EVALUATION OF HETEROSIS AND HETEROSIS RETENTION IN *BOS TAURUS -BOS INDICUS* CROSSBRED CATTLE FOR PRODUCTIVITY TRAITS IN COWS

A Thesis

by

MEREDITH CHRISTINE MEUCHEL

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

August 2005

Major Subject: Animal Breeding

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Approved by:

Chair of Committee,	James O. Sanders
Committee Members,	Andy D. Herring
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Head of Department,	Gary Acuff

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ABSTRACT

Evaluation of Heterosis and Heterosis Retention in *Bos taurus-Bos indicus* Crossbred Cattle for Productivity Traits in Cows. (August 2005)

Meredith Christine Meuchel, B.S., Montana State University

Chair of Advisory Committee: Dr. James O. Sanders

Reproductive and weight traits were analyzed for Angus (A), Brahman (B), Hereford (H), and Nellore (N) straightbred cows; F_1 NA cows; 3/8N 5/8A cows and quarter blood composite cows (BANH) of the four straightbreds in Central Texas. Heterosis was estimated for calf crop born (CCB), calf crop weaned (CCW), and calf survival (CS) by linear contrasts within cow breed groups. F_1 NA cows expressed heterosis ($P < 0.0001$) for CCB (0.22) and CCW (0.20). Except for the 3/8N $5/8A_c$ cows, which resulted from the mating of NA bulls to 3/4A 1/4N cows, all of the crossbred cow breed types expressed significant heterosis ($P < 0.05$) when compared to the weighted average of the parental purebreds for CCB. $BANH_c$ cows that were the result of mating NA bulls to HB cows expressed heterosis for CCB (0.35) ($P < 0.001$) and CCW (0.29) ($P < 0.05$). The 3/8N $5/8A_a$ females produced by mating 3/4N 1/4A bulls to NA cows expressed heterosis ($P < 0.0001$) for CCW (0.20). Heterosis for calf survival was near zero for all breed types, but only two breed types of 3/8N 5/8A cows were significantly greater than the weighted average of the parental purebreds. Heterosis for birth weight (BWT) and weaning weight (WWT) was also analyzed by linear

contrasts within cow breed groups. The $BANH_b$ and $BANH_c$ cows produced from mating NA bulls to BH and HB F_1 cows, respectively, expressed heterosis for BWT (2.89 $\pm$ 0.79 ($P < 0.001$) and 3.38 $\pm$ 1.51 ($P < 0.05$)). All cow breed types expressed significant heterosis ($P < 0.05$) for WWT. The $BANH_2$ cows resulting from the mating of NA bulls to F_2 HB or BH cows expressed heterosis ($P < 0.0001$) for WWT (52.01 kg $\pm$ 9.88).

ACKNOWLEDGMENTS

I would like to express my appreciation and gratitude to my committee chair, Dr. Sanders, and my committee members, Dr. Herring and Dr. Speed, who gave me support, guidance, and answers to my many questions from the moment I came to Texas A&M University. I would also like to thank my friends, near and far, colleagues, students and other faculty and staff at Texas A&M University. Their willingness to listen and then give needed advice and encouragement has made my experience here at A&M one that will never be forgotten.

A special thanks goes to my family. Their unwavering patience, support, and love provided me with the strength to achieve this great accomplishment. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

Page

INTRODUCTION

Heterosis is an increase in performance of crossbred animals over that of their straightbred parents. It is associated with increased heterozygosity and the degree of dominance expressed by genes. Heterosis affects traits such as fertility and the number of calves born and weaned compared to the number of cows exposed to bulls during the breeding season. It can also affect traits of the calf such as birth and weaning weight, which reflects on the performance of the cow, due to uterine environment and milk production. Although the highest levels of heterosis are seen in the F_1 (100%), heterosis can be retained to an extent in later generations. It can be predicted by the dominance model, assuming that hybrid vigor is proportional to the degree of retained heterozygosity.

Crossbreeding among cattle breeds, and thus creating heterosis, is used to increase production in the beef cattle industry. Many crossbreeding systems are very hard to implement in smaller herds, and unfortunately a large majority of the US beef cattle herds are smaller than 50 cows. Cow-calf operations could have the potential to take advantage of heterosis by utilizing composite breeds. A composite is a breed made up of a crossbred foundation and has the potential to benefit from hybrid vigor retained in later generations. Composites can be maintained in smaller herds due to their simplicity of management and, if inbreeding is avoided, can retain high levels of hybrid vigor (Gregory et al., 1999). The breeds of cattle used can be of the same species, such

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as Angus and Hereford, or a cross of *Bos taurus* x *Bos indicus* where, when crossed, a greater amount of heterosis is expected due to the fact that their genes differ at more loci than between two *Bos taurus* breeds or two *Bos indicus* breeds. The *Bos taurus* x *Bos indicus* cross benefits from traits seen in both species, such as heat tolerance and maternal effects of the *Bos indicus* and carcass qualities seen in some *Bos taurus* breeds.

LITERATURE REVIEW

Hybrid vigor, or heterosis, has been shown to increase the performance of cattle and their offspring. Heterosis is an increase in performance of crossbred animals over that of their straightbred parents and is affected by homozygous or heterozygous genes and the degree of dominance expressed by those genes. The effects of crossbreeding among *Bos taurus* breeds, *Bos indicus* breeds and between the two have provided the potential for increased performance of cattle in the United States (US) beef industry. Use of composite breeds may also increase performance of cattle in the industry.

King and Stansfield (2002) stated that heterosis is associated with increased heterozygosity. Traits that are most noticeably affected by heterosis are fertility and survivability (King and Stansfield, 2002). Gregory and Cundiff (1980) stated that heterosis obtained by continuous crossbreeding increases the weaning weights of calves per cow exposed to breeding by 20%. Heterosis retention is the hybrid vigor that is expressed in later generations of crossbred animals, either in rotations or composite populations. The term F_1 refers to the first cross between two unrelated populations (Bourdon, 2000). The F_1 crosses have one allele from each of the two parent breeds at 100% of their gene pairs. To the extent that the parent breeds differ genetically, those gene pairs will be heterozygous. Bourdon (2000) also states “the more unrelated two breeds or lines are, the greater the hybrid vigor expected in crosses between them.” Breeds that are more alike, for example, the Hereford and Angus, can be expected to express less heterosis. Since Hereford and Angus are the same species they will have more genes in common compared to a cross of Nellore and Angus.

A composite breed is a breed of cattle made up of two or more foundation breeds that even in advanced generations can expect to benefit from hybrid vigor. Gregory et al. (1999) concluded that composite breeds can be simply managed and still retain high levels of heterosis if inbreeding is avoided. Composites make use of breed complementarity and have uniformity from one generation to the next, as in straightbreds. Results from most studies indicate that a composite of *Bos taurus* breeds will retain levels of heterosis that are consistent with expected heterozygosity.

Discussion of the Breeds of Cattle Used in the Study

Angus and Hereford cattle are both *Bos taurus* beef cattle breeds utilized in the US. Angus are a general all-purpose breed, originally from Scotland, that are moderate in frame size. They are known for their maternal characteristics, such as milking ability, as well as their above average carcass qualities like marbling. The Hereford, originally from England, is larger framed than the Angus, but less muscular. Herefords produce less milk, but are efficient in production. They are also very hardy, being able to withstand cold winters and hot, humid summers. (Oklahoma State University Website)

Brahman cattle are a *Bos indicus* breed developed in Texas from four Asian Zebu breeds: Gir, Guzerat, Indu-Brazil, and Nellore. Brahmans are large framed with a hump over the shoulder. They have high maternal abilities, including high levels of milk production. The Nellore, called Ongole in India, is also a *Bos indicus* breed of cattle. In India, the Nellore is a dual-purpose breed, providing milk and used as a heavy draft animal (Sanders, 1980). While the Nellore resembles the Brahman by having a hump, they don’t have as large of ears. Both the Nellore and Brahman are able to thrive in the heat and humidity of tropical and subtropical regions, as seen in the Gulf Coast area of the US. (Oklahoma State University Website)

Cundiff et al. (1998) evaluated birth weight, weaning weight at 200-days, gestation length, calf crop weaned, and unassisted calving percentage in calves from matings of Angus, Hereford, Nellore, Longhorn, Galloway, Shorthorn, Pinzgauer, Gelbvieh, Charolais, Piedmontese, and Salers bulls to Angus and Hereford dams from Cycle IV of the GPE (Germ Plasm Evaluation) program. Nellore-sired calves had one of the heaviest average birth weights (40.4 kg), which corresponded to a weaning weight of 229.7 kg, which was 2 kg lighter than the Charolais cross average. Cundiff et al. (1998) stated "breed differences can generally be exploited to optimize performance levels in crosses or in composite populations relatively more quickly than performance can be optimized by intrapopulation selection".

Riley et al. (2001) evaluated reproductive, maternal and size traits on cows sired by *Bos taurus* and *Bos indicus* bulls in central Texas. Cows were sired by Angus, Nellore, Gir, Indu-Brazil, and Gray and Red Brahman bulls and out of Hereford dams. The authors reported that the Gir and Nellore crossbred cows produced calves that had the lowest adjusted birth weights compared to the Angus, Indu-Brazil, and Red and Gray Brahman crossbred cows. Angus crossbred cows had the highest adjusted birth weights and the lowest adjusted weaning weights. Calves from Nellore crossbred cows had one of the highest average adjusted weaning weights compared to the other crossbred dams. The highest rates ($P < 0.10$) of calf crop born were 97.1 and 95.6% for the Nellore and Gray Brahman-sired cows, respectively. Nellore-sired cows had the highest calf crop weaned at 96.1% ($P < 0.05$), which corresponded to the highest calf survival rate of 98.9% (Riley et al., 2001). Angus-sired cows were among the lowest for calf survival rates as heifers. Gir-sired cows were second highest at 91.5% calf crop weaned. Sanders et al. (2005a) reported cow productivity, carcass, birth, and growth traits in calves out of Hereford dams mated to Angus, Gray and Red Brahman, Gir, Indu-Brazil, and Nellore bulls from the same study reported by Riley et al. (2001). Nellore-Hereford crossbred cows had the highest pregnancy rates and were significantly higher than the Angus crosses. Gir and Nellore F_1 calves as well as calves out of Gir and Nellore F_1 cows tended to have lower birth weights than the other *Bos indicus*-Hereford crosses, although not always significantly different. The results from that study showed that the Nellore and Gir crossbred cows have high reproductive and maternal performance and could be utilized in central-Texas conditions, much like the Brahman crossbreds have been used.

Heterosis and Heterosis Retention

Gregory et al. (1999) researched composite breeds of *Bos taurus* cattle for retained heterosis and its effect on efficiency through the USDA Germplasm Utilization (GPU) Project. Three composite populations, MARC I, II, and III, were created from beef breeds of *Bos taurus* cattle used in the US. The composition of the three populations were:

MARC I: 1/4 Braunvieh 1/4 Charolais 1/4 Limousin 1/8 Hereford 1/8 Angus

MARC II: 1/4 Gelbvieh 1/4 Simmental 1/4 Hereford 1/4 Angus

MARC III: 1/4 Pinzgauer 1/4 Red Poll 1/4 Hereford 1/4 Angus

Retention of heterosis in this study was compared to that calculated in Dickerson (1969): (F_1 heterosis * (n-1)/n), where each breed contributed equally to the cross and n is the number of base breeds in the composite. When the breeds do not contribute equally, the fraction of F_1 heterosis expected to be retained in the cross is (1- sum of $(P_i)^2$), where P_i is the fraction of each breed in the mating (Gregory et al., 1999). A table in this bulletin describes different mating types, from crossbred rotations to eight-breed composites and their expected retained heterozygosity relative to the F_1. Of the mating types in their table, the four-breed rotation has the second most expected retained heterozygosity at 93.3% after the F_1, which is expected to have the maximum amount (Gregory et al., 1999). The composites have less expected heterozygosity, but as the number of different breeds used in the composite increases, so does the expected heterozygosity. The eight-breed composite has the most expected heterozygosity at 87.5% (Gregory et al, 1999 and Bourdon, 2000). The greatest loss of heterozygosity occurs between the F_1 and F_2 generations, but if inbreeding is avoided, heterosis should stabilize (Dickerson, 1969).

Many different traits were analyzed in the study reported by Gregory et al. (1999) including growth traits, puberty traits in females, carcass traits, and maternal and reproductive traits in cows. The results from this study generally supported the assumption that retained heterosis is proportional to the degree of heterozygosity and can be accounted for by dominance effects of genes. Heterosis for the maternal trait, 200-day calf weight, for the MARC II population and the mean of the three populations exceeded the expected retained heterosis for the trait. Reproductive traits evaluated in the study were percent pregnant, percent calves born and percent calves weaned. Composite populations MARC II and III had less heterosis effects for reproductive traits in the F_1 generation than the MARC I population (Gregory et al., 1999). The MARC III population expressed a loss of heterosis for calves born and calves weaned that was greater than genetic expectation based on retained heterozygosity. Gregory et al. (1999) stated that, “generally, retained heterosis in advanced generations was equal to or greater than expected based on retained heterozygosity in the three composite populations.”

Gregory et al. (1999) also stated “effects of heterosis were significant for birth weight for each generation of each composite population and for the mean of the three composite populations.” Heterosis retained for percent survival and birth weight as traits of the dams for the F_3 and F_4 progeny of combined F_2 and F_3 dams did not differ ($P > 0.05$) from genetic expectation based on retained heterozygosity. The effects of heterosis on 200-day weight of progeny evaluated on the F_2-generation females nursing F_3-generation progeny were significant ($P < 0.01$) in all three populations and for the mean of the composite populations. The progeny of the composites weighed more than the average of the purebreds in all three populations indicating the crossbred dams had an increased amount of milk yield. Estimated milk yield was evaluated and heterosis was found to be significant in all three composites.

Koger et al. (1975) researched heterosis effects on weaning age, condition score, 205-day weight, weaning rate, and weaning weight in Brahman and Shorthorn cross calves. Brahman bulls mated to Brahman-Shorthorn F_1 cows had calves with heavier weaning weights than Shorthorn-sired calves (215 vs. 205 kg, respectively). When the calves were evaluated by breed of dam, F_1 dams weaned the heaviest calves at 210 kg. The 3/4 Brahman-1/4 Shorthorn and 3/4 Shorthorn-1/4 Brahman cows had the highest average weaning rates at 76 and 75%, respectively. These results show the "utility of *Bos indicus-Bos taurus* crosses for improvement of production performance in environments where the improved temperature–zone breeds are not well adapted." In a study by Peacock et al. (1981), offspring of Angus, Brahman and Charolais cattle were analyzed for breed and heterosis effects on maternal and calf components of weaning traits. Calf heterosis effects for weight and condition were positive for all breed crosses, with the Angus-Brahman cross excelling in both. Estimated maternal heterosis was positive and large for all traits and breed combinations, making obvious the advantages to be gained from the use of crossbreeding systems for commercial beef production (Peacock et al., 1981). The authors stated the need for the addition of Zebu germ plasm into crossbreeding systems in the Gulf Coast region. Crockett et al. (1978) analyzed Brahman (B), Hereford (H) and Angus (A) cattle in two-breed rotational crosses for pregnancy, survival and weaning rates. Average performance values in the crosses of BH, AB, and AH were higher than in the straightbreds, illustrating that crossbred females have a higher fertility rate.

Discussion of Composites

Although the use of crossbred cattle tends to increase production, crossbreeding is difficult to implement in small herds. A crossbreeding program does not function well in herds that use less than four bulls. A large majority of the cow/calf herds in the US are made up of 50 cows or less. More research needs to be conducted on utilizing composite breeds compared to crossbreeding to utilize heterosis in the average herd. Rotational crossbreeding systems create fluctuations between generations in genetic composition. These fluctuations restrict the effective use of breed differences, so breed complementarity rarely gets used to its full advantage (Gregory and Cundiff, 1980).

Gregory et al. (1992) discussed breed effects and heterosis retained for pregnancy percentage, calf crop born, calf crop weaned, 200-day calf weight per heifer or cow exposed, and 200-day calf weight using the same three composite populations of *Bos taurus* cattle as in Gregory et al. (1999). "Heterosis observed in F_1 dams and retained heterosis in combined F_2 and F_3 dams was generally not consistent among the three composite populations for the three age groupings, suggesting differences among breeds in specific cross heterosis and in negative recombination effects for fetal survival between pregnancy diagnosis and parturition" (Gregory et al., 1992). The authors concluded that heterosis for fetal survival in one of the populations was less than proportional to expected retained heterozygosity, so no generalizations could be made about heterosis and heterozygosity retention in composites for reproductive traits. But the authors did find that for "growth traits, survival traits, puberty traits in heifers, and scrotal traits in bulls, retained heterosis is equal to, or greater than, expectation based on retained heterozygosity" (Gregory et al., 1992). For these traits, "retained heterosis in combined F_2 and F_3 dams was important ($P < .01$) for all traits and did not differ ($P > .05$) from expectation based on retained heterozygosity" (Gregory et al., 1992). In the MARC II population, 200-day calf weight had a retained heterosis that was greater ($P < .01$) than expectation based on retained heterozygosity, and retained heterosis did not differ ($P > .05$) from expectation for other traits. For three maternal traits of calf crop born and calf crop weaned percentage and 200-day calf weight per heifer or cow exposed in the MARC III population, heterosis retention was less than ($P < .05$) expected based on retained heterozygosity in combined F_2 and F_3 dams (Gregory et al., 1992).

The formation of composites using a multi-breed foundation is an attractive alternative to continuous crossbreeding (Gregory and Cundiff, 1980). The four-breed composite relative to the F_1 has 75% predicted retained heterozygosity. The more breeds in the composite, the more hybrid vigor is predicted to be retained based on the expected retained heterozygosity. Gregory and Cundiff (1980) suggested "there is the potential to develop general purpose composite breeds through careful selection of fully characterized candidate breeds to achieve an additive genetic composition that is much better adapted to the production situation than is feasible through continuous crossbreeding." Through heterosis and retained heterozygosity, composites can achieve the same or close to the same level of retained heterozygosity as crossbreeding, with much simpler management and utilize breed complementarity.

In the Gulf Coast region of the US, crossbreeding using Zebu cattle is very important because of their adaptation to the environment. There are composite breeds that have been formed between the Brahman, a *Bos indicus* breed, and some *Bos taurus* breeds that perform well in the southern US. Some of these are the Braford, Santa Gertrudis, Brangus, and Beefmaster. Koger (1980) discussed the formation of composites and stated that breed complementarity and heterosis levels should be taken into consideration. He discussed the unique ability of the Brahman to combine with the European breeds, resulting in crosses that have high levels of heterosis for growth, maternal ability, and reproductive performance. He encouraged a cross of three breeds with half being Zebu and the other half a combination of European breeds, or a four breed cross with equal proportions of the Brahman and three European breeds. The amount of each breed is important depending on the environment and production goals.

Crosses of *Bos indicus* and *Bos taurus* cattle are important because of their proven breed complementarity and high levels of heterosis. Damon et al. (1959) found that "crosses among Brahman and other breeds of cattle have shown a considerable advantage over the pure breeds with respect to weaning weights…" Magana and Segura (2003) presented results of crossbreeding between Zebu breeds and suggested that more hybrid vigor would be expected between *Bos indicus* and *Bos taurus* breeds than that expected between *Bos indicus* breeds. Gregory et al. (1999) concluded that a "…large scale, comprehensive experiment is needed to estimate retention of heterosis in advanced generations of *inter se* mated composite populations with contributions by both *Bos taurus* and *Bos indicus* breeds. However, from the limited information available, results suggest that heterosis from breed crosses of *Bos taurus* with *Bos indicus* breeds can be accounted for by dominance effects of genes because heterosis in advanced generations seems to be retained in proportion to retained heterozygosity."

Models

If the heterosis in various crosses is proportional to the degree of heterozygosity, heterosis can be accounted for by dominance effects of the genes. That is, heterosis can be accounted for by the “dominance model.” The dominance model has been found to adequately predict heterosis in various studies, including rotational crossbred matings involving Brahman and some *Bos taurus* breeds, but has not been found to adequately predict heterosis in *inter se* matings of *Bos indicus*-*Bos taurus* breeds in some of the studies that have been conducted.

Most of the studies that found heterosis to be adequately explained by the dominance model were studying *Bos taurus* crosses (Robison et al., 1981; Gregory and Cundiff, 1980; Koch et al., 1985; Gregory et al., 1999). In Koger et al. (1975) the authors evaluated Brahman and Shorthorn cattle using traits such as weaning age, condition score, 205-day weight, weaning weight and weaning rate. A simple linear model was used in evaluating the additive breed and F_1 heterosis effects for maternal and offspring components. This model fit well for condition score, 205-day weight, and weaning weight. Weaning rate data recorded did not fit the model assumed because the F_1 cows’ weaning rate was less than the backcross cows’ weaning rate, implying that heterosis was not linear with breed heterozygosity. Results from this study indicate that heterosis levels for crosses of these breeds were higher than in crosses of *Bos taurus* breeds which confirms reports of high heterosis in *Bos taurus* x *Bos indicus* crosses. The authors of this study concluded that, “the realized hybrid vigor levels in this trial of 50 and 52% in annual production per cow for backcross and 3/8 to 5/8 calves suggest that a two-breed rotation using Brahman and European breeds would be an effective procedure for crossbreeding cattle in a sustained program” (Koger et al., 1975).

Seebeck (1973) stated that the F_2 and F_3 generation of calves from *Bos indicus* x *Bos taurus* crossbred cows had a lower level of heterosis retained than expected by the dominance model for calf crop born. MacKinnon et al. (1989) reported estimated heterosis in calving rate to be 16.4%, -5.2%, and 1.6% for F_1, F_2, and F_n (F_3 and greater) generations in groups of half Brahman and one-fourth each of Hereford and Shorthorn cows. The authors also reported levels of heterosis for calving rate in the four breed quarter-blood composites (1/4 Africander 1/4 Brahman 1/4 Hereford 1/4 Shorthorn) were 5.0% for the first cross and 4.8% for the F_2 and F_3 cows combined.

In a study evaluating traits in rotational, three-breed and *inter se* mated cows in Florida, backcross dams maintained roughly the same level of heterosis as the F_1 dams. The three-breed crossbred dams exhibited a higher level of heterosis than the F_1 and the backcross dams (Olson et al., 1993). These authors stated that calves from the three-breed crossbred and backcross dams would be expected to display a higher degree of heterozygosity than the *inter se* calves. For birth weight and survival rate, heterosis estimates were higher for the three breed cross. For weaning weight and weaning condition score, heterosis estimates were higher in calves produced from the *inter se* matings. The authors suggested that epistatic recombination loss may have a greater effect in *Bos taurus* x *Bos indicus* crosses than Gregory et al. (1992) concluded in *Bos taurus* x *Bos taurus* crosses.

In Sanders et al. (2005b) where Brahman, Angus, Nellore, and Hereford cattle and various crosses of these breeds were being evaluated for heterosis and heterosis retention in calf crop born, calf crop weaned, calf survival rates, weaning weight of calves, and cow weights, "heterosis retention estimates for the traits of interest were found to be lower than expectations of the dominance model for some groups and higher than expectations of the dominance model for other groups" (Sanders et al., 2005b). The authors reported more heterosis was lost between the F_1 and F_2 Brahman/Angus groups than predicted by the dominance model for calf crop born. The F_2 Brahman/Hereford group showed a smaller loss compared to the F_1 Brahman/Hereford group for heterosis for calf crop born than the F_2 Brahman/Angus group compared to the F_1 Brahman/Angus group; the loss in the F_2 Brahman/Hereford group was less than predicted from the dominance model. Maternal effects on calf survival also showed more heterosis lost between the F_1 and F_2 generations than predicted by the dominance model for the Brahman/Angus group but less loss than predicted between the Brahman/Hereford F_1 and F_2 generations (Sanders et al., 2005b).

OBJECTIVES

The objectives of this study are to:

1. Estimate heterosis of *Bos indicus* and *Bos taurus* breeds (Nellore, Brahman, Angus and Hereford) for cow reproductive traits and maternal effects on traits of the calves.
2. Estimate retained heterosis in crosses produced by the *inter se* mating of crosses between *Bos indicus* and *Bos taurus* breeds.
3. Evaluate the adequacy of the dominance model to represent heterosis retention in crosses produced by the *inter se* mating of crosses between *Bos indicus* and *Bos taurus* breeds.

MATERIALS AND METHODS

Description of Data

Data for this study were collected at the McGregor Research Center as part of the Texas Agricultural Experiment Station Project H6883. Groups of approximately 50 cows each have been formed of the various breeds and their crosses (sire breed is listed first):

- Straightbreds: Angus (A)
  Brahman (B)
  Hereford (H)
  Nellore (N)
- F_1: 1/2N 1/2A (NA)
- Crossbreds: 3/8N 5/8A (includes 3/4N 1/4A x A, and NA x 3/4A 1/4N and its reciprocal)
  1/4B 1/4A 1/4N 1/4H (includes BA x NH, NA x BH, NA x HB, and NA x F_2BH)

The oldest cows were born in the spring of 1997 and all cows that are included in this research were produced at the McGregor Station. Table 1 shows the breed designations for the different cow breeds evaluated. Table 2 gives the numbers of cows of each breed and the years in which they were born. Heifers were first exposed to bulls at about fourteen months of age for two months to calve in the spring as two year olds for the first time. In subsequent years all cows were bred to calve in the spring, with the majority of calves born between February and May.

Table 1. Breed designations and mating used to produce the "breed"

Breeds	Mating (sire breed first)
Angus (A)	A x A
Brahman (A)	B x B
Hereford (H)	H x H
Nellore (N)	N x N
Nellore x Angus (F_1 NA)	N x A
3/8Nellore x 5/8Angus (3/8N 5/8A(a))	3/4A 1/4N x 1/2N 1/2A
3/8Nellore x 5/8Angus (3/8N 5/8A(b))	3/4N 1/4A x A
3/8Nellore x 5/8Angus (3/8N 5/8A(c))	1/2N 1/2A x 3/4A 1/4N
Brahman, Angus, Nellore, Hereford[a] (BANH(a))	1/2B 1/2A x 1/2N 1/2H
Brahman, Angus, Nellore, Hereford[a] (BANH(b))	1/2N 1/2A x 1/2B 1/2H
Brahman, Angus, Nellore, Hereford[a] (BANH(c))	1/2N 1/2A x 1/2H 1/2B
Brahman, Angus, Nellore, Hereford[a] ($BANH_2$)	1/2N 1/2A x F_2 BH[b]

[a]Quarter blood cows of the four breeds shown
[b]F_2 BH = second generation Brahman – Hereford and Hereford – Brahman cross cows

Table 2. Number and birth years for each cow breed[a]

Cow breed	Numbers	Birth years
A	30	1997, 1998, 1999
B	58	1995, 1996, 1997, 1998, 1999, 2000
H	50	1996, 1997, 1998, 1999
N	42	1997, 1998, 1999, 2000, 2001, 2002
F_1 NA	46	1997, 1998, 1999
3/8N 5/8A(a)	61	2000, 2001, 2002
3/8N 5/8A(b)	10	1997, 1998, 2000
3/8N 5/8A(c)	9	1999, 2000, 2001, 2002
BANH(a)	16	1996, 1998, 1999, 2000
BANH(b)	23	1999, 2000, 2001
BANH(c)	6	2000, 2001
$BANH_2$	9	1999, 2000, 2001
Total	360	

[a]See Table 1 for breed designations

Table 3. Breeds of bulls exposed to cow breed groups

Cow breed group	Breeds of bulls
A	A, C[a], 1/2N 1/2A
B	B, H, A
H	W[c], H, B, A
N	N, A
F_1 NA	A, 3/4A 1/4N
3/8N 5/8A[d]	1/2N 1/2A, 3/8N 5/8A, A, 3/4A 1/4N
BANH[e]	Bn[b], 3/4A 1/4N, A, 3/8N 5/8A

[a]C - Charolais
[b]Bn - Brangus(3/8 B 5/8 A)
[c]W - Wagyu
[d]Includes a, b, and c
[e]Includes a, b, c, and $BANH_2$

Table 3 presents the breeds of bulls that were bred to cows of the different breed groups. Calf birth weights were recorded within 48 hours of birth. Calves were weaned in the fall at approximately 7 months of age. At the time of weaning, calf weight and body condition score were collected and cows were palpated for pregnancy determination. Weight and condition score at the time of weaning were also recorded on most cows. Culling decisions were also made at weaning. The majority of the cows that fail to wean a calf for the second time are culled. Brahman and Nellore cows that fail to wean a calf as a heifer get two more opportunities to fail before they are culled for reproductive reasons; also, Brahman and Nellore cows that wean calves as two-year-olds, get three opportunities to fail before they are culled. The cows can also be culled for structural unsoundness at any time.

Traits Analyzed

The cow reproduction traits that were evaluated were calf crop born, calf crop weaned and calf survival. Table 4 presents these traits by cow breed and the numbers of observations for each trait. Calf crop born is the fraction of cows that were exposed to bulls during the breeding season that gave birth to a calf. Calf crop weaned is the fraction of all females exposed to bulls that successfully weaned a calf in the fall of the following year. These traits were analyzed as binary traits, one indicating a success and zero indicating a failure. Calf survival is the percentage of calves born (either alive or dead) that survive to weaning.

The calf traits that were analyzed were birth and weaning weight. Table 5 presents the weight traits and the numbers of observations by cow breed. Birth weight is the weight recorded at birth. Weaning weight is the weight taken in the fall of the year when the calves are weaned from their dams, at about seven months of age. These reproductive and weight traits described above were analyzed in SAS using the PROC MIXED procedure (SAS, 1990). The independent variables in the models for reproductive traits of the cows evaluated were the cow's age, and the cow's breed composition. The independent variables in the models for the weight traits of the calves were sex of the calf, weaning age of the calf in days, and the dam's age and breed composition.

Table 4. Numbers of observations for reproductive traits within each cow breed[a]

Cow Breed	Calf Crop Born	Calf Crop Weaned	Calf Survival
A	156	156	144
B	278	278	176
H	228	228	170
N	115	115	66
F_1 NA	219	219	201
3/8N 5/8A(a)	113	113	105
3/8N 5/8A(b)	38	38	36
3/8N 5/8A(c)	18	18	16
BANH(a)	69	69	60
BANH(b)	67	67	57
BANH(c)	14	14	14
$BANH_2$	24	24	20
Total	1338	1338	1065

[a]See Table 1 for breed designations

Table 5. Numbers of observations for weight traits within each cow breed[a]

Cow Breed	Birth Weight	Weaning Weight
A	143	135
B	173	148
H	171	156
N	65	53
F_1 NA	201	180
3/8N 5/8A(a)	105	98
3/8N 5/8A(b)	36	28
3/8N 5/8A(c)	16	16
BANH(a)	60	52
BANH(b)	57	52
BANH(c)	13	12
$BANH_2$	20	17
Total	1060	947

[a]See Table 1 for breed designations

Statistical Analysis

Two methods were used to analyze the data. In the first method, the crossbred females were separated according to the breeds of their parents. For example, 3/8N 5/8A females were divided into three groups: those that had 3/4A 1/4N sires and NA dams, 3/4N 1/4A sires and Angus dams, and those that had NA sires and 3/4A 1/4N dams. In the second method, the crossbred females were combined into their respective breed groups according to their own breed combinations.

Reproductive Traits

Calf crop born and calf crop weaned were analyzed as dependent variables using mixed linear models. Fixed effects for these two traits and calf survival included breed of cow and age of cow for the overall analysis. Because of partial confounding with age of cow, year could not be included. Interactions among these main effects were investigated and included if important ($P < 0.10$). Random effects were dam within sire breed of dam and dam within cow breed. They were also evaluated by age of dam using a model that included dam within cow breed as a random effect and breed of cow and year as fixed effects. Heterosis expressed in crossbred cows within the three different age groupings (2, 3, and 4 year old dams) was estimated in units of the trait by linear contrasts of the crossbred adjusted mean from the midparent value of the breeds involved. Ages 2, 3, and 4 were used because they were represented in all cow breeds.

Weight Traits

Calf birth weight and weaning weight were analyzed by cow breed and by cow breed group. The model used contained breed of cow, age of cow, year, and sex of calf as fixed effects. The weaning weight model also contained age of calf at weaning as a fixed effect. Both models contained dam within dam breed as a random effect. As with the reproductive traits, heterosis was evaluated in 2-, 3-, and 4-year-old dams by linear contrasts.

RESULTS AND DISCUSSION

Calf Crop Born

Unadjusted means for cow breed x dam age are presented in Table 6 and unadjusted means for cow breed group x dam age are presented in Table 7. The Nellore 2-year-old cows had the lowest calf crop born at 0.05. Note that this lower calf crop born performance is expected due to the fact that *Bos indicus* cattle are later maturing than *Bos taurus* cattle (Turner, 1980 and Franke, 1980). The 5- and 6-year-old cows averaged over all breed groups had the highest calf crop born at 93%. The 3/8N 5/8A breed group had a calf crop born percentage of 96%.

Adjusted means for calf crop born by cow breed are shown in Table 8 and by cow breed group in Table 9. The 3/8N 5/8A females with Angus dams had the highest calf crop born for the 3/8N 5/8A cows at 96%. The $BANH_2$ females had a lower calf crop born percentage than the BANH females. Adjusted means by dam age are in Tables 10 and 11; adjusted means for cows as 2-, 3-, and 4-year-olds are in Tables A, B, K, and L of the appendix.

Table 6. Unadjusted means, standard deviations, and numbers of observations for calf crop born by cow breed[a] by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	Total
A	0.97	0.93	0.87	0.87	0.96	1.0			0.93
	(0.18)	(0.25)	(0.35)	(0.35)	(0.21)	(0.0)	—	—	(0.22)
	30	30	30	30	23	13			156
B	0.19	0.77	0.60	0.85	0.73	0.84	0.79	0.86	0.70
	(0.40)	(0.43)	(0.49)	(0.36)	(0.45)	(0.37)	(0.43)	(0.38)	(0.42)
	58	56	53	41	30	19	14	7	278
H	0.80	0.57	0.66	0.79	0.91	0.86	1.00		0.80
	(0.41)	(0.50)	(0.48)	(0.41)	(0.30)	(0.36)	(0.0)	—	(0.35)
	49	47	44	39	32	14	3		228
N	0.05	0.83	0.80	0.94	1.0	1.0			0.77
	(0.22)	(0.38)	(0.41)	(0.25)	(0.0)	(0.0)	—	—	(0.21)
	41	29	20	16	6	3			115
F_1 NA	0.93	0.83	0.98	0.93	0.88	1.0			0.93
	(0.25)	(0.38)	(0.15)	(0.25)	(0.33)	(0.0)	—	—	(0.23)
	46	46	46	46	26	9			219
3/8N 5/8A(a)	0.95	0.87	1.0						0.94
	(0.22)	(0.34)	(0.0)	—	—	—	—	—	(0.19)
	61	38	14						113
3/8N 5/8A(b)	1.0	0.89	0.89	1.0	1.0	1.0			0.96
	(0.0)	(0.33)	(0.33)	(0.0)	(0.0)	(0.0)	—	—	(0.11)
	10	9	9	4	4	2			38
3/8N 5/8A(c)	0.89	0.86	1.0	1.0					0.94
	(0.33)	(0.38)	(0.0)	(0.0)	—	—	—	—	(0.18)
	9	7	1	1					18
BANH(a)	0.81	0.87	0.93	0.91	1.0	0.75	0.75		0.86
	(0.40)	(0.35)	(0.27)	(0.44)	(0.0)	(0.50)	(0.50)	—	(0.35)
	16	15	14	11	5	4	4		69
BANH(b)	0.83	0.83	0.89	1.0					0.89
	(0.39)	(0.39)	(0.32)	(0.0)	—	—	—	—	(0.28)
	23	23	18	3					67
BANH(c)	1.0	1.0	1.0						1.0
	(0.0)	(0.0)	(0.0)	—	—	—	—	—	(0.0)
	6	6	2						14
$BANH_2$	0.67	0.89	1.0	1.0					0.89
	(0.50)	(0.33)	(0.0)	(0.0)	—	—	—	—	(0.21)
	9	9	4	2					24
Total	0.76	0.85	0.89	0.93	0.93	0.92	0.85	0.86	0.88
	(0.27)	(0.34)	(0.23)	(0.21)	(0.18)	(0.18)	(0.31)	(0.38)	(0.23)
	358	315	255	193	126	64	21	7	1339

[a]See Table 1 for breed designations

Table 7. Unadjusted means, standard deviations and numbers of observations for calf crop born by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	Total
A	0.97	0.93	0.87	0.87	0.96	1.0			0.93
	(0.18)	(0.25)	(0.35)	(0.35)	(0.21)	(0.0)	—	—	(0.22)
	30	30	30	30	23	13			156
B	0.19	0.77	0.60	0.85	0.73	0.84	0.79	0.86	0.70
	(0.40)	(0.43)	(0.49)	(0.36)	(0.45)	(0.37)	(0.43)	(0.38)	(0.41)
	58	56	53	41	30	19	14	7	278
H	0.80	0.57	0.66	0.79	0.91	0.86	1.00		0.80
	(0.41)	(0.50)	(0.48)	(0.41)	(0.30)	(0.36)	(0.0)	—	(0.35)
	49	47	44	39	32	14	3		228
N	0.05	0.83	0.80	0.94	1.0	1.0			0.77
	(0.22)	(0.38)	(0.41)	(0.25)	(0.0)	(0.0)	—	—	(0.21)
	41	29	20	16	6	3			115
F_1 NA	0.93	0.83	0.98	0.93	0.88	1.0			0.93
	(0.25)	(0.38)	(0.15)	(0.25)	(0.33)	(0.0)	—	—	(0.23)
	46	46	46	46	26	9			219
3/8N 5/8A[a]	0.95	0.87	0.96	1.0	1.0	1.0			0.96
	(0.22)	(0.34)	(0.20)	(0.0)	(0.0)	(0.0)	—	—	(0.13)
	80	54	24	5	4	2			169
BANH[b]	0.81	0.87	0.92	0.94	1.00	0.75	0.75		0.86
	(0.39)	(0.34)	(0.27)	(0.25)	(0.0)	(0.50)	(0.50)	—	(0.32)
	54	53	38	16	5	4	4		174
Total	0.67	0.81	0.83	0.90	0.93	0.92	0.85	0.86	0.85
	(0.29)	(0.37)	(0.34)	(0.27)	(0.18)	(0.18)	(0.31)	(0.38)	(0.27)
	358	315	255	193	126	64	21	7	1339

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 8. Least squares means and standard errors (SE) for calf crop born by cow breed[a]

Cow Breed	LS means ± SE
A	0.92 ± 0.03
B	0.63 ± 0.02
H	0.75 ± 0.03
N	0.57 ± 0.04
F_1 NA	0.92 ± 0.03
3/8N 5/8A(a)	0.93 ± 0.04
3/8N 5/8A(b)	0.95 ± 0.06
3/8N 5/8A(c)	0.89 ± 0.09
BANH(a)	0.87 ± 0.05
BANH(b)	0.85 ± 0.05
BANH(c)	1.00 ± 0.10
$BANH_2$	0.83 ± 0.08

[a]See Table 1 for breed designations

Table 9. Least squares means and standard errors (SE) for calf crop born by cow breed group

Cow breed group	LS means ± SE
A	0.92 ± 0.03
B	0.63 ± 0.02
H	0.75 ± 0.03
N	0.57 ± 0.04
F_1 NA	0.92 ± 0.03
3/8N 5/8A[a]	0.93 ± 0.03
BANH[b]	0.87 ± 0.03

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 10. Least squares means and standard errors (SE) for calf crop born by cow breed[a] by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs
A	0.97 ± 0.07	0.93 ± 0.07	0.87 ± 0.07	0.87 ± 0.07	0.96 ± 0.07	1.0 ± 0.10	—	—
B	0.19 ± 0.05	0.77 ± 0.05	0.60 ± 0.05	0.85 ± 0.06	0.73 ± 0.07	0.80 ± 0.08	0.79 ± 0.10	0.86 ± 0.13
H	0.80 ± 0.05	0.57 ± 0.05	0.66 ± 0.05	0.79 ± 0.06	0.91 0.06	0.86 ± 0.09	1.00 ± 0.20	—
N	0.05 ± 0.06	0.83 ± 0.07	0.80 ± 0.08	0.94 ± 0.09	1.0 ± 0.15	1.0 ± 0.21	—	—
F_1 NA	0.93 ± 0.05	0.83 ± 0.05	0.98 ± 0.05	0.93 ± 0.05	0.88 ± 0.07	1.0 ± 0.12	—	—
3/8N 5/8A(a)	0.95 ± 0.04	0.87 ± 0.06	1.0 ± 0.09	—	—	—	—	—
3/8N 5/8A(b)	1.0 ± 0.11	0.89 ± 0.12	0.89 ± 0.12	1.0 ± 0.35	1.0 ± 0.17	1.0 ± 0.25	—	—
3/8N 5/8A(c)	0.89 ± 0.12	0.86 ± 0.13	1.0 ± 0.35	—	—	—	—	—
BANH(a)	0.81 ± 0.09	0.86 ± 0.09	0.93 ± 0.09	0.91 ± 0.11	1.0 ± 0.16	0.75 ± 0.17	0.75 ± 0.17	—
BANH(b)	0.83 ± 0.07	0.83 ± 0.07	0.89 ± 0.08	1.0 ± 0.20	—	—	—	—
BANH(c)	1.0 ± 0.14	1.0 ± 0.14	1.0 ± 0.25	—	—	—	—	—
$BANH_2$	0.67 ± 0.12	0.89 ± 0.12	1.0 ± 0.17	1.0 ± 0.25	—	—	—	—

[a]See Table 1 for breed designations

Table 11. Least squares means and standard errors (SE) for calf crop born by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs
A	0.97 ± 0.06	0.93 ± 0.06	0.87 ± 0.06	0.87 ± 0.06	0.96 ± 0.07	1.0 ± 0.10	—	—
B	0.19 ± 0.05	0.77 ± 0.05	0.60 ± 0.05	0.85 ± 0.06	0.73 ± 0.06	0.80 ± 0.08	0.79 ± 0.10	0.86 ± 0.13
H	0.80 ± 0.05	0.57 ± 0.05	0.66 ± 0.05	0.79 ± 0.06	0.91 ± 0.06	0.86 ± 0.09	1.00 ± 0.20	—
N	0.05 ± 0.06	0.83 ± 0.07	0.80 ± 0.08	0.94 ± 0.09	1.0 ± 0.15	1.0 ± 0.21	—	—
F_1 NA	0.93 ± 0.05	0.83 ± 0.05	0.98 ± 0.05	0.93 ± 0.05	0.88 ± 0.07	1.0 ± 0.12	—	—
3/8N 5/8A[a]	0.95 ± 0.04	0.85 ± 0.05	0.96 ± 0.07	1.00 ± 0.16	1.0 ± 0.17	1.0 ± 0.25	—	—
BANH[b]	0.81 ± 0.05	0.85 ± 0.05	0.90 ± 0.06	0.94 ± 0.09	1.00 ± 0.16	0.75 ± 0.17	0.75 ± 0.17	—

[a]Includes 3/8N 5/8A a, b and c

[b]Includes BANH a, b, c and BANH

Calf crop born contrast estimates for 2-, 3-, and 4-year-old cows are shown in Tables 12 and 13 and separated by age in Table 14. The four breed quarter blood composite females produced from mating F_1 NA bulls to 1/2H 1/2B cows showed important heterosis ($P < 0.001$) for calf crop born at 0.35. The contrast between the F_1 Nellore-Angus and the midparent (Table 12) is the estimated heterosis between Nellore and Angus for calf crop born. For the 3/8N 5/8A_b that resulted from mating ¾ Nellore ¼ Angus bulls to Angus cows, if heterosis in the cross were proportional to degree of heterozygosity (i.e., adequately explained by dominance effects), three-fourths of the heterosis of the F_1 would by expressed. Therefore, the heterosis estimated for this cross (0.18) is slightly, but not significantly, more than that predicted from the dominance model (0.165).

For both the 3/8N 5/8A_a and the 3/8N 5/8A_c, which are the results of reciprocal matings between ¼ Nellore ¾ Angus and F_1 Nellore-Angus, one-half of the heterosis of the F_1 would be expected to be expressed based on the dominance model. In both cases, the estimated heterosis (0.18 and 0.13 for 3/8N 5/8A_a and 3/8N 5/8A_c, respectively) is more than that predicted by the dominance model (0.11).

For the three types of ¼ Brahman ¼ Angus ¼ Nellore ¼ Hereford crosses resulting from mating F_1 NA bulls to ½ Brahman ½ Hereford cows, i.e., $BANH_b$, $BANH_c$, and $BANH_2$, if heterosis were proportional to degree of expected heterozygosity, the amount of heterosis expected to be expressed in the cross would be one-fourth of the heterosis between Nellore and Hereford plus one-fourth of that between Brahman and Angus plus one-fourth of that between Brahman and Nellore plus one-fourth of that between Angus and Hereford. Similarly, that expected in the $BANH_a$ would be one-fourth of the heterosis between Nellore and Angus plus one-fourth of that between Brahman and Hereford plus one-fourth of that between Brahman and Nellore plus one-fourth of that between Angus and Hereford. As shown in Table 12, the heterosis estimated between Nellore and Angus in this study is 0.22. In another report from this study, Key (2004) reported estimates of the heterosis for calf crop born between Brahman and Angus and between Brahman and Hereford to be 0.10 and 0.15, respectively. The matings were not made in this study to allow the estimates of heterosis between Nellore and Hereford, Brahman and Nellore, or Angus and Hereford. However, based on the results of other studies, it would be reasonable to expect the heterosis between Nellore and Hereford to be similar to that between the other *Bos indicus* by British combinations in the study. It would also be reasonable to expect the heterosis between both Brahman and Nellore and between Angus and Hereford to be about half of that between the *Bos indicus* by British combinations in the study. Using this logic, the heterosis between Nellore and Hereford can be predicted to be the average of 0.22, 0.15, and 0.10, which is about 0.16. The heterosis between both Brahman and Nellore and between Angus and Hereford can be predicted to be about one-half of this value (0.08).

From these predictions, it could be predicted based on the dominance model that the heterosis expressed in the $BANH_b$, $BANH_c$, and $BANH_2$ should be about 0.105 and that in the $BANH_a$ should be about 0.135. From Table 12, the amount of heterosis expressed in these crosses was estimated to range from 0.17 to 0.35. Even if the heterosis between the different pairs of *Bos indicus* by British combinations were assumed to be the same as that estimated between Nellore and Angus in this study (0.22), and that between Brahman and Nellore and between Angus and Hereford were assumed to be half of the above values (i.e., half of 0.22 or 0.11), the amount of heterosis expected in the various BANH crosses would be equal to 0.165. That is, even by the most conservative estimate, the amount of heterosis expressed in the four different types of BANH crosses appears to be as much as predicted by the dominance model.

The three crossbred cow types (NA, 3/8N 5/8A, and BANH) were all significantly different than the average of the parental purebreds ($P < 0.0001$), but the $BANH_2$ cows were not significantly different than the average of the BANH cows. That is, all three of the breed groups in Table 13 had significant levels of heterosis ($P < 0.0001$). All of the breed groups in Table 14 showed significant heterosis at 2 years of age, but none of them did at 3 years of age. Both the F_1 NA and the 3/8N 5/8A breed groups had lower performance than the midparent average as 3 year olds, but were not significantly different from the midparent average.

Table 12. Calf crop born contrasts and standard errors (SE) by cow breed[a]

L	**Contrast ± SE**
F_1 NA vs MP[b]	0.22 ± 0.04***
3/8N 5/8A(a) vs MP	0.18 ± 0.05**
3/8N 5/8A(b) vs MP	0.18 ± 0.08°
3/8N 5/8A(c) vs MP	0.13 ± 0.10
BANH(a) vs MP	0.22 ± 0.06**
BANH(b) vs MP	0.20 ± 0.05**
BANH(c) vs MP	0.35 ± 0.11**
$BANH_2$ vs MP	0.17 ± 0.09°
$BANH_2$ vs $\overline{\text{BANH}}$ F_1[c]	-0.02 ± 0.09

[a]See Table 1 for breed designations
[b]MP – midparent average of the purebreds in the cross
[c]BANH F_1 – average calf crop born contrasts for BANH a, b, and c
Note: See Table K in appendix for LS means for calf crop born by cow breed for 2-, 3-, and 4-year-old dams
ϕ $P < 0.10$
° $P < 0.05$
* $P < 0.01$
** $P < 0.001$
*** $P < 0.0001$

Table 13. Calf crop born contrasts and standard errors (SE) for breed group differences

L	**Contrast ± SE**
F_1 NA vs MP[a]	0.22 ± 0.04***
BANH[b] **vs MP**	0.22 ± 0.04***
3/8N 5/8A[c] **vs MP**	0.17 ± 0.04***

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table A in appendix for LS means for calf crop born by cow breed group for 2-, 3-, and 4-year-old dams
*** P < 0.0001

Table 14. Calf crop born contrasts and standard errors (SE) for 2-, 3-, and 4-year-old dams

	2 yrs	**3 yrs**	**4 yrs**
F_1 NA vs MP[a]	0.44 ± 0.06***	-0.05 ± 0.08	0.14 ± 0.08$^{\phi}$
BANH[b] **vs MP**	0.32 ± 0.06***	0.09 ± 0.06	0.19 ± 0.07*
3/8N 5/8A[c] **vs MP**	0.34 ± 0.05***	-0.02 ± 0.07	0.12 ± 0.09

[a]MP – midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table B in appendix for LS means for calf crop born by cow breed group for 2-, 3-, and 4-year-old dams
ϕ P < 0.10
° P < 0.05
* P < 0.001
*** P < 0.0001

Calf Crop Weaned

Unadjusted means for calf crop weaned x dam age are presented in Tables 15 and 16. Angus and F_1 NA cows had calf crop weaned percentages of 0.87 and 0.84, respectively. The Nellore and Brahman cows had the lowest calf crop weaned percentages due to low calf crop born as 2 year olds. The 7-year-old cows had the highest calf crop weaned percentage at 0.84. The 3/8N 5/8A females had the highest calf crop weaned of the crossbreds at 0.86, although not as high as in the Nellore-Hereford F_1 crossbred cows, which had a calf crop weaned percent of 0.96 as reported in Sanders et al. (2005a).

Adjusted means for cow breed are in Table 17 and for cow breed group in Table 18. The 3/8N 5/8A females with crossbred dams had higher performance for calf crop weaned than those females with the straightbred dams. The $BANH_2$ females had a lower calf crop weaned than the other four breed quarter blood composites. Adjusted means for calf crop weaned x dam age are in Tables 19 and 20; adjusted means for calf crop weaned for cows as 2-, 3-, and 4-year-olds are in Tables C, D, M, and N of the appendix. Contrast estimates for calf crop weaned are presented in Tables 21 and 22 and by dam age for 2-, 3-, and 4-year-old cows in Table 23. The $BANH_2$ females did not show significant heterosis for calf crop weaned. All three cow breed groups in Table 22 had significant levels of heterosis for calf crop weaned ($P < 0.0001$). The 2-year-old 3/8N 5/8A breed group showed important heterosis at 0.32 ($P < 0.0001$).

Table 15. Unadjusted means, standard deviations and numbers of observations for calf crop weaned by cow breed[a] by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	Total
A	0.83 (0.38) 30	0.90 (0.31) 30	0.83 (0.38) 30	0.87 (0.35) 30	0.87 (0.34) 23	0.92 (0.28) 13	—	—	0.87 (0.34) 156
B	0.14 (0.35) 58	0.68 (0.47) 56	0.49 (0.50) 53	0.76 (0.43) 41	0.63 (0.49) 30	0.79 (0.42) 19	0.57 (0.51) 14	0.43 (0.53) 7	0.56 (0.46) 278
H	0.69 (0.46) 49	0.51 (0.51) 47	0.61 (0.49) 44	0.77 (0.43) 39	0.91 (0.30) 32	0.71 (0.47) 14	1.0 (0.0) 3	—	0.74 (0.38) 228
N	0.02 (0.16) 41	0.69 (0.47) 29	0.55 (0.51) 20	0.75 (0.45) 16	1.0 (0.0) 6	1.0 (0.0) 3	—	—	0.67 (0.27) 115
F_1 NA	0.80 (0.40) 46	0.78 (0.42) 46	0.83 (0.38) 46	0.83 (0.38) 46	0.88 (0.33) 26	0.89 (0.33) 9	—	—	0.84 (0.37) 219
3/8N 5/8A(a)	0.85 (0.36) 61	0.84 (0.37) 38	1.0 (0.0) 14	—	—	—	—	—	0.90 (0.24) 113
3/8N 5/8A(b)	0.80 (0.42) 10	0.89 (0.33) 9	0.67 (0.50) 9	0.75 (0.50) 4	0.75 (0.50) 4	1.0 (0.0) 2	—	—	0.81 (0.38) 38
3/8N 5/8A(c)	0.89 (0.33) 9	0.86 (0.38) 7	1.0 (0.0) 1	1.0 (0.0) 1	—	—	—	—	0.94 (0.18) 18
BANH(a)	0.56 (0.51) 16	0.80 (0.41) 15	0.86 (0.36) 14	0.91 (0.30) 11	1.0 (0.0) 5	0.75 (0.50) 4	0.25 (0.50) 4	—	0.73 (0.37) 69
BANH(b)	0.74 (0.45) 23	0.74 (0.45) 23	0.83 (0.38) 18	1.0 (0.0) 3	—	—	—	—	0.83 (0.32) 67
BANH(c)	0.83 (0.41) 6	0.83 (0.41) 6	1.0 (0.0) 2	—	—	—	—	—	0.89 (0.27) 14
$BANH_2$	0.56 (0.53) 9	0.78 (0.44) 9	0.75 (0.50) 4	1.0 (0.0) 2	—	—	—	—	0.77 (0.37) 24
Total	0.64 (0.40) 358	0.78 (0.43) 315	0.78 (0.33) 255	0.86 (0.28) 193	0.86 (0.28) 126	0.87 (0.29) 64	0.61 (0.34) 21	0.43 (0.53) 7	0.80 (0.33) 1339

[a]See Table 1 for breed designations

Table 16. Unadjusted means, standard deviations, and numbers of observations for calf crop weaned by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	Total
A	0.83 (0.38) 30	0.90 (0.31) 30	0.83 (0.38) 30	0.87 (0.35) 30	0.87 (0.34) 23	0.92 (0.28) 13	—	—	0.87 (0.34) 156
B	0.14 (0.35) 58	0.68 (0.47) 56	0.49 (0.50) 53	0.76 (0.43) 41	0.63 (0.49) 30	0.79 (0.42) 19	0.57 (0.51) 14	0.42 (0.53) 7	0.56 (0.46) 278
H	0.69 (0.47) 49	0.51 (0.51) 47	0.61 (0.49) 44	0.77 (0.43) 39	0.91 (0.30) 32	0.71 (0.47) 14	1.0 (0.0) 3	—	0.74 (0.38) 228
N	0.02 (0.16) 41	0.69 (0.47) 29	0.55 (0.51) 20	0.75 (0.45) 16	1.0 (0.0) 6	1.0 (0.0) 3	—	—	0.67 (0.27) 115
F_1 NA	0.80 (0.40) 46	0.78 (0.42) 46	0.83 (0.38) 46	0.83 (0.38) 46	0.88 (0.33) 26	0.89 (0.33) 9	—	—	0.84 (0.37) 219
3/8N 5/8A[a]	0.85 (0.36) 80	0.85 (0.36) 54	0.88 (0.34) 24	0.80 (0.45) 5	0.75 (0.50) 4	1.0 (0.0) 2	—	—	0.86 (0.34) 169
BANH[b]	0.67 (0.48) 54	0.77 (0.42) 53	0.84 (0.37) 38	0.94 (0.25) 16	1.0 (0.0) 5	0.75 (0.50) 4	0.25 (0.50) 4	—	0.75 (0.36) 174
Total	0.57 (0.37) 358	0.74 (0.42) 315	0.72 (0.42) 255	0.82 (0.39) 193	0.86 (0.28) 126	0.87 (0.29) 64	0.61 (0.34) 21	0.43 (0.53) 7	0.76 (0.36) 1339

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 17. Least squares means and standard errors (SE) for calf crop weaned by cow breed[a]

Cow breed	LS means ± SE
A	0.87 ± 0.04
B	0.53 ± 0.03
H	0.69 ± 0.03
N	0.46 ± 0.04
F_1 NA	0.82 ± 0.03
3/8N 5/8A(a)	0.87 ± 0.04
3/8N 5/8A(b)	0.79 ± 0.07
3/8N 5/8A(c)	0.89 ± 0.10
BANH(a)	0.75 ± 0.05
BANH(b)	0.78 ± 0.05
BANH(c)	0.86 ± 0.12
$BANH_2$	0.71 ± 0.09

[a]See Table 1 for breed designations

Table 18. Least squares means and standard errors (SE) for calf crop weaned by cow breed group

Cow breed group	LS means ± SE
A	0.87 ± 0.04
B	0.53 ± 0.03
H	0.69 ± 0.03
N	0.46 ± 0.04
F_1 NA	0.82 ± 0.03
3/8N 5/8A[a]	0.85 ± 0.03
BANH[b]	0.76 ± 0.03

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 19. Least squares means and standard errors (SE) for calf crop weaned by cow breed[a] by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs
A	0.83 ± 0.08	0.90 ± 0.08	0.83 ± 0.08	0.87 ± 0.08	0.87 ± 0.09	0.92 ± 0.11	—	—
B	0.14 ± 0.05	0.68 ± 0.06	0.49 ± 0.06	0.76 ± 0.06	0.63 ± 0.08	0.75 ± 0.09	0.57 ± 0.11	0.43 ± 0.16
H	0.69 ± 0.06	0.51 ± 0.06	0.61 ± 0.06	0.77 ± 0.07	0.91 ± 0.07	0.71 ± 0.11	1.00 ± 0.24	—
N	0.02 ± 0.06	0.69 ± 0.08	0.55 ± 0.09	0.75 ± 0.10	1.00 ± 0.17	1.00 ± 0.24	—	—
F_1 NA	0.80 ± 0.06	0.78 ± 0.06	0.83 ± 0.06	0.83 ± 0.06	0.88 ± 0.08	0.89 ± 0.14	—	—
3/8N 5/8A(a)	0.85 ± 0.05	0.84 ± 0.07	1.00 ± 0.11	—	—	—	—	—
3/8N 5/8A(b)	0.80 ± 0.13	0.89 ± 0.14	0.67 ± 0.14	0.75 ± 0.20	0.75 ± 0.20	1.00 ± 0.29	—	—
3/8N 5/8A(c)	0.89 ± 0.14	0.86 ± 0.15	1.00 ± 0.41	1.00 ± 0.41	—	—	—	—
BANH(a)	0.56 ± 0.10	0.80 ± 0.11	0.86 ± 0.11	0.91 ± 0.12	1.00 ± 0.18	0.75 ± 0.20	0.25 ± 0.20	—
BANH(b)	0.74 ± 0.09	0.74 ± 0.09	0.83 ± 0.10	1.00 ± 0.24	—	—	—	—
BANH(c)	0.83 ± 0.17	0.83 ± 0.17	1.00 ± 0.29	—	—	—	—	—
$BANH_2$	0.56 ± 0.14	0.78 ± 0.14	0.75 ± 0.20	1.00 ± 0.29	—	—	—	—

[a]See Table 1 for breed designations

Table 20. Least squares means and standard errors (SE) for calf crop weaned by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs
A	0.83 ± 0.08	0.93 ± 0.08	0.83 ± 0.08	0.87 ± 0.08	0.87 ± 0.09	0.92 ± 0.11	—	—
B	0.14 ± 0.05	0.68 ± 0.06	0.49 ± 0.06	0.76 ± 0.06	0.63 ± 0.08	0.75 ± 0.09	0.57 ± 0.11	0.43 ± 0.16
H	0.69 ± 0.06	0.51 ± 0.06	0.61 ± 0.06	0.77 ± 0.07	0.91 ± 0.07	0.71 ± 0.11	1.00 ± 0.24	—
N	0.02 ± 0.06	0.69 ± 0.08	0.55 ± 0.09	0.75 ± 0.10	1.0 ± 0.17	1.00 ± 0.24	—	—
F_1 NA	0.80 ± 0.06	0.78 ± 0.06	0.83 ± 0.06	0.83 ± 0.06	0.88 ± 0.08	0.89 ± 0.14	—	—
3/8N 5/8A[a]	0.85 ± 0.05	0.85 ± 0.06	0.88 ± 0.08	0.80 ± 0.18	0.75 ± 0.20	1.0 ± 0.29	—	—
BANH[b]	0.67 ± 0.05	0.77 ± 0.06	0.84 ± 0.07	0.94 ± 0.10	1.00 ± 0.18	0.75 ± 0.20	0.25 ± 0.20	—

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 21. Calf crop weaned contrasts and standard errors (SE) by cow breed[a]

L	**Contrast ± SE**
F_1 NA vs MP[b]	0.20 ± 0.05***
3/8N 5/8A(a) vs MP	0.20 ± 0.05***
3/8N 5/8A(b) vs MP	0.12 ± 0.09
3/8N 5/8A(c) vs MP	0.21 ± 0.11$^{\phi}$
BANH(a) vs MP	0.17 ± 0.07°
BANH(b) vs MP	0.20 ± 0.06**
BANH(c) vs MP	0.29 ± 0.12°
$BANH_2$ vs MP	0.12 ± 0.10
$BANH_2$ vs $\overline{BANH}$ F_1[c]	-0.05 ± 0.10

[a]See Table 1 for breed designations
[b]MP – midparent average of the purebreds in the cross
[c]BANH F_1 – average calf crop weaned contrasts for BANH a, b, and c
Note: See Table M in appendix for LS means for calf crop weaned by cow breed for 2-, 3-, and 4-year-old dams
$^{\phi}$ P < 0.10
° P < 0.05
* P < 0.01
** P < 0.001
*** P < 0.0001

Table 22. Calf crop weaned contrasts and standard errors (SE) for breed group differences

L	**Contrast ± SE**
F_1 NA vs MP[a]	0.20 ± 0.05***
BANH[b] vs MP	0.19 ± 0.04***
3/8N 5/8A[c] vs MP	0.19 ± 0.05***

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table C in appendix for LS means for calf crop weaned by cow breed group for 2-, 3-, and 4-year-old dams
*** P < 0.0001

Table 23. Calf crop weaned contrasts and standard errors (SE) for 2-, 3-, and 4-year-old dams

	2 yrs	**3 yrs**	**4 yrs**
F_1 NA vs MP	0.38 ± 0.07***	-0.01 ± 0.08	0.13 ± 0.09
BANH[b] vs MP	0.24 ± 0.06***	0.08 ± 0.07	0.22 ± 0.08*
3/8N 5/8A[c] vs MP	0.32 ± 0.06***	0.03 ± 0.08	0.15 ± 0.11

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table D in appendix for LS means for calf crop weaned by cow breed group for 2-, 3-, and 4-year-old dams
ϕP < 0.10
°P < 0.05
* P < 0.01
** P < 0.001
*** P < 0.0001

The estimated heterosis between Nellore and Angus for calf crop weaned was 0.20 (Table 21). The heterosis estimated in the 3/8N 5/8A_a and 3/8N 5/8A_c crosses (0.20 and 0.21) was more than that predicted from the dominance model (half of the estimate from the F_1 or 0.10). The heterosis estimate from the 3/8N 5/8A_b (0.12 $\pm$ 0.09) was slightly, but not significantly, less than that predicted from the dominance model (three-fourths of the estimate from the F_1 or 0.15).

Key (2004) reported estimates of the heterosis for calf crop born between Brahman and Angus and between Brahman and Hereford to be 0.11 and 0.16, respectively. Using the same logic as was used for calf crop born, the heterosis expected in the $BANH_b$, $BANH_c$, and $BANH_2$ crosses would be about 0.11; for the $BANH_a$ cross the expected amount would be about 0.13. In all four cases the heterosis estimates from Table 21 are higher than those estimated from the dominance model.

Calf Survival

Unadjusted means by cow breed and cow breed group x dam age are presented in Tables 24 and 25, respectively. Averaged over all breed groups, the 7 year olds had the highest calf survival of 0.94. Averaged over all ages, the Angus cows also had a calf survival rate, of 0.94, the highest for all breed groups. The NA-sired four breed quarter blood composites had higher calf survival rates than the BA-sired four breed quarter blood composites. The 3/8N 5/8A females with the crossbred dams had higher calf survival rates than the females with the Angus dams.

Least squares means for calf survival are in Tables 26 and 27 and by dam age in Tables 28 and 29. The 3/8N 5/8A cows produced from mating ¾ Angus ¼ Nellore bulls to NA cows had a calf survival rate of 0.93. The Nellore and the 3/4N 1/4A-sired 3/8N 5/8A cows had the lowest adjusted calf survival rates of 0.80 (Table 26). Calves out of Nellore cows expressed the lowest calf survival rate of 0.80 of the breed groups in Table 27. The F_1 NA breed group had a calf survival rate of 0.89, compared to the calf survival rate of 0.91 of the F_1 BA or BH groups in Sanders et al. (2005b). Adjusted means for calf survival out of 2-, 3-, and 4-year-old cows are in Tables E, F, O, and P of the appendix. Contrast estimates for calf survival by cow breed are presented in Table 30. Only two crossbred cow breeds showed significant heterosis ($P < 0.10$) for calf survival, both being types of the 3/8N 5/8A group. Table 31 shows contrast estimates by cow breed group. The 3/8N 5/8A females showed heterosis of 0.06. Contrast estimates for calf survival x dam age are shown in Table 32. Calf survival for calves out of crossbred dams as 2 year olds was less than that of calves out of the parental straightbreds, but no breed groups were significantly different from the midparent values.

Table 24. Unadjusted means, standard deviations, and numbers of observations for calf survival by cow breed[a] by cow age

	2 yrs	**3 yrs**	**4 yrs**	**5 yrs**	**6 yrs**	**7 yrs**	**8 yrs**	**9 yrs**	**Total**
A	0.86	0.96	0.96	1.0	0.91	0.92			0.94
	(0.35)	(0.19)	(0.20)	(0.0)	(0.29)	(0.28)	—	—	(0.22)
	29	28	26	26	22	13			144
B	0.73	0.88	0.81	0.89	0.86	0.94	0.73	0.50	0.79
	(0.47)	(0.32)	(0.40)	(0.32)	(0.35)	(0.25)	(0.47)	(0.55)	(0.39)
	11	43	32	35	22	16	11	6	176
H	0.88	0.89	0.96	0.97	1.0	0.83	1.0		0.93
	(0.33)	(0.32)	(0.19)	(0.18)	(0.0)	(0.39)	(0.0)	—	(0.20)
	40	27	28	31	29	12	3		170
N	0.50	0.83	0.69	0.80	1.0	1.0			0.80
	(0.71)	(0.38)	(0.48)	(0.41)	(0.0)	(0.0)	—	—	(0.33)
	2	24	16	15	6	3			66
F_1 NA	0.86	0.95	0.84	0.88	1.0	0.89			0.90
	(0.35)	(0.23)	(0.37)	(0.32)	(0.0)	(0.33)	—	—	(0.27)
	43	38	45	43	23	9			201
3/8N 5/8A(a)	0.90	0.97	1.0						0.96
	(0.31)	(0.17)	(0.0)	—	—	—	—	—	(0.16)
	58	33	14						105
3/8N 5/8A(b)	0.80	1.0	0.75	0.50	0.75	1.0			0.80
	(0.42)	(0.0)	(0.46)	(0.58)	(0.50)	(0.0)	—	—	(0.33)
	10	8	8	4	4	2			36
3/8N 5/8A(c)	1.0	1.0	1.0	1.0					1.0
	(0.0)	(0.0)	(0.0)	(0.0)	—	—	—	—	(0.0)
	8	6	1	1					16
BANH(a)	0.69	0.92	0.92	1.0	1.0	1.0	0.33		0.84
	(0.48)	(0.28)	(0.28)	(0.0)	(0.0)	(0.0)	(0.58)	—	(0.23)
	13	13	13	10	5	3	3		60
BANH(b)	0.89	0.89	0.94	1.0					0.93
	(0.32)	(0.32)	(0.25)	(0.0)	—	—	—	—	(0.22)
	19	19	16	3					57
BANH(c)	0.83	0.83	1.0						0.89
	(0.41)	(0.41)	(0.0)	—	—	—	—	—	(0.27)
	6	6	2						14
$BANH_2$	0.83	0.88	0.75	1.0					0.87
	(0.41)	(0.35)	(0.50)	(0.0)	—	—	—	—	(0.32)
	6	8	4	2					20
Total	0.81	0.92	0.89	0.90	0.93	0.94	0.69	0.50	0.89
	(0.38)	(0.25)	(0.26)	(0.19)	(0.16)	(0.18)	(0.35)	(0.55)	(0.25)
	245	253	205	170	111	58	17	6	1065

[a]See Table 1 for breed designations

Table 25. Unadjusted means, standard deviations, and numbers of observations for calf survival by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	Total
A	0.86 (0.35) 29	0.96 (0.19) 28	0.96 (0.20) 26	1.0 (0.0) 26	0.91 (0.29) 22	0.92 (0.28) 13	—	—	0.94 (0.22) 144
B	0.73 (0.47) 11	0.88 (0.32) 43	0.81 (0.40) 32	0.89 (0.32) 35	0.86 (0.35) 22	0.94 (0.25) 16	0.73 (0.47) 11	0.50 (0.55) 6	0.79 (0.39) 176
H	0.88 (0.33) 40	0.89 (0.32) 27	0.96 (0.19) 28	0.97 (0.18) 31	1.0 (0.0) 29	0.83 (0.39) 12	1.0 (0.0) 3	—	0.93 (0.20) 170
N	0.50 (0.71) 2	0.83 (0.38) 24	0.69 (0.48) 16	0.80 (0.41) 15	1.0 (0.0) 6	1.0 (0.0) 3	—	—	0.80 (0.33) 66
F_1 NA	0.86 (0.35) 43	0.95 (0.23) 38	0.84 (0.37) 45	0.88 (0.32) 43	1.0 (0.0) 23	0.89 (0.33) 9	—	—	0.90 (0.27) 201
3/8N 5/8A[a]	0.89 (0.31) 76	0.98 (0.15) 47	0.91 (0.29) 23	0.60 (0.55) 5	0.75 (0.50) 4	1.0 (0.0) 2	—	—	0.86 (0.30) 157
BANH[b]	0.82 (0.39) 44	0.89 (0.31) 46	0.91 (0.28) 35	1.0 (0.0) 15	1.0 (0.0) 5	1.0 (0.0) 3	0.33 (0.58) 3	—	0.85 (0.22) 151
Total	0.79 (0.42) 245	0.91 (0.27) 253	0.87 (0.32) 205	0.88 (0.25) 170	0.93 (0.16) 111	0.94 (0.18) 58	0.69 (0.35) 17	0.50 (0.55) 6	0.87 (0.28) 1065

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 26. Least squares means and standard errors (SE) for calf survival by cow breed[a]

Cow breed	LS means ± SE
A	0.94 ± 0.03
B	0.84 ± 0.02
H	0.92 ± 0.02
N	0.80 ± 0.04
F_1 NA	0.89 ± 0.02
3/8N 5/8A(a)	0.93 ± 0.03
3/8N 5/8A(b)	0.80 ± 0.05
3/8N 5/8A(c)	1.0 ± 0.08
BANH(a)	0.87 ± 0.04
BANH(b)	0.91 ± 0.04
BANH(c)	0.86 ± 0.08
$BANH_2$	0.85 ± 0.07

[a]See Table 1 for breed designations

Table 27. Least squares means and standard errors (SE) for calf survival by cow breed group

Cow breed group	LS means ± SE
A	0.94 ± 0.03
B	0.84 ± 0.02
H	0.92 ± 0.02
N	0.80 ± 0.04
F_1 NA	0.89 ± 0.02
3/8N 5/8A[a]	0.91 ± 0.03
BANH[b]	0.88 ± 0.02

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 28. Least squares means and standard errors (SE) for calf survival by cow breed[a] by cow age

	2 yrs	**3 yrs**	**4 yrs**	**5 yrs**	**6 yrs**	**7 yrs**	**8 yrs**	**9 yrs**
A	0.86 ± 0.06	0.96 ± 0.06	0.96 ± 0.06	1.00 ± 0.06	0.91 ± 0.07	0.92 ± 0.09	—	—
B	0.72 ± 0.09	0.89 ± 0.05	0.81 ± 0.05	0.88 ± 0.05	0.86 ± 0.07	0.94 ± 0.08	0.73 ± 0.09	0.49 ± 0.13
H	0.87 ± 0.05	0.89 ± 0.06	0.93 ± 0.06	0.97 ± 0.06	1.00 ± 0.06	0.83 ± 0.09	0.99 ± 0.18	—
N	0.49 ± 0.22	0.83 ± 0.06	0.67 ± 0.08	0.80 ± 0.08	0.99 ± 0.13	1.00 ± 0.18	—	—
F_1 NA	0.86 ± 0.05	0.95 ± 0.05	0.84 ± 0.05	0.88 ± 0.05	1.00 ± 0.06	0.89 ± 0.10	—	—
3/8N 5/8A(a)	0.90 ± 0.04	0.97 ± 0.05	1.00 ± 0.08	0.50 ± 0.15	0.75 ± 0.15	0.98 ± 0.22	—	—
3/8N 5/8A(b)	0.80 ± 0.10	1.0 ± 0.11	0.75 ± 0.11	1.0 ± 0.31	—	—	—	—
3/8N 5/8A(c)	1.0 ± 0.11	1.0 ± 0.13	1.0 ± 0.31	—	—	—	—	—
BANH(a)	0.69 ± 0.09	0.92 ± 0.09	0.92 ± 0.09	0.99 ± 0.10	1.00 ± 0.14	0.99 ± 0.18	0.33 ± 0.18	—
BANH(b)	0.89 ± 0.07	0.90 ± 0.07	0.94 ± 0.08	1.00 ± 0.18	—	—	—	—
BANH(c)	0.83 ± 0.13	0.83 ± 0.13	0.99 ± 0.22	—	—	—	—	—
$BANH_2$	0.84 ± 0.13	0.87 ± 0.11	0.75 ± 0.15	1.00 ± 0.22	—	—	—	—

[a]See Table 1 for breed designations

Table 29. Least squares means and standard errors (SE) for calf survival by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs
A	0.86 ± 0.06	0.96 ± 0.06	0.96 ± 0.06	1.00 ± 0.06	0.91 ± 0.07	0.92 ± 0.08	—	—
B	0.72 ± 0.09	0.89 ± 0.05	0.81 ± 0.05	0.88 ± 0.05	0.86 ± 0.07	0.94 ± 0.08	0.73 ± 0.09	0.49 ± 0.12
H	0.87 ± 0.05	0.89 ± 0.06	0.96 ± 0.06	0.97 ± 0.05	1.00 ± 0.06	0.83 ± 0.09	0.99 ± 0.18	—
N	0.49 ± 0.22	0.83 ± 0.06	0.69 ± 0.08	0.80 ± 0.08	0.99 ± 0.12	1.00 ± 0.18	—	—
F_1 NA	0.86 ± 0.05	0.95 ± 0.05	0.84 ± 0.05	0.88 ± 0.05	1.00 ± 0.06	0.89 ± 0.10	—	—
3/8N 5/8A[a]	0.89 ± 0.04	0.98 ± 0.04	0.91 ± 0.06	0.60 ± 0.14	0.75 ± 0.15	0.98 ± 0.22	—	—
BANH[b]	0.82 ± 0.05	0.89 ± 0.05	0.91 ± 0.05	1.00 ± 0.08	1.00 ± 0.14	0.99 ± 0.18	0.33 ± 0.18	—

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Most of the estimates in Table 30 of the levels of heterosis expressed in the different cow breed classifications were near zero with large standard errors in comparison to the estimates. Although some of the estimates were slightly negative, none were significantly less than that predicted from the dominance model.

Two of the 3/8N 5/8A groups expressed more and one expressed less heterosis than predicted from the dominance model, but none were significantly different from the expected amounts. Key (2004) estimated the heterosis for calf survival as a maternal trait between Brahman and Angus and between Brahman and Hereford to be 0.04 and 0.03, respectively. Using the same logic as for calf crop born and calf crop weaned, the heterosis in the various BANH crosses would be predicted to be about 0.03 based on the dominance model. $BANH_b$ females that were the result of mating NA bulls to BH cows showed greater performance than predicted by the dominance model, but not significantly greater. The other four breed quarter blood females expressed less (although not significantly less) heterosis than predicted by the dominance model.

Table 30. Calf survival contrasts and standard errors (SE) by cow breed[a]

L	Contrast ± SE
F_1 NA vs MP[b]	0.04 ± 0.04
3/8N 5/8A(a) vs MP	0.07 ± 0.04$^{\phi}$
3/8N 5/8A(b) vs MP	-0.02 ± 0.09
3/8N 5/8A(c) vs MP	0.13 ± 0.07$^{\phi}$
BANH(a) vs MP	-0.01 ± 0.06
BANH(b) vs MP	0.05 ± 0.05
BANH(c) vs MP	-0.01 ± 0.09
$BANH_2$ vs MP	-0.02 ± 0.08
$BANH_2$ vs $\overline{BANH}$ F_1[c]	-0.03 ± 0.08

[a]See Table 1 for breed designations
[b]MP – midparent average of the purebreds in the cross
[c]BANH F_1 – average calf survival contrasts for BANH a, b, and c
Note: See Table O in appendix for LS means for calf survival by cow breed for 2-, 3-, and 4-year-old dams
ϕ P < 0.10

Table 31. Calf survival contrasts and standard errors (SE) for cow breed group differences

L	Contrast ± SE
F_1 NA vs MP[a]	0.04 ± 0.04
BANH[b] **vs MP**	0.01 ± 0.04
3/8N 5/8A[c] **vs MP**	0.06 ± 0.04

[a]MP – midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table E in appendix for LS means for calf survival by cow breed group for 2-, 3-, and 4-year-old dams
ϕ P < 0.10

Table 32. Calf survival contrasts and standard errors (SE) for 2-, 3-, and 4-year-old dams

	2 yrs	**3 yrs**	**4 yrs**
F_1 NA vs MP[a]	-0.07 ± 0.18	0.05 ± 0.06	0.02 ± 0.07
BANH[b] vs MP	-0.07 ± 0.11	0.001 ± 0.05	0.07 ± 0.07
3/8N 5/8A[c] vs MP	-0.02 ± 0.17	0.05 ± 0.06	0.05 ± 0.09

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table F in appendix for LS means for calf survival by cow breed group for 2-, 3-, and 4-year-old dams
ϕ P < 0.10

Birth Weight

Unadjusted birth weight means and numbers of observations by cow breed are in Table 33 and unadjusted birth weight means and numbers of observations by cow breed group are in Table 34. The calves out of the Nellore cows were the lightest at birth at 30.68 kg. The Angus cows produced the heaviest calves, weighing 35.29 kg. The $BANH_2$ cows produced the lightest calves of the four breed quarter blood composites at 32.93 kg. Of the crossbred cow breed groups in Table 34, the BANH females produced the heaviest calves (34.43 kg), but lighter than the Angus and Hereford females (35.29 and 34.59 kg, respectively). Tables 35 and 36 show adjusted birth weights by cow breed and by cow breed group, respectively. The Brahman and the quarter blood composite produced by mating NA bulls to HB cows had the highest adjusted birth weights at 35.60 kg. Adjusted birth weights by dam age are in Tables 37 and 38.

Table 33. Unadjusted means, standard deviations, and numbers of observations (n) for birth weight by cow breed[a]

Cow breed	Birth weight (kg)	n
A	35.29(5.66)	143
B	33.53(4.69)	173
H	34.59(6.27)	171
N	30.68(4.95)	65
F_1 NA	32.51(5.68)	201
3/8N 5/8A(a)	32.46(5.05)	105
3/8N 5/8A(b)	33.31(6.52)	36
3/8N 5/8A(c)	34.30(6.99)	16
BANH(a)	34.49(6.41)	60
BANH(b)	34.77(4.75)	57
BANH(c)	34.96(7.41)	13
$BANH_2$	32.93(4.87)	20
Average	33.65(5.77)	1060

[a]See Table 1 for breed designations

Table 34. Unadjusted means, standard deviations, and numbers of observations (n) for birth weight by cow breed group

Cow breed group	Birth weight (kg)	n
A	35.29(5.66)	143
B	33.53(4.69)	173
H	34.59(6.27)	171
N	30.68(4.95)	65
F_1 NA	32.51(5.68)	201
3/8N 5/8A[a]	32.84(5.62)	157
BANH[b]	34.43(5.71)	150
Average	33.41(5.51)	1060

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 35. Least squares means and standard errors (SE) for birth weight by cow breed[a]

Cow Breed	LS means ± SE
A	35.28 ± 0.46
B	35.60 ± 0.42
H	34.58 ± 0.42
N	30.84 ± 0.68
F_1 NA	32.59 ± 0.39
3/8N 5/8A(a)	32.51 ± 0.53
3/8N 5/8A(b)	33.18 ± 0.91
3/8N 5/8A(c)	34.01 ± 1.37
BANH(a)	34.41 ± 0.71
BANH(b)	35.04 ± 0.72
BANH(c)	35.60 ± 1.52
$BANH_2$	33.05 ± 1.22

[a]See Table 1 for breed designations

Table 36. Least squares means and standard errors (SE) for birth weight by cow breed group

Cow breed group	LS means ± SE
A	35.28 ± 0.46
B	33.60 ± 0.42
H	34.58 ± 0.42
N	30.84 ± 0.68
F_1 NA	32.59 ± 0.39
3/8N 5/8A[a]	32.82 ± 0.44
BANH[b]	34.57 ± 0.45

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 37. Least squares means and standard errors (SE) for birth weight (kg) by cow breed[a] by cow age

	2 yrs	**3 yrs**	**4 yrs**	**5 yrs**
A	30.76 ± 0.92	32.92 ± 0.95	36.24 ± 0.97	37.60 ± 0.97
B	31.63 ± 1.65	32.55 ± 0.76	34.40 ± 0.87	33.18 ± 0.84
H	28.71 ± 0.78	32.92 ± 0.95	34.72 ± 0.92	37.23 ± 0.89
N	28.59 ± 3.50	29.92 ± 1.03	32.23 ± 1.28	30.91 ± 1.28
F_1 NA	29.00 ± 0.76	32.26 ± 0.80	33.58 ± 0.74	33.55 ± 0.76
3/8N 5/8A(a)	31.87 ± 0.65	32.66 ± 0.86	34.87 ± 1.32	36.50 ± 2.47
3/8N 5/8A(b)	28.72 ± 1.57	35.66 ± 1.75	33.97 ± 1.75	—
3/8N 5/8A(c)	30.92 ± 1.75	35.26 ± 2.02	38.23 ± 4.94	46.01 ± 4.94
BANH(a)	28.71 ± 1.37	35.34 ± 1.37	35.43 ± 1.37	38.70 ± 1.56
BANH(b)	34.40 ± 1.17	34.57 ± 1.17	36.51 ± 1.24	34.75 ± 2.85
BANH(c)	34.24 ± 2.22	36.48 ± 2.03	36.49 ± 3.49	—
$BANH_2$	34.06 ± 2.02	30.70 ± 1.76	35.70 ± 2.47	34.09 ± 3.49

Table 37. Continued

	6 yrs	**7 yrs**	**8 yrs**	**9 yrs**
A	37.73 ± 1.05	40.03 ± 1.37	—	—
B	34.46 ± 1.05	35.65 ± 1.24	42.16 ± 2.86	31.66 ± 2.01
H	39.15 ± 0.92	37.97 ± 1.42	33.63 ± 1.49	—
N	30.98 ± 2.01	30.85 ± 2.85	—	—
F_1 NA	36.40 ± 1.03	32.23 ± 1.64	—	—
3/8N 5/8A(a)	36.18 ± 2.47	28.23 ± 3.48	—	—
3/8N 5/8A(b)	—	—	—	—
3/8N 5/8A(c)	—	—	—	—
BANH(a)	31.62 ± 2.21	35.11 ± 2.84	41.77 ± 2.84	—
BANH(b)	—	—	—	—
BANH(c)	—	—	—	—
$BANH_2$	—	—	—	—

[a]See Table 1 for breed designations

Table 38. Least squares means and standard errors (SE) for birth weight (kg) by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs
A	30.76 $\pm$ 0.93	32.92 $\pm$ 0.96	36.24 $\pm$ 0.98	37.60 $\pm$ 0.98
B	31.63 $\pm$ 1.66	32.55 $\pm$ 0.77	34.40 $\pm$ 0.88	33.18 $\pm$ 0.84
H	28.71 $\pm$ 0.79	32.92 $\pm$ 0.96	34.72 $\pm$ 0.92	37.23 $\pm$ 0.90
N	28.59 $\pm$ 3.52	29.92 $\pm$ 1.04	32.23 $\pm$ 1.29	30.91 $\pm$ 1.29
F_1 NA	29.00 $\pm$ 0.76	32.26 $\pm$ 0.81	33.58 $\pm$ 0.74	33.55 $\pm$ 0.76
3/8N 5/8A[a]	31.35 $\pm$ 0.57	33.52 $\pm$ 0.73	34.73 $\pm$ 1.04	38.40 $\pm$ 2.22
BANH[b]	32.55 $\pm$ 0.77	34.34 $\pm$ 0.75	36.04 $\pm$ 0.85	37.42 $\pm$ 1.24

Table 38. Continued

	6 yrs	7 yrs	8 yrs	9 yrs
A	37.73 ± 1.06	40.03 ± 1.38	—	—
B	34.46 ± 1.06	35.65 ± 1.25	33.64 ± 1.49	31.66 ± 2.02
H	39.15 ± 0.92	37.97 ± 1.43	42.16 ± 2.85	—
N	30.98 ± 2.03	30.86 ± 2.87	—	—
F_1 NA	36.40 ± 1.04	32.23 ± 1.65	—	—
3/8N 5/8A[a]	36.37 ± 2.48	28.42 ± 3.50	—	—
BANH[b]	30.84 ± 2.03	35.30 ± 2.48	41.78 ± 2.85	—

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Least squares means for 2-, 3-, and 4-year-old cows are in Tables G, H, Q, and R of the appendix. Contrast estimates for differences in cow breed for birth weight are presented in Table 39. Only the four breed quarter blood composites produced by mating NA bulls to BH or HB F_1 cows expressed significant heterosis for birth weight, which is in contrast to Gregory et al. (1999) where all three composite populations expressed significant heterosis effects for birth weight. The F_1 NA group had lower average birth weights than the parental breed average although not significantly different. Table 40 presents birth weight contrasts for differences in cow breed groups. The BANH cows expressed positive heterosis ($P < 0.01$) for birth weight, indicating that calves out of the BANH cows were heavier at birth than the average of calves out of the parental purebreds. The F_1 NA and 3/8N 5/8A calves were not significantly different at birth than the midparent values. Birth weight contrast estimates by dam age are shown in Table 41.

Table 39. Birth weight (kg) contrasts and standard errors (SE) by cow breed[a]

L	**Contrast ± SE**
F_1 NA vs MP[b]	-0.26 ± 0.69
3/8N 5/8A(a) vs MP	0.29 ± 0.73
3/8N 5/8A(b) vs MP	0.30 ± 1.46
3/8N 5/8A(c) vs MP	1.01 ± 1.16
BANH(a) vs MP	0.97 ± 0.91
BANH(b) vs MP	2.89 ± 0.79**
BANH(c) vs MP	3.38 ± 1.51°
$BANH_2$ vs MP	0.77 ± 1.29
$BANH_2$ vs $\overline{BANH}$ F_1[c]	-1.04 ± 1.34

[a]See Table 1 for breed designations
[b]MP – midparent average of the purebreds in the cross
[c]BANH F_1 – average birth weight contrasts for BANH a, b, and c
Note: See Table Q in appendix for LS means for birth weight by cow breed for 2-, 3-, and 4-year-old dams
° P < 0.05
** P < 0.001

Table 40. Birth weight (kg) contrasts and standard errors (SE) for breed group differences

L	**Contrast ± SE**
F_1 NA vs MP[a]	-0.26 ± 0.69
BANH[b] vs MP	2.03 ± 0.58*
3/8N 5/8A[c] vs MP[a]	0.37 ± 0.67

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table G in appendix for LS means for birth weight by cow breed group for 2-, 3-, and 4-year-old dams
* $P < 0.01$

Table 41. Birth weight (kg) contrasts and standard errors (SE) for 2-, 3-, and 4-year-old dams

	2 yrs	**3 yrs**	**4 yrs**
F_1 NA vs MP[a]	-1.28 ± 2.72	1.04 ± 1.13	-0.58 ± 1.05
BANH[b] vs MP	2.44 ± 1.58	2.21 ± 0.92*	1.67 ± 0.94$^{\phi}$
3/8N 5/8A[c] vs MP	0.90 ± 2.68	1.89 ± 1.06$^{\phi}$	0.04 ± 1.26

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table H in appendix for LS means for birth weight by cow breed group for 2-, 3-, and 4-year-old dams
ϕ P < 0.10
* P < 0.01

Weaning Weight

Unadjusted means for cow breed x dam age and for cow breed group x dam age are presented in Tables 42 and 43, respectively. The F_1 NA cows weaned the heaviest calves at 236.81 kg. As stated earlier, Riley et al. (2001) also reported that Nellore crossbred cows produced calves that were almost as heavy at weaning as those out of any of the other crosses in the study. The calves out of $BANH_2$ cows were also among the heaviest at weaning at 235.44 kg. Even though the calves out of Angus cows had the heaviest birth weights, they were among the lightest at weaning (208.92 kg).

Adjusted means for weaning weights are in Tables 44 through 47. Table 44 shows the adjusted weaning weights of calves by cow breed. The NA-sired four breed quarter blood composites weaned heavier calves than the BA-sired four breed quarter blood cows. Hereford and Nellore cows weaned the lightest calves at 182.98 and 181.02 kg, respectively. Table 46 shows adjusted weaning weights for cow breed x dam age, and Table 47 shows adjusted weaning weights for cow breed group x dam age. The 4-year-old $BANH_2$ cows weaned the heaviest calves at 262.87 kg. Least squares means for 2-, 3-, and 4-year-old dams for weaning weights are in Tables I, J, S, and T of the appendix.

Table 42. Unadjusted means, standard deviations, and numbers of observations (n) for weaning weight by cow breed[a]

Cow breed	Weaning weight (kg)	n
A	208.92(38.8)	135
B	213.30(35.9)	148
H	183.41(40.2)	156
N	181.35(27.7)	53
F_1 NA	236.81(29.1)	180
3/8N 5/8A(a)	202.71(29.3)	98
3/8N 5/8A(b)	212.40(29.1)	28
3/8N 5/8A(c)	207.89(27.7)	16
BANH(a)	208.83(35.1)	52
BANH(b)	224.50(36.8)	52
BANH(c)	216.29(25.5)	12
$BANH_2$	235.44(24.5)	17
Average	210.99(31.6)	947

[a]See Table 1 for breed designation

Table 43. Unadjusted means, standard deviations, and numbers of observations (n) for weaning weight by cow breed group

Cow breed group	Weaning weight (kg)	n
A	208.92(38.8)	135
B	213.30(35.9)	148
H	183.41(40.2)	156
N	181.35(27.7)	53
F_1 NA	236.81(29.1)	180
3/8N 5/8A[a]	205.20(29.1)	142
BANH[b]	219.03(34.9)	133
Average	206.86(33.7)	947

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 44. Least squares means and standard errors (SE) for weaning weight by cow breed[a]

Cow breed	LS means ± SE
A	208.68 ± 3.35
B	213.50 ± 3.09
H	182.98 ± 3.07
N	181.02 ± 5.05
F_1 NA	236.97 ± 2.83
3/8N 5/8A(a)	203.51 ± 3.61
3/8N 5/8A(b)	211.43 ± 7.14
3/8N 5/8A(c)	205.56 ± 8.99
BANH(a)	208.71 ± 5.31
BANH(b)	226.34 ± 5.05
BANH(c)	219.75 ± 10.43
$BANH_2$	235.30 ± 9.53

[a]See Table 1 for breed designations

Table 45. Least squares means and standard errors (SE) for weaning weight by cow breed group

Cow breed group	LS means ± SE
A	208.68 ± 3.35
B	213.50 ± 3.09
H	182.98 ± 3.07
N	181.02 ± 5.05
F_1 NA	236.97 ± 2.83
3/8N 5/8A[a]	205.18 ± 3.05
BANH[b]	220.20 ± 3.28

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Table 46. Least squares means and standard errors (SE) for weaning weight (kg) by cow breed[a] by cow age

	2 yrs	**3 yrs**	**4 yrs**	**5 yrs**
A	173.57 ± 5.75	182.09 ± 5.55	218.63 ± 5.75	232.19 ± 5.65
B	180.15 ± 9.92	204.89 ± 4.66	205.24 ± 5.57	215.40 ± 5.13
H	147.38 ± 4.87	147.09 ± 5.90	176.67 ± 5.57	205.55 ± 5.24
N	170.36 ± 27.80	179.11 ± 6.46	175.97 ± 8.58	183.49 ± 8.25
F_1 NA	211.92 ± 4.73	231.51 ± 4.78	245.41 ± 4.51	241.94 ± 4.67
3/8N 5/8A(a)	207.90 ± 4.02	191.24 ± 5.07	215.72 ± 7.54	—
3/8N 5/8A(b)	195.56 ± 10.22	199.58 ± 10.23	231.09 ± 12.70	245.69 ± 19.63
3/8N 5/8A(c)	194.43 ± 10.24	212.73 ± 11.77	225.40 ± 27.87	229.41 ± 27.88
BANH(a)	179.46 ± 9.48	221.63 ± 8.31	216.67 ± 8.32	209.15 ± 9.05
BANH(b)	244.48 ± 6.99	215.37 ± 6.80	221.33 ± 7.64	205.32 ± 16.17
BANH(c)	228.33 ± 12.93	214.41 ± 12.96	211.08 ± 19.94	—
$BANH_2$	227.02 ± 12.91	222.20 ± 14.41	262.87 ± 16.57	243.30 ± 19.96

Table 46. Continued

	6 yrs	7 yrs	8 yrs	9 yrs
A	236.94 ± 6.36	226.11 ± 8.04	—	—
B	226.76 ± 6.45	253.44 ± 7.30	220.94 ± 9.75	222.68 ± 15.69
H	222.09 ± 5.31	223.95 ± 8.73	248.98 ± 15.61	—
N	189.51 ± 11.46	203.85 ± 16.05	—	—
F_1 NA	255.46 ± 5.87	254.94 ± 9.73	—	—
3/8N 5/8A(a)	—	—	—	—
3/8N 5/8A(b)	235.76 ± 16.21	230.24 ± 19.65	—	—
3/8N 5/8A(c)	—	—	—	—
BANH(a)	201.59 ± 12.50	214.4. ± 15.88	253.41 ± 27.12	—
BANH(b)	—	—	—	—
BANH(c)	—	—	—	—
$BANH_2$	—	—	—	—

[a]See Table 1 for breed designations

Table 47. Least squares means and standard errors (SE) for weaning weight (kg) by cow breed group by cow age

	2 yrs	3 yrs	4 yrs	5 yrs
A	173.56 ± 5.84	182.11 ± 5.64	218.66 ± 5.84	232.21 ± 5.74
B	180.04 ± 10.10	204.91 ± 4.73	205.21 ± 5.66	215.37 ± 5.21
H	147.36 ± 4.95	147.12 ± 6.00	176.64 ± 5.67	205.57 ± 5.33
N	170.42 ± 28.31	179.10 ± 6.56	175.90 ± 8.73	183.45 ± 8.38
F_1 NA	211.94 ± 4.81	234.51 ± 4.86	254.39 ± 4.59	241.91 ± 4.75
3/8N 5/8A[a]	204.85 ± 3.56	195.63 ± 4.30	220.49 ± 6.42	239.48 ± 16.16
BANH[b]	223.97 ± 4.86	217.62 ± 4.69	223.51 ± 5.23	215.34 ± 7.38

Table 47. Continued

	6 yrs	7 yrs	8 yrs	9 yrs
A	236.90 ± 6.46	226.10 ± 8.19	—	—
B	226.74 ± 6.57	253.29 ± 7.43	220.90 ± 9.93	222.51 ± 15.99
H	222.10 ± 5.40	223.87 ± 8.89	248.86 ± 15.92	—
N	189.47 ± 11.66	203.91 ± 16.34	—	—
F_1 NA	255.46 ± 5.98	254.96 ± 9.91	—	—
3/8N 5/8A[a]	235.34 ± 16.21	229.21 ± 19.73	—	—
BANH[b]	206.50 ± 12.53	219.69 ± 16.02	255.62 ± 27.57	—

[a]Includes 3/8N 5/8A a, b and c
[b]Includes BANH a, b, c and $BANH_2$

Contrast estimates for weaning weights are presented in Tables 48, 49 and 50. All crosses expressed important ($P < 0.05$) levels of heterosis for weaning weight (Table 48). The $BANH_2$ dams produced calves that expressed important heterosis ($P < 0.0001$) at 52.01 kg above that of the midparent value. The 3/8N 5/8A cows with Angus dams showed the most heterosis of the 3/8N 5/8A cows. The F_1 NA breed group expressed the most heterosis of the breed groups at 46.02 kg ($P < 0.0001$) (Table 49). Table 50 presents the contrast estimates for weaning weight by dam age. The F_1 NA breed group had a level of heterosis ($P < 0.0001$) of 54.34 kg above that of the midparent value at 3 years of age. All breed groups at all age levels had significantly higher weaning weights than that of the midparents ($P < 0.05$).

Table 48 shows the estimated heterosis for the crossbred cows. The heterosis estimates were compared to that predicted by the dominance model like what was done for calf crop born. The 3/8N 5/8A cow breed types all expressed less heterosis than was predicted by the dominance model. The 3/8N 5/8A females produced by mating ¾ Nellore ¼ Angus bulls to Angus dams had a level of heterosis of 18.99 kg ($P < 0.05$); the dominance model predicted the cross would be 34.52 kg greater than the weighted average of the parental purebreds. The heterosis estimates for the BANH breed groups that resulted from the mating of NA bulls to BH dams were all significantly greater than the 22.71 kg advantage that was predicted by the dominance model. However, the heterosis estimate for the BANH breed group that was produced from mating BA bulls to NH cows (27.2 kg), was slightly less than the dominance model predicted (28.6 kg).

Table 48. Weaning weight (kg) contrasts and standard errors (SE) by cow breed[a]

L	Contrast ± SE
F_1 NA vs MP[b]	46.02 ± 4.83***
3/8N 5/8A(a) vs MP	17.64 ± 4.98***
3/8N 5/8A(b) vs MP	18.99 ± 9.49°
3/8N 5/8A(c) vs MP	17.25 ± 8.59°
BANH(a) vs MP	27.20 ± 6.58***
BANH(b) vs MP	45.42 ± 5.55***
BANH(c) vs MP	38.06 ± 10.40**
$BANH_2$ vs MP	52.01 ± 9.88***
$BANH_2$ vs $\overline{BANH}$ F_1[c]	24.34 ± 10.17°

[a]See Table 1 for breed designations
[b]MP – midparent average of the purebreds in the cross
[c]BANH F_1 – average weaning weight contrasts for BANH a, b, and c
Note: See Table S in appendix for LS means for weaning weight by cow breed for 2-, 3-, and 4-year-old dams
° P < 0.05
* P < 0.01
** P < 0.001
*** P < 0.0001

Table 49. Weaning weight (kg) contrasts and standard errors (SE) for cow breed group differences

L	**Contrast ± SE**
F_1 NA vs MP[a]	46.02 ± 4.83***
BANH[b] vs MP	39.83 ± 4.12***
3/8N 5/8A[c] vs MP	17.36 ± 4.68***

[a]MP - midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table I in appendix for LS means for weaning weight by cow breed group for 2-, 3-, and 4-year-old dams
*** P < 0.0001

Table 50. Weaning weight (kg) contrasts and standard errors (SE) for 2-, 3-, and 4-year-old dams

	2 yrs	**3 yrs**	**4 yrs**
F_1 NA vs MP[a]	31.80 ± 14.20°	54.34 ± 6.52***	36.16 ± 6.71***
BANH[b] vs MP	51.53 ± 8.42***	40.03 ± 5.54***	29.36 ± 5.44***
3/8N 5/8A[c] vs MP	27.96 ± 13.91°	14.65 ± 6.12°	18.16 ± 7.35°

[a]MP – midparent average of the purebreds in the cross
[b]Includes a, b, c and $BANH_2$
[c]Includes a, b and c
Note: See Table J in appendix for LS means for weaning weight by cow breed group for 2-, 3-, and 4-year-old dams
ϕP < 0.10
° P < 0.05
* P < 0.01
** P < 0.001
*** P < 0.0001

SUMMARY AND CONCLUSIONS

Calf Crop Born and Weaned

Heterosis for calf crop born and calf crop weaned by cow breed and cow breed group was estimated using linear contrasts of least squares means. All crossbred cow breed types expressed heterosis for calf crop born. Performance of all the breed types were also above the midparent values for calf crop weaned. The 3/8N 5/8A cows resulting from mating ¾ Nellore ¼ Angus bulls to Angus cows showed slightly less heterosis than predicted by the dominance model for calf crop weaned. The only cow breed types that did not express significant heterosis for calf crop weaned were the 3/8N $5/8A_b$ and $BANH_2$ cows. BANH females resulting from the mating of NA bulls to HB cows ($BANH_c$) outperformed the other BANH females for calf crop born ($P < 0.001$) and calf crop weaned ($P < 0.10$).

Across all ages of cows, heterosis was important ($P < 0.0001$) for all three breed groups for both calf crop born and calf crop weaned (Tables 13 and 22). Heterosis for calf crop born and calf crop weaned by cow breed group was also estimated using linear contrasts of least squares means within cow age groups. Heterosis was important ($P < 0.0001$) for calf crop born and calf crop weaned for two-year-old cows for the crossbred breed groups. The straightbred Nellore and Brahman cows, as two year olds, had very low calf crop born percentages due to the fact that they are later maturing.

There were differences in the performance of the different cow breed types. The 3/8N 5/8A females produced from NA and Angus dams had higher adjusted means than those produced from ¾ Angus ¼ Nellore dams for calf crop born (Table 8), but just the opposite occurred for calf crop weaned (Table 17).

Calf Survival

Calf survival was analyzed by least squares means by cow breed and cow breed group. The Angus females had the highest calf survival rate (0.94 $\pm$ 0.03) among all breed groups. Heterosis for calf survival by cow breed and cow breed group was estimated using linear contrasts of least squares means. Most of the estimates were near zero with large standard errors. Only two cow breed types expressed significant heterosis ($P < 0.10$) for calf survival. The 3/8N 5/8A females produced from mating 3/4N 1/4A bulls to Angus cows expressed less heterosis ($P > 0.10$) than predicted by the dominance model and the other two types of 3/8N 5/8A females expressed more heterosis ($P > 0.10$) than predicted by the dominance model.

Birth and Weaning Weight

Heterosis for birth weight was estimated for cow breed and cow breed group using linear contrasts of least squares means. All of the crossbred cow breed types except the F_1 NA expressed positive heterosis for birth weight, but only two were significantly different from zero ($P < 0.05$). Weaning weight heterosis was also estimated for cow breed and cow breed group using linear contrasts of least squares means. All of the 3/8N 5/8A and BANH cow breed types expressed less heterosis ($P < 0.05$) than predicted except for the BANH b, c, and $BANH_2$ females produced by mating NA bulls to F_1 or F_2 BH or HB cows. The 3/8N $5/8A_b$ females only expressed about half (18.99 $\pm$ 9.49) of what was predicted by the dominance model (34.52 kg).

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APPENDIX

Table A. Least squares means and standard errors (SE) for calf crop born for 2-, 3-, and 4-year- old dams by cow breed group

Cow breed group	LS means ± SE
A	0.92 ± 0.04
B	0.52 ± 0.03
H	0.68 ± 0.03
N	0.47 ± 0.04
F_1 NA	0.91 ± 0.03
3/8N 5/8A[a]	0.92 ± 0.03
BANH[b]	0.86 ± 0.03

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table B. Least squares means and standard errors (SE) for calf crop born for 2-, 3-, and 4-year-old dams by cow breed group by cow age

Cow breed group	2 yrs	3 yrs	4 yrs
A	0.97 ± 0.06	0.93 ± 0.07	0.87 ± 0.07
B	0.21 ± 0.04	0.77 ± 0.05	0.60 ± 0.05
H	0.80 ± 0.04	0.57 ± 0.06	0.66 ± 0.06
N	0.02 ± 0.05	0.82 ± 0.07	0.80 ± 0.08
F_1 NA	0.93 ± 0.05	0.83 ± 0.06	0.98 ± 0.05
3/8N 5/8A[a]	0.95 ± 0.04	0.87 ± 0.05	0.96 ± 0.08
BANH[b]	0.81 ± 0.04	0.87 ± 0.05	0.92 ± 0.06

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table C. Least squares means and standard errors (SE) for calf crop weaned for 2-, 3-, and 4-year-old dams by cow breed group

Cow breed group	LS means ± SE
A	0.86 ± 0.05
B	0.43 ± 0.03
H	0.61 ± 0.04
N	0.36 ± 0.05
F_1 NA	0.80 ± 0.04
3/8N 5/8A[a]	0.85 ± 0.03
BANH[b]	0.75 ± 0.04

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table D. Least squares means and standard errors (SE) for calf crop weaned for 2-, 3-, and 4-year-old dams by cow breed group by cow age

Cow breed group	2 yrs	3 yrs	4 yrs
A	0.83 ± 0.07	0.90 ± 0.08	0.83 ± 0.08
B	0.16 ± 0.05	0.68 ± 0.06	0.49 ± 0.06
H	0.70 ± 0.05	0.51 ± 0.06	0.61 ± 0.07
N	0.02 ± 0.06	0.68 ± 0.08	0.55 ± 0.10
F_1 NA	0.80 ± 0.06	0.78 ± 0.06	0.83 ± 0.06
3/8N 5/8A[a]	0.85 ± 0.04	0.85 ± 0.06	0.88 ± 0.09
BANH[b]	0.67 ± 0.05	0.77 ± 0.06	0.84 ± 0.07

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table E. Least squares means and standard errors (SE) for calf survival for 2-, 3-, and 4-year-old dams by cow breed group

Cow breed group	**LS means ± SE**
A	0.93 ± 0.04
B	0.84 ± 0.04
H	0.90 ± 0.03
N	0.76 ± 0.05
F_1 NA	0.88 ± 0.03
3/8N 5/8A[a]	0.92 ± 0.03
BANH[b]	0.87 ± 0.03

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table F. Least squares means and standard errors (SE) for calf survival for 2-, 3-, and 4-year-old dams by cow breed group by cow age

Cow breed group	2 yrs	3 yrs	4 yrs
A	0.86 $\pm$ 0.06	0.96 $\pm$ 0.05	0.96 $\pm$ 0.06
B	0.79 $\pm$ 0.09	0.88 $\pm$ 0.04	0.81 $\pm$ 0.06
H	0.90 $\pm$ 0.06	0.89 $\pm$ 0.05	0.93 $\pm$ 0.06
N	1.00 $\pm$ 0.34	0.83 $\pm$ 0.06	0.69 $\pm$ 0.08
F_1 NA	0.86 $\pm$ 0.05	0.95 $\pm$ 0.04	0.84 $\pm$ 0.05
3/8N 5/8A[a]	0.89 $\pm$ 0.04	0.98 $\pm$ 0.04	0.91 $\pm$ 0.07
BANH[b]	0.82 $\pm$ 0.05	0.89 $\pm$ 0.04	0.91 $\pm$ 0.06

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table G. Least squares means and standard errors (SE) for birth weight (kg) for 2-, 3-, and 4-year-old dams by cow breed group

Cow breed group	LS means ± SE
A	33.23 ± 0.59
B	33.18 ± 0.58
H	31.71 ± 0.54
N	30.52 ± 0.83
F_1 NA	31.61 ± 0.47
3/8N 5/8A[a]	32.58 ± 0.44
BANH[b]	34.19 ± 0.48

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table H. Least squares means and standard errors (SE) for birth weight (kg) for 2-, 3-, and 4-year-old dams by cow breed group by cow age

Cow breed group	2 yrs	3 yrs	4 yrs
A	30.65 ± 0.96	33.00 ± 1.01	36.24 ± 0.93
B	32.01 ± 1.48	32.63 ± 0.81	34.40 ± 0.84
H	28.62 ± 0.82	32.88 ± 1.01	34.70 ± 0.88
N	30.10 ± 5.14	29.41 ± 1.10	32.07 ± 1.23
F_1 NA	29.09 ± 0.79	32.24 ± 0.85	33.58 ± 0.71
3/8N 5/8A[a]	31.34 ± 0.59	33.54 ± 0.76	34.72 ± 0.99
BANH[b]	32.73 ± 0.78	34.19 ± 0.78	36.02 ± 0.80

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table I. Least squares means and standard errors (SE) for weaning weight (kg) for 2-, 3-, and 4-year-old dams by cow breed group

Cow breed group	**LS means ± SE**
A	191.14 ± 4.15
B	201.97 ± 3.91
H	156.27 ± 3.80
N	177.76 ± 5.89
F_1 NA	228.47 ± 3.43
3/8N 5/8A[a]	203.88 ± 2.99
BANH[b]	221.61 ± 3.44

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table J. Least squares means and standard errors (SE) for weaning weight (kg) for 2-, 3-, and 4-year-old dams by cow breed group by cow age

Cow breed group	2 yrs	3 yrs	4 yrs
A	169.26 ± 5.33	182.31 ± 5.60	217.87 ± 5.12
B	188.23 ± 8.28	205.89 ± 4.72	205.87 ± 5.01
H	140.13 ± 4.65	147.83 ± 6.07	168.94 ± 5.16
N	193.51 ± 26.69	178.32 ± 6.70	190.42 ± 8.39
F_1 NA	213.19 ± 4.37	234.66 ± 4.85	240.31 ± 4.23
3/8N 5/8A[a]	206.31 ± 3.22	195.46 ± 4.29	225.74 ± 5.78
BANH[b]	224.32 ± 4.40	218.62 ± 4.72	225.13 ± 4.57

[a]Includes a, b, and c
[b]Includes a, b, c, and $BANH_2$

Table K. Least squares means and standard errors (SE) for calf crop born for 2-, 3-, and 4-year-old dams by cow breed[a]

Cow Breed	LS means ± SE
A	0.92 ± 0.04
B	0.52 ± 0.03
H	0.68 ± 0.03
N	0.47 ± 0.04
F_1 NA	0.91 ± 0.03
3/8N 5/8A(a)	0.93 ± 0.04
3/8N 5/8A(b)	0.93 ± 0.07
3/8N 5/8A(c)	0.88 ± 0.09
BANH(a)	0.87 ± 0.06
BANH(b)	0.84 ± 0.05
BANH(c)	1.00 ± 0.10
$BANH_2$	0.82 ± 0.08

[a]See Table 1 for breed designations

Table L. Least squares means and standard errors (SE) for calf crop born for 2-, 3-, and 4-year-old dams by cow breed[a] by cow age

Cow breed	2 yrs	3 yrs	4 yrs
A	0.97 ± 0.06	0.93 ± 0.07	0.87 ± 0.07
B	0.21 ± 0.04	0.77 ± 0.05	0.60 ± 0.05
H	0.80 ± 0.04	0.57 ± 0.06	0.66 ± 0.06
N	0.02 ± 0.05	0.82 ± 0.07	0.80 ± 0.08
F_1 NA	0.93 ± 0.05	0.83 ± 0.06	0.98 ± 0.06
3/8N 5/8A(a)	0.95 ± 0.04	0.87 ± 0.06	1.0 ± 0.10
3/8N 5/8A(b)	1.0 ± 0.10	0.80 ± 0.13	0.89 ± 0.13
3/8N 5/8A(c)	0.89 ± 0.08	0.86 ± 0.15	1.0 ± 0.38
BANH(a)	0.81 ± 0.08	0.81 ± 0.10	0.87 ± 0.10
BANH(b)	0.83 ± 0.07	0.83 ± 0.08	0.89 ± 0.09
BANH(c)	1.0 ± 0.13	1.0 ± 0.16	1.0 ± 0.27
$BANH_2$	0.67 ± 0.11	0.89 ± 0.13	1.0 ± 0.19

[a]See Table 1 for breed designations

Table M. Least squares means and standard errors (SE) for calf crop weaned for 2-, 3-, and 4-year-old dams by cow breed[a]

Cow Breed	LS means ± SE
A	0.86 ± 0.05
B	0.43 ± 0.03
H	0.61 ± 0.04
N	0.36 ± 0.05
F_1 NA	0.80 ± 0.04
3/8N 5/8A(a)	0.87 ± 0.04
3/8N 5/8A(b)	0.79 ± 0.08
3/8N 5/8A(c)	0.88 ± 0.11
BANH(a)	0.73 ± 0.06
BANH(b)	0.77 ± 0.05
BANH(c)	0.86 ± 0.12
$BANH_2$	0.68 ± 0.09

[a]See Table 1 for breed designations

Table N. Least squares means and standard errors (SE) for calf crop weaned for 2-, 3-, and 4-year-old dams by cow breed[a] by cow age

Cow breed	2 yrs	3 yrs	4 yrs
A	0.83 ± 0.07	0.90 ± 0.08	0.83 ± 0.08
B	0.16 ± 0.05	0.68 ± 0.06	0.49 ± 0.06
H	0.71 ± 0.06	0.51 ± 0.06	0.61 ± 0.07
N	0.02 ± 0.06	0.68 ± 0.08	0.55 ± 0.10
F_1 NA	0.80 ± 0.06	0.78 ± 0.06	0.83 ± 0.06
3/8N 5/8A(a)	0.85 ± 0.05	0.84 ± 0.07	1.0 ± 0.12
3/8N 5/8A(b)	0.80 ± 0.05	0.80 ± 0.14	0.67 ± 0.15
3/8N 5/8A(c)	0.89 ± 0.13	0.86 ± 0.17	1.0 ± 0.44
BANH(a)	0.56 ± 0.10	0.75 ± 0.11	0.80 ± 0.11
BANH(b)	0.74 ± 0.08	0.74 ± 0.09	0.83 ± 0.10
BANH(c)	0.83 ± 0.16	0.83 ± 0.18	1.0 ± 0.31
$BANH_2$	0.56 ± 0.13	0.78 ± 0.15	0.75 ± 0.22

[a]See Table 1 for breed designations

Table O. Least squares means and standard errors (SE) for calf survival for 2-, 3-, and 4-year-old dams by cow breed[a]

Cow Breed	LS means ± SE
A	0.93 ± 0.04
B	0.84 ± 0.04
H	0.90 ± 0.03
N	0.76 ± 0.05
F_1 NA	0.88 ± 0.03
3/8N 5/8A(a)	0.93 ± 0.03
3/8N 5/8A(b)	0.84 ± 0.07
3/8N 5/8A(c)	1.00 ± 0.08
BANH(a)	0.85 ± 0.05
BANH(b)	0.91 ± 0.05
BANH(c)	0.85 ± 0.09
$BANH_2$	0.83 ± 0.08

[a]See Table 1 for breed designations

Table P. Least squares means and standard errors (SE) for calf survival for 2-, 3-, and 4-year-old dams by cow breed[a] by cow age

Cow breed	2 yrs	3 yrs	4 yrs
A	0.86 ± 0.06	0.96 ± 0.05	0.96 ± 0.06
B	0.79 ± 0.09	0.88 ± 0.04	0.81 ± 0.06
H	0.90 ± 0.06	0.89 ± 0.05	0.93 ± 0.06
N	1.0 ± 0.34	0.83 ± 0.06	0.69 ± 0.08
F_1 NA	0.86 ± 0.05	0.95 ± 0.05	0.84 ± 0.05
3/8N 5/8A(a)	0.90 ± 0.05	0.97 ± 0.05	1.0 ± 0.09
3/8N 5/8A(b)	0.80 ± 0.11	1.0 ± 0.10	0.75 ± 0.12
3/8N 5/8A(c)	1.0 ± 0.12	1.0 ± 0.11	1.0 ± 0.33
BANH(a)	0.69 ± 0.10	0.92 ± 0.08	0.92 ± 0.09
BANH(b)	0.89 ± 0.08	0.89 ± 0.06	0.94 ± 0.08
BANH(c)	0.83 ± 0.14	0.83 ± 0.11	1.0 ± 0.23
$BANH_2$	0.83 ± 0.14	0.88 ± 0.10	0.75 ± 0.17

[a]See Table 1 for breed designations

Table Q. Least squares means and standard errors (SE) for birth weight (kg) for 2-, 3-, and 4-year-old dams by cow breed[a]

Cow Breed	LS means ± SE
A	33.23 ± 0.59
B	33.18 ± 0.58
H	31.71 ± 0.54
N	30.53 ± 0.83
F_1 NA	31.61 ± 0.47
3/8N 5/8A(a)	32.51 ± 0.52
3/8N 5/8A(b)	32.52 ± 1.04
3/8N 5/8A(c)	33.23 ± 1.37
BANH(a)	33.13 ± 0.85
BANH(b)	35.05 ± 0.72
BANH(c)	35.55 ± 1.48
$BANH_2$	32.93 ± 1.25

[a]See Table 1 for breed designations

Table R. Least squares means and standard errors (SE) for birth weight (kg) for 2-, 3-, and 4-year-old dams by cow breed[a] by cow age

Cow breed	2 yrs	3 yrs	4 yrs
A	30.68 ± 0.94	33.01 ± 1.0	36.24 ± 0.94
B	31.76 ± 1.45	32.62 ± 0.80	34.40 ± 0.85
H	28.65 ± 0.81	32.89 ± 1.0	34.70 ± 0.89
N	29.98 ± 5.04	29.38 ± 1.09	32.07 ± 1.24
F_1 NA	29.06 ± 0.77	32.24 ± 0.84	33.58 ± 0.72
3/8N 5/8A(a)	31.83 ± 0.66	32.65 ± 0.90	34.89 ± 1.28
3/8N 5/8A(b)	28.77 ± 1.59	35.83 ± 1.83	33.96 ± 1.70
3/8N 5/8A(c)	30.96 ± 1.78	35.41 ± 2.13	38.33 ± 4.81
BANH(a)	28.83 ± 1.40	35.26 ± 1.44	35.36 ± 1.33
BANH(b)	34.58 ± 1.16	34.16 ± 1.20	36.60 ± 1.20
BANH(c)	34.10 ± 2.25	36.48 ± 2.14	36.29 ± 3.39
$BANH_2$	34.19 ± 2.06	30.65 ± 1.85	35.72 ± 2.40

[a]See Table 1 for breed designations

Table S. Least squares means and standard errors (SE) for weaning weight (kg) for 2-, 3-, and 4-year-old dams by cow breed[a]

Cow Breed	LS means ± SE
A	191.10 ± 4.01
B	201.96 ± 3.77
H	156.35 ± 3.66
N	177.75 ± 5.67
F_1 NA	230.45 ± 3.31
3/8N 5/8A(a)	203.73 ± 3.35
3/8N 5/8A(b)	205.08 ± 7.57
3/8N 5/8A(c)	203.34 ± 8.50
BANH(a)	208.96 ± 6.00
BANH(b)	227.30 ± 4.93
BANH(c)	220.05 ± 9.85
$BANH_2$	233.72 ± 9.29

[a]See Table 1 for breed designations

Table T. Least squares means and standard errors (SE) for weaning weight (kg) for 2-, 3-, and 4-year-old dams by cow breed[a] by cow age

Cow breed	2 yrs	3 yrs	4 yrs
A	169.55 ± 4.91	182.33 ± 5.62	217.97 ± 5.10
B	187.66 ± 7.63	205.84 ± 4.74	205.76 ± 4.99
H	140.66 ± 4.28	147.78 ± 6.09	169.28 ± 5.15
N	192.01 ± 24.59	178.18 ± 6.72	189.61 ± 8.38
F_1 NA	212.86 ± 4.03	234.60 ± 4.87	240.52 ± 4.22
3/8N 5/8A(a)	209.09 ± 3.39	190.90 ± 5.17	223.59 ± 6.98
3/8N 5/8A(b)	200.28 ± 8.65	200.47 ± 10.32	232.04 ± 11.35
3/8N 5/8A(c)	194.79 ± 8.59	212.91 ± 11.99	219.44 ± 25.44
BANH(a)	182.14 ± 8.11	221.11 ± 8.43	218.15 ± 7.32
BANH(b)	244.38 ± 5.94	215.44 ± 6.94	226.16 ± 6.79
BANH(c)	228.73 ± 10.87	217.15 ± 13.21	212.85 ± 17.93
$BANH_2$	228.35 ± 10.92	225.22 ± 14.67	255.93 ± 14.69

[a]See Table 1 for breed designations

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Education

TEXAS A&M UNIVERSITY; *M.S. – Animal Breeding and Genetics*
Advisor: Dr. James O. Sanders; August 2005

MONTANA STATE UNIVERSITY; *B.S. – Animal Science, Livestock Management*
Advisor: Sandy Gagnon; May 2003

UNIVERSITY OF MONTANA; *General Studies; September 1998 – May 1999*

Employment Experiences

TEXAS A&M UNIVERSITY
Department of Animal Science
Graduate Student, Research Assistant — Sept. 2003–present

ANIMAL NUTRITION CENTER
Research Assistant, data collector, data entry — Sept. 2000-May 2003

PLANT GROWTH CENTER
Research Assistant, data collector — October 1999 to May 2001

LUBE QUICK, INC.
Courtesy Tech, cashier, car care — Summers of 1999 and 2000

Teaching Experiences

TEXAS A&M UNIVERSITY
Teaching Assistant:
Animal Science 108: Introduction to Animal Science Laboratory – 1 credit
Fall 2003, Spring, Summer, Fall 2004, Spring, Summer 2005
Animal Science 305: Animal Breeding – 3 credits
Fall 2003, Spring, Summer, Fall 2004, Spring 2005

Memberships and Activities

Collegiate Cattlewomen – 2 years, MSU
Block and Bridle Club – 3 years, MSU; Ag Student Council Rep 2001, Secretary 2002