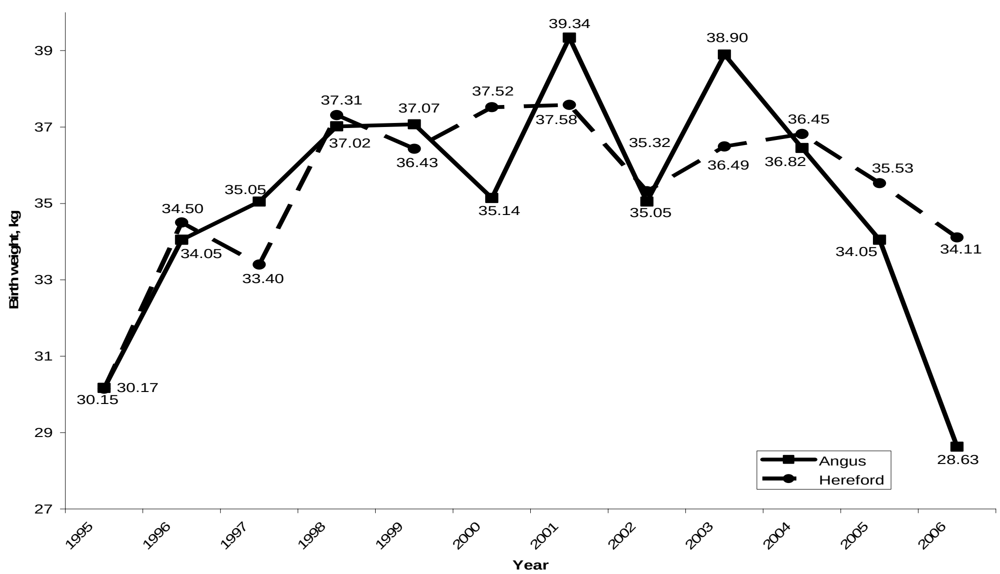

Figure 12. Least squares means for birth weight by dam breed of dam x birth year of calf / age of cow interaction in cows born in 1993

Calf crop weaned

Table 10 gives the adjusted values of calf crop at weaning by sire breed of dam and calf's birth year / age of dam. Sire breed of dam was not significant (P = 0.131), even though a numerical difference of 0.05 was observed between the Boran- (0.898) and Brahman-sired cows (0.848), with Tuli-sired cows (0.869) having intermediate values. The same rankings and lack of significance were observed in the analyses by Cunningham (2005), with rates of 0.887, 0.857 and 0.834 through 11 and 12 years of age and by Ducoing Watty (2002), with rates of 0.874, 0.837 and 0.808 through 8 and 9 years of age, respectively, for Boran-, Tuli- and Brahman-sired F1 cows. In Africa, Hetzel (1988) reported weaning rates of 63, 68 and 82%, respectively, for straightbred Brahman, Tuli and Boran. The Boran was evaluated in Zambia, wheareas, both Brahman and Tuli were evaluated in Botswana.

Birth year of calf / age of dam was an important source of variation (P < 0.001) for calf crop weaned, and the pattern of this source of variation is illustrated by Figure 13. The adjusted means followed the same trend as those observed by pregnancy rate and calf crop born. In Figure 13 it is seen that cows born in 1992 showed a significant drop (0.564) for this variable in 1995 at 3 years of age, while those born in 1993 recorded their lowest crop of calf weaned in 1997 as 4-year old cows. Both the group of cows born in 1992 and in 1993 showed their highest value for crop of calf weaned in 2005, with adjusted values of 1.001 and 1.000 respectively. The same trends were observed by Ducoing Watty (2002) and Cunningham (2005) when the F1 cows were 9-10 and 11-12 years of age, respectively.

Table 10. Least squares means (LSM) and standards errors (SE) for calf crop weaned by sire breed of dam and calf's birth year/age of dam.

	LSM ± SE	n
Sire breed of dam		
Brahman	0.848 ± 0.016	491
Boran	0.898 ± 0.019	343
Tuli	0.869 ± 0.016	460
Calf's birth year/age of dam		
1994/2	0.913 ± 0.042	66
1995/2	0.731 ± 0.039	77
1995/3	0.564 ± 0.042	66
1996/3	0.855 ± 0.040	74
1996/4	0.711 ± 0.042	65
1997/4	0.712 ± 0.040	72
1997/5	0.879 ± 0.043	64
1998/5	0.946 ± 0.041	69
1998/6	0.907 ± 0.043	62
1999/6	0.847 ± 0.041	70
1999/7	0.823 ± 0.044	61
2000/7	0.889 ± 0.044	61
2000/8	0.925 ± 0.047	52
2001/8	0.896 ± 0.046	56
2001/9	0.936 ± 0.051	45
2002/9	0.911 ± 0.046	54
2002/10	0.959 ± 0.051	45
2003/10	0.924 ± 0.048	50
2003/11	0.902 ± 0.054	40
2004/11	0.934 ± 0.051	44
2004/12	0.878 ± 0.059	33
2005/12	1.001 ± 0.053	41
2005/13	1.000 ± 0.066	27

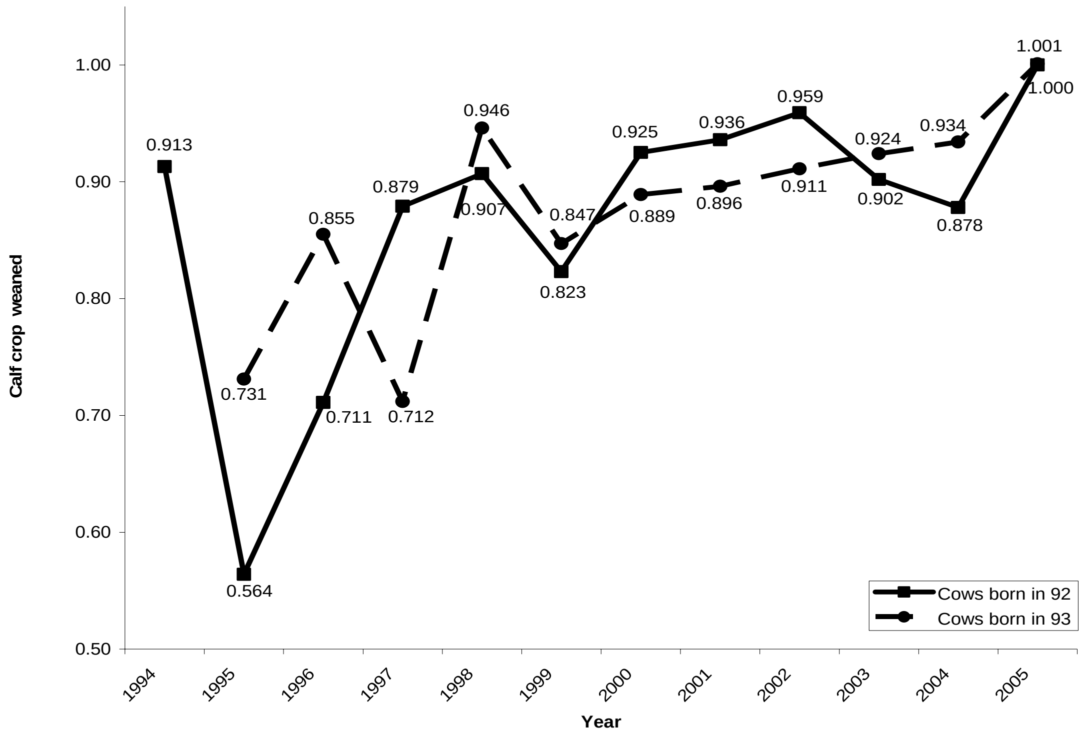

Figure 13. Least squares means for calf crop weaned by year in cows born in 1992 and 1993

Weaning weight

The adjusted means for weaning weight by sire breed of dam, gender of calf and calf's birth year / age of dam are presented in Table 11.

Significant differences ($P < 0.001$) were observed among the paternal breeds of the F1 cows being evaluated, with calves born to Brahman-sired cows (235.87 kg) being heavier at weaning than those born to Boran- (221.10 kg) and Tuli-sired cows (208.35 kg). These adjusted means are similar to those obtained by Cunningham (2005) at an earlier phase of this study with means of 233.4, 220.1 and 208.2 kg, respectively, but slightly higher than those of Ducoing Watty (2002) with values of 229.6, 214.6 and 200.4 kg for calves out of Brahman-, Boran- and Tuli-sired F1 cows. Herring et al. (1996) obtained means of 243.3, 217.1 and 209.1 kg, respectively, in F1 calves sired by Brahman-, Boran- and Tuli-sired bulls.

As in the case of birth weight, calf's gender accounted for variation in weaning weight, with female calves (215.11 kg) being significantly lighter ($P < 0.001$) than male calves (228.52 kg). The same observations were reported by Ducoing Watty (2002) and Cunningham (2005) in the calves out of the F1 cows of the current study. Herring et al. (1996) reported a difference of 14.7 kg in weaning weight between steer and heifer F1 calves in the early stage of this study.

Table 11. Least squares means (LSM) and standards errors (SE) for weaning weight by sire breed of dam, calf's gender, and calf's birth year/age of dam.

	LSM ± SE, kg	n
Sire breed of dam		
Brahman	235.87[a] ± 2.34	405
Boran	221.10[b] ± 3.07	302
Tuli	208.35[c] ± 2.70	394
Calf's gender		
Female	215.11[a] ± 1.75	554
Male	228.52[b] ± 1.74	547
Calf's birth year / age of dam		
1994/2	187.92 ± 3.02	60
1995/2	207.81 ± 3.17	56
1995/3	217.49 ± 9.01	37
1996/3	190.50 ± 3.11	63
1996/4	205.67 ± 3.15	47
1997/4	227.18 ± 4.54	50
1997/5	232.85 ± 3.27	56
1998/5	237.92 ± 3.81	65
1998/6	230.53 ± 4.12	55
1999/6	236.72 ± 3.02	59
1999/7	233.37 ± 3.77	50
2000/7	207.02 ± 4.13	54
2000/8	207.48 ± 5.26	48
2001/8	227.99 ± 3.52	50
2001/9	218.09 ± 4.35	42
2002/9	230.19 ± 3.04	49
2002/10	223.13 ± 3.38	43
2003/10	225.86 ± 3.79	46
2003/11	217.87 ± 3.98	35
2004/11	231.64 ± 3.96	41
2004/12	228.54 ± 6.81	29
2005/12	244.71 ± 3.25	39
2005/13	231.26 ± 3.91	27

[a, b, c] Least squares means in the same column without common superscript differ ($P < 0.05$).

The estimates of weaning weight by sire breed of dam x gender of calf interaction are presented in Table 12. This interaction was a significant source of variation (P = 0.030) on weaning weight. The pattern of the adjusted means for this interaction is shown in Figure 14. By contrasting steer and female calves within sire breed of dam, the difference between genders was 17 kg between male and female calves out of Brahman-sired cows, while it was about 11 kg in those born to Boran- and Tuli-sired cows. This difference was also observed by Ducoing Watty (2002) who found differences between bull and heifer calves to be 10 kg in Brahman-sired cows, while it was about 8 kg between male and female calves out of Boran-sired cows.

Unlike other variables analyzed in this study, calf's birth year / age of dam was not important (P = 0.205) in explaining the differences in weaning weight. Nonetheless, Figure 15 shows that in the same year, calves out of cows born in 1992 were only heavier in 1995, 1996 and 1997 than those out of cows born in 1993. McCarter et al. (1991) found weaning weight to increase from 226 to 237 kg, as a result of an increase of dam age from 3 to 5 years.

The interaction of sire breed of the cow by birth year /age of the cow was involved (P = 0.002) in explaining the variability in weaning weight. The adjusted means of this interaction are presented in Figures 16 and 17 respectively for the groups of cows born 1992 and 1993. In the group of cows born in 1992, across years, the calves out of Brahman-sired cows were always heavier than those out Boran-sired cows, which in turn were always heavier than those born to Tuli-sired cows. The difference between the calves out of the Brahman-sired cows and those out of Boran-sired cows tended to be larger in the years when the averages were higher. In the group of cows born in 1993, the same trends were observed as in the group of cows born in 1992, except for 1997 when the calves born to Tuli-sired cows were heavier than those born to Boran-sired cows, and in 2003 when calves born to Brahman-sired cows were lighter than those born to Boran-sired cows.

Calf's birth year / age of dam by gender of calf interaction was found to be an important source of variation ($P < 0.001$) on weaning weight. The pattern for this interaction is shown in Figures 18 and 19, respectively, in the groups of cows born in 1992 and 1993. Except for the year 1994 in the calves out of the group of cows born in 1992, bull calves were heavier than heifer calves. Similarly Ducoing Watty (2002) found that in all years for both group of cows, male calves were heavier than female calves, except for the first weaning season for cows born in 1992, and the second weaning season for cows born in 1993.

Weaning age nested within calf's birth year / age of dam had a significant effect ($P < 0.001$) on the weight at weaning. The regression coefficients and standard errors of weaning weight on weaning age within year / age of dam are presented in Table 13. These coefficients ranged from 0.234 to 1.128 kg/d. Cunningham reported coefficients ranging from 0.217 to 1.080 kg/d when the dams of these calves were 11 and 12 years old.

Table 12. Least squares means (LSM) and standard errors (SE) for weaning weight by sire breed of dam by calf's gender interaction.

	LSM ± SE, kg	n
Female x Brahman	$227.13^{a} \pm 2.50$	209
Male x Brahman	$244.60^{b} \pm 2.53$	196
Female x Boran	$215.64^{c} \pm 3.27$	141
Male x Boran	$226.57^{a} \pm 3.23$	161
Female x Tuli	$202.56^{d} \pm 2.88$	204
Male x Tuli	$214.38^{c} \pm 2.84$	190

[a, b, c, d] Least squares means in the same column without common superscript differ ($P < 0.05$).

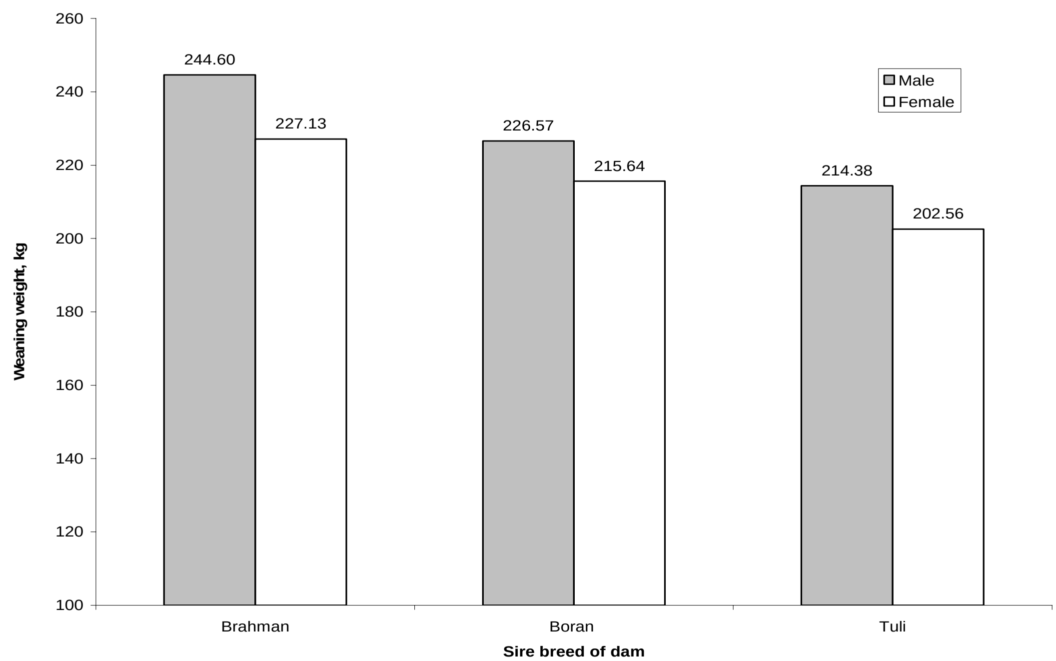

Figure 14. Least squares means for weaning weight by sire breed of the cow x gender of calf interaction

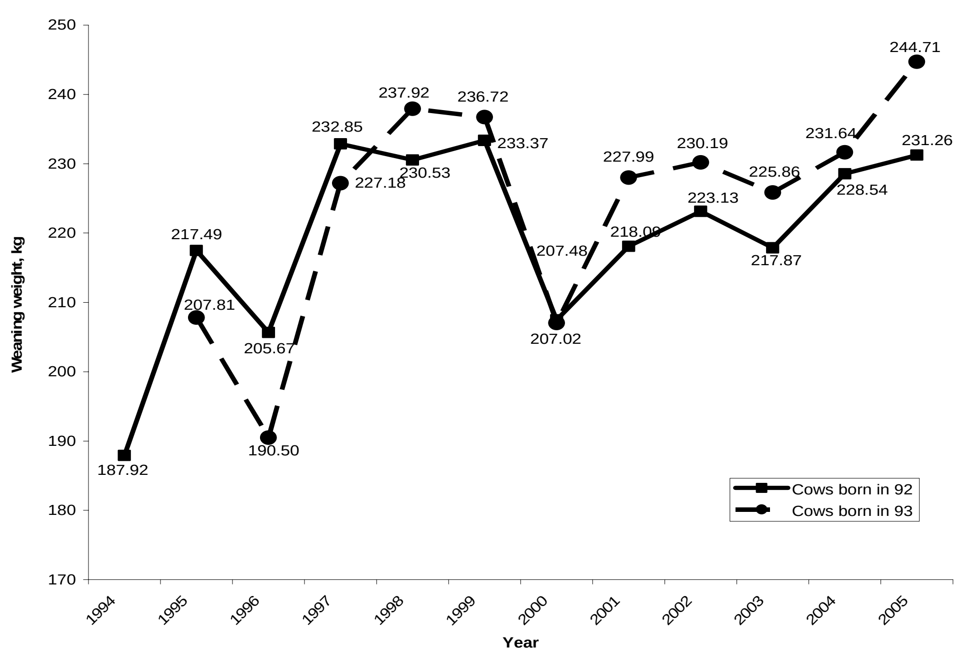

Figure 15. Least squares means for weaning weight by year in cows born in 1992 and 1993

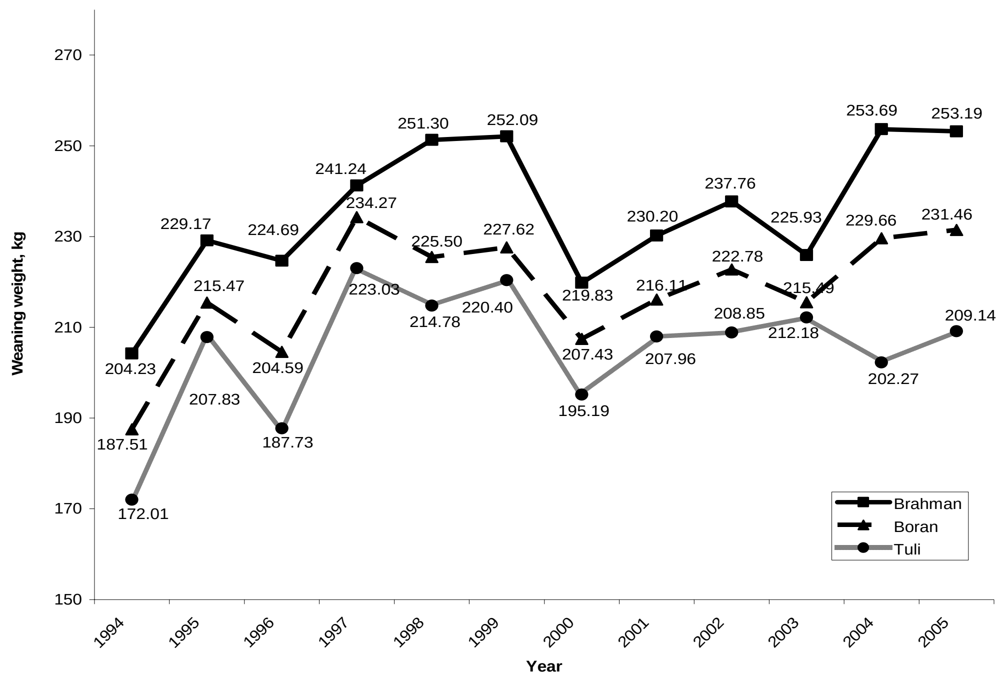

Figure 16. Least squares means for weaning weight by sire breed of cow x birth year of the calf / age of cow interaction in cows born in 1992

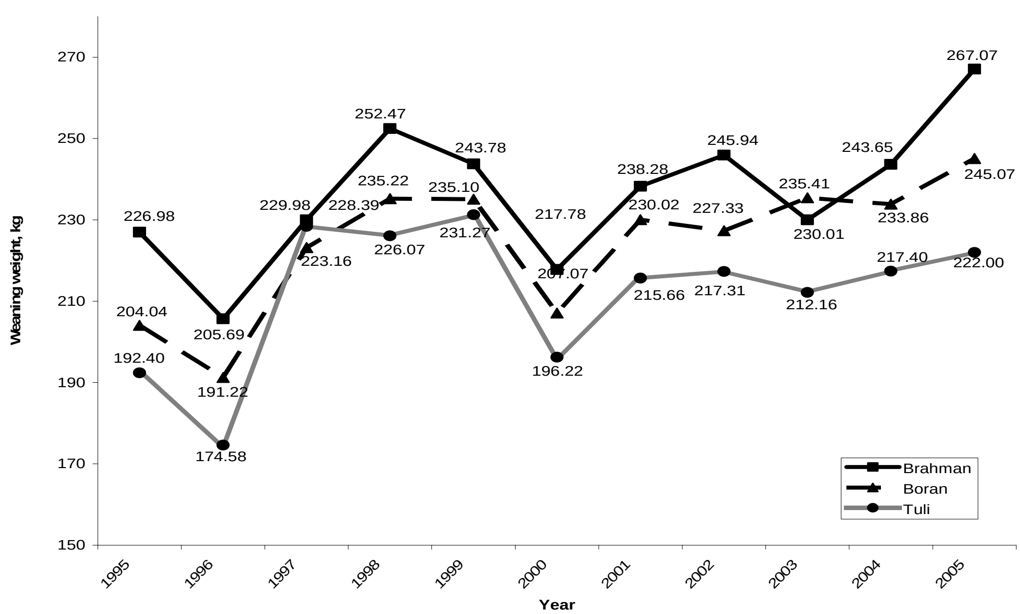

Figure 17. Least squares means for weaning weight by sire breed of cow x birth year of the calf / age of cow interaction in cows born in 1993

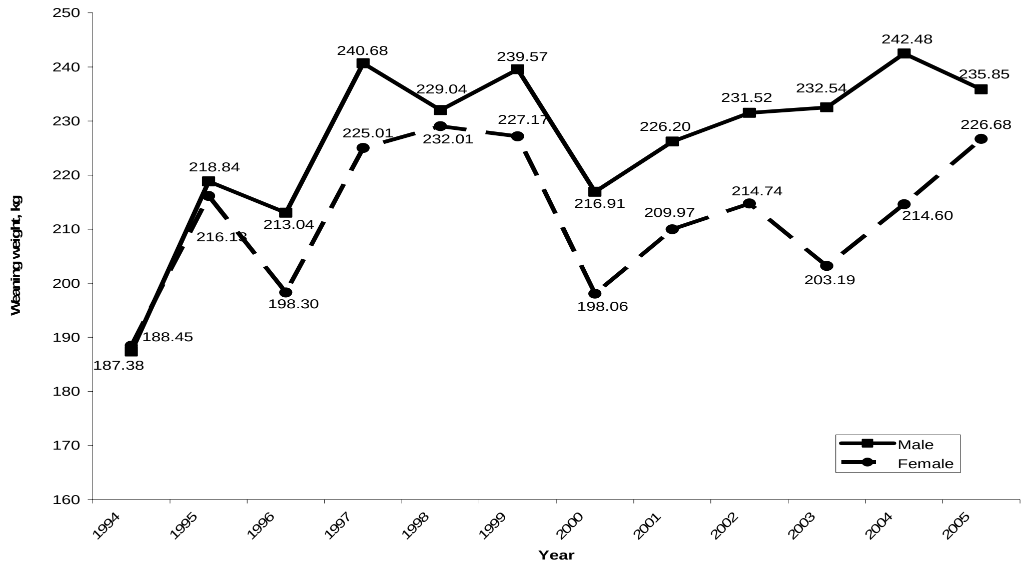

Figure 18. Least squares means for weaning weight by gender of calf x birth year of the calf / age of cow interaction in cows born in 1992

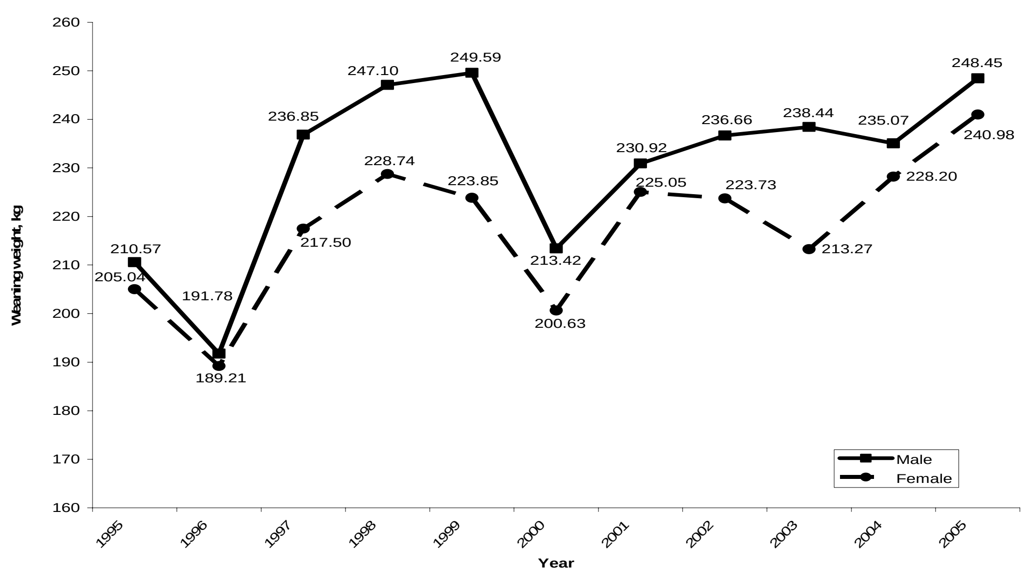

Figure 19. Least squares means for weaning weight by gender of calf x birth year of the calf / age of cow interaction in cows born in 1993

Table 13. Regression coefficients (b) and standards errors (SE) of weaning weight on weaning age within calf’s birth year / age of dam.

	b ± SE, kg/d (year/age)	n
Calf's birth year / age of dam		
1994/2	0.690 ± 0.156	60
1995/2	0.584 ± 0.133	56
1995/3	0.689 ± 0.177	37
1996/3	0.719 ± 0.110	63
1996/4	0.627 ± 0.132	47
1997/4	0.804 ± 0.169	50
1997/5	1.128 ± 0.174	56
1998/5	0.745 ± 0.117	65
1998/6	0.484 ± 0.152	55
1999/6	1.090 ± 0.152	59
1999/7	0.843 ± 0.204	50
2000/7	0.790 ± 0.150	54
2000/8	0.600 ± 0.187	48
2001/8	1.027 ± 0.154	50
2001/9	1.015 ± 0.220	42
2002/9	0.525 ± 0.196	49
2002/10	0.686 ± 0.171	43
2003/10	0.884 ± 0.162	46
2003/11	0.614 ± 0.142	35
2004/11	0.889 ± 0.161	41
2004/12	0.234 ± 0.334	29
2005/12	1.111 ± 0.166	39
2005/13	0.690 ± 0.214	27

SUMMARY AND CONCLUSIONS

Cow weight and cow body condition score at palpation, mouth score, pregnancy rate, calf crop born, and calf crop weaned of the cows and birth weight and weaning weight of their calves were evaluated in F1 cows sired by Brahman, Boran and Tuli bulls. These traits that represent maternal and reproductive performance and cow longevity were investigated on these three breeds in order to assess the differences among them on these aspects of cow productivity.

Significant differences ($P < 0.001$) among sire breeds were found for cow weight at palpation, with Brahman-sired cows (600.8 kg in 2000, when the cows were either eight or nine years of age) heavier than those sired by Boran and Tuli bulls (514.6 and 513.1 kg, respectively). The sire breed of dam by dam breed of dam interaction was also significant ($P = 0.044$). In both Brahman- and Boran-sired cows, those out of Angus dams (533.68 and 462.61 kg, respectively, averaged across ages from 1.5 to 13.5 years) were heavier than those out of Hereford dams (512. 22 and 450 kg, respectively, for Brahman- and Boran-sired cows). However, in Tuli-sired cows, those born to Hereford dams (457.02 kg) were heavier than those out of Angus dams (444.78 kg). Birth year / age of dam was also a significant source of variation ($P < 0.001$). As yearling heifers, the adjusted values of the group of cows born in 1993 were higher (305.88 kg) than those born in 1992 (277.13 kg). However, as two-year old heifers, in 1994 and 1995 and from 1998 to 2005, within the same year, the differences between the 2 groups were of small magnitude. The interaction of year / age of dam x sire breed of dam was also significant

(P < 0.001). However, within the same year, in both groups, Brahman-sired females had the highest adjusted means compared to the Boran-and Tuli-sired females.

Higher body condition scores (P < 0.001) were assigned to the Boran-sired cows (5.48) compared to the Brahman- and Tuli-sired cows (5.23 and 5.18, respectively). Year / age of cow affected (P < 0.001) cow condition score. In both group of cows, condition score fluctuated from one year to the next year. These fluctuations might be explained by the availability of nutritional resources, which is dependent upon environmental conditions such as the rainfall.

The assignment of mouth scores revealed the effect of sire breed of the cow to be important. In the first model where both broken and solid mouths were assigned a value 1 and smooth mouths were assigned a value of 0, Boran- and Brahman-sired cows (0.95 and 0.94 respectively) showed higher scores (P < 0.020) than Tuli-sired cows (0.78), while in the second model where both smooth and broken mouth were assigned a value of 0 and solid a value of 1, Brahman crosses (0.53) had significantly higher mouth scores (P < 0.052) than Tuli crosses (0.24), and the Boran crosses (0.34) had intermediate values. Year / age of cow also had an important effect (P = 0.048) on mouth scores in this first model. Cows born in 1992 showed similar values across the two years, but not statistically different from those born in 1993. On the other hand, cows born in 1993 were assigned different scores across the two years, with the 13-year old cows averaging higher adjusted values (1.01) than the 12 year-old cows (0.78). Note that the scoring system differed between the two years. Also, in the second model, year / age of cow was important (P = 0.01). Both groups of cows were scored the same value (0.51) in 2004, significantly higher than the 12-year old cows scored in 2005, while the 13-year old cows in this year (2005) were intermediate. The sire of cow breed by calf's birth year / age of dam interaction was important (P = 0.026) only for the second model with the highest score assigned to the 12-year old Boran-sired cows in 2004, while the lowest values were assigned to the 13-year old Boran-sired cows in 2005 (i.e., the same cows).

In the analysis of pregnancy rate, no significant differences were found among the sire breeds of the cows evaluated. Nevertheless, the Boran-sired females had the highest adjusted mean (0.955) followed by the Tuli- and Brahman-sired females (0.936 and 0.922, respectively). However, birth year / age of the cow was found to be a significant source of variation (P < 0.001) on pregnancy rate. The group of cows born in 1992 showed a significant drop in pregnancy rate in their second season (0.591) compared to their first season (0.940). The cows born in 1993 had adjusted means of 0.899 and 0.949, respectively, in their first and second seasons, and then showed a decrease in their third season (0.784), before fluctuating across years.

Similarly to pregnancy rate, the effect of sire breed of dam was not important on calf crop born. Following the same trend as for pregnancy rate, the Boran-sired cows averaged the highest value (0.9427) for calving rate followed by the Tuli- and Brahman-sired cows (0.9197 and 0.9067, respectively). Significant differences (P < 0.001) due to year / age of dam were found for this variable. The group of cows born in 1992 observed a remarkable drop in their rate of calf crop born during their second potential parity (from 0.942 in 1994 to 0.579 in 1995) and then increased gradually until 1998 and fluctuated slightly across years up to 2006. The cows born in 1993 with mean values of

0.875 and 0.911, respectively, in their first and second calving seasons, dropped to 0.731 in 1997 and increased to 0.975 the following year and then fluctuated across years up to 2006.

No significant differences were attributed to the sire breed of dam for birth weight, although calves born to Brahman-sired cows ranked heaviest (35.08 kg) followed by those born to Tuli- (34.87 kg) and Boran-sired cows (34.76 kg). Differences between genders were about 2.28 kg between bull calves (36.05 kg) and heifer calves (33.77 kg).

The interaction of dam breed of dam by sex of calf interaction was important ($P < 0.001$) in explaining the variation in birth weight. The bull calves born to cows out of Angus dam (36.41 kg) were 3.20 kg heavier than the heifer calves (33.21 kg), whereas the bull calves born to cows out of Hereford dam (35.68 kg) were only 1.36 kg heavier than the heifer calves (34.32 kg). The calf birth year / age of dam was important ($P < 0.001$) for birth weight. In both groups of cows, the adjusted means for birth weight were the lowest for the first-calf heifers at two years of age (except in 2004 in the 1992-born cows); the peak was observed in 2001 when the 1992 and 1993-born cows were 9 and 8-year old, respectively, with means of 38.22 and 38.46 kg. Within the same year, from 1995 to 1997, the calves out of the group of cows born in 1992 were the heaviest, and from 1998 to 2006 those out the group born in 1993 were the heaviest. The interaction between dam of dam breed and calf's birth year / age of dam also accounted ($P = 0.003$) for variability in birth weight.

The effect of the sire breed of the cow was not significant (P = 0.131) on calf crop weaned, although the Boran-sired cows (0.898) ranked higher by the difference of 0.05 than the Brahman-sired cows (0.848), and the Tuli-sired cows had the intermediate value of 0.869. Year/age of dam affected (P < 0.001) the rate of weaned calves. Similarly to pregnancy rate and calf crop born, the group of cows born in 1992 showed a significant drop (0.564) for this variable in 1995 at 3 years of age, while those born in 1993 recorded their lowest rate of calf weaned in 1997 as 4-year old cows. Both groups of cows, born in 1992 and 1993, showed their highest value for the rate of calf crop weaned in 2005, with adjusted values of 1.001 and 1.000, respectively.

The analysis of weaning weight revealed significant differences (P < 0.001) among the paternal breed of the F1 cows being evaluated, with calves born to Brahman-sired cows (235.87 kg) being heavier at weaning than those born to Boran- (221.10 kg) and Tuli-sired cows (208.35 kg). Similarly to birth weight, calf's gender contributed to the variation in weaning weight, with male calves (228.52 kg) being heavier (P < 0.001) than female calves (215.11 kg).

Sire breed of dam by calf's gender interaction was also a significant source of variation (P = 0.030) on weaning weight. The difference between genders was 17 kg between male and female calves out of Brahman-sired cows, while it was about 11 kg in those born to Boran- and Tuli-sired cows.

The effect of calf's birth year / age of dam was not important (P = 0.205) in explaining the variability in weaning weight. However, the interaction of the sire breed of the cow by birth year /age of the cow contributed (P = 0.002) to the variation in weaning weight. In the group of cows born in 1992, across years, the calves out of Brahman-sired cows were always heavier than those out Boran-sired cows, which in turn were always heavier than those born to Tuli-sired cows. In the group of cows born in 1993, the same trends were observed as in the group of cows born in 1992, except for 1997 when the calves born to Tuli-sired cows were heavier than those born to Boran-sired cows, and in 2003 when calves born to Brahman-sired cows were lighter than those born to Boran-sired cows.

The interaction of calf's birth year / age of dam by gender of calf was significant ($P < 0.001$) for weaning weight. Except for the year 1994 in the calves out of the group of cows born in 1992, bull calves were heavier than heifer calves. Finally, weaning age nested within calf's birth year / age of dam had a significant effect ($P < 0.001$) on the weight at weaning. The regression coefficients ranged from 0.234 to 1.128 kg/d.

The results of this study indicate the advantages in terms of reproductive rates of the Boran-sired cows over those sired by Brahman and Tuli bulls. On the other hand, Brahman-sired cows weaned heavier calves than the two other dam breeds; this can partially offset their lower reproductive abilities. However, Brahman-sired cows were about 85 kg heavier at maturity than the two other breeds evaluated. The moderate size of the Boran- and Tuli-sired females could be a management advantage in a production system where nutritional availability is limited and would result in lower maintenance requirements. Thus, they could be considered as alternatives to Brahman for cow-calf producers under climatic condition where heat adaptation is needed, but still maintaining high reproductive capabilities. However, the lower incisors condition of Tuli-sired cows as they aged might be an obstacle to harvest forage and maintain an adequate body condition, which are essential to a long productive life.

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