MATURE CROSSBRED COW PRODUCTIVITY AMONG GROUPS CONTAINING ZERO, ONE-FOURTH AND ONE-HALF BRAHMAN IN SPRING AND FALL CALVING SYSTEMS

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NOMENCLATURE

A	Angus
ABBA	American Brahman Breeders Association
ADG	average daily gain
B	Brahman
cm	centimeter(s)
d	day(s)
F	fall
H	Hereford
IZBA	International Zebu Breeders Association
kg	kilogram(s)
mo	month(s)
NA	not applicable
NS	non-significant
Repro	reproductive
S	spring
Spr	spring
stat	status
wk	week(s)
USDA	United States Department of Agriculture
yr	year(s)

CHAPTER I

INTRODUCTION

Within the beef cattle industry, the practice of crossbreeding has become widely accepted as a means of improving production efficiency in a commercial cow herd. Currently, a vast majority of the beef calves fed in commercial feedlots are crossbred. Unfortunately, many of these cattle are the result of crossbreeding for the sake of crossbreeding, rather than the result of breeding systems specifically designed for a particular environment and market. Limited resources available to small producers, and a lack of forethought on the part of many in the industry have resulted in herds of cows that are extremely variable in their breed make-up, especially in the Gulf Coast region where Brahman-cross cows have traditionally been quite popular. In part, because of this mongrelization of the cow herd and the resulting variability in calf crops going to market, the Brahman breed has lost considerable favor among producers and buyers as a desirable component of an effective crossbreeding program. In addition, there is considerable discussion among those involved in all segments of the beef industry as to the need for the diversity of breeds that are currently available and utilized by breeders, and to a certain extent, crossbreeding itself. Here again, the discussion revolves around the lack of uniformity in the beef products going to market. It should be noted, however, that crossbreeding conducted in a planned system can result in increased uniformity, regardless of the diversity of breeds utilized.

The advantages of a well designed crossbreeding program include the combination of favorable breed characteristics, the utilization of breed complementarity and the benefits of heterosis (hybrid vigor) expressed in the crossbred individual (Cartwright, 1970). Breed characteristics are the qualities that identify a straightbred individual with a particular breed or strain. Through crossbreeding, offspring can be produced that express the desirable characteristics of more than one breed, such that the blending of traits results in crossbred animals that have greater overall desirability than those of any of the parental breed types. This is accomplished primarily by a "masking" of characteristics that are less desirable in the parental types. Breed complementarity allows those characteristics that are desirable in the breeding female to be concentrated in female lines, whereas the characteristics that may be antagonistic to maternal productivity but beneficial in the offspring can be concentrated in the male lines. Heterosis is the deviation in performance among crossbred individuals from the mean performance of parental types. In general, heterosis results in increased overall vigor, and a tendency to adapt to stressful conditions better than straightbred animals of the same age.

Desirable characteristics of the Brahman breed include subtropic environmental adaptation, parasite and disease resistance, superior maternal ability and an overall genetic divergence from the Taurine (*Bos taurus*) breeds (Turner, 1980). Although subtropic adaptation may be of major importance to cattle producers in the southern states, other aspects would be considered more important in more temperate regions. Maternal ability, and a general lack of desirable carcass characteristics are important considerations in the development of crossbreeding programs, and would indicate the Brahman breed to be more desirable in crossbred dam lines. Genetic divergence from Taurine breeds suggests that high levels of heterosis would be expressed in both dams and offspring, a favorable attribute in any crossbreeding program. Parasite and disease resistance are characteristics that would be an advantage to producers in many regions of the country.

This study is a segment of a long term project designed to investigate the adaptability of Brahman-cross cattle to the production environments in north-central Oklahoma. Beginning in 1980, calves that contained 0, ¼ and ½ Brahman breeding were produced in a designed mating program, and females were kept to create a cow herd that allowed comparisons in maternal performance for their productive lifetime. In addition to breed type comparisons, breeding seasons were arranged such that comparisons could be made between spring- and fall-calving management systems. Previous results that have been reported include the performance of the percentage Brahman calves from birth to weaning (Bolton et al., 1987a), and from weaning to first conception (Bolton et al., 1987b), as well as the maternal performance as young cows (McCarter et al. 1990, 1991a,b,c). The objective of this segment of the study was to compare the maternal performance and season of calving effects among mature 0, ¼ and ½ Brahman cows on the basis of reproductive efficiency and weaned calf production.

CHAPTER II

REVIEW OF LITERATURE

The Development of the Brahman Breed and Its Impact on Breed Variability

In the United States, the Brahman is commonly thought of as a relatively pure breed, imported directly from India in much the same fashion as the continental European breeds, such as Charolais, Limousin and Simmental. The American Brahman, however, has an interesting history, a knowledge of which may give animal scientists and producers a better understanding of the adaptability and characteristics of the "breed." Sanders (1980) reviewed the development and history of "humped cattle" in this country, and argued that when referring to this type of cattle, the term Zebu was most appropriate, as *Bos indicus* infers a species separation from the European and other non-humped types. Although the Brahman is by far the most common and identified Zebu "breed" in this country, there are several other examples of Zebu breeds produced here to a lesser extent, including Gir, Guzerat (Kankrej in India), Nellore (Ongole in India), Sahiwal, Red Sindhi and Indu-Brazil.

The Santa Gertrudis is often referred to as the original "American breed," since it was the first developed by mixing Zebu and Taurine cattle in the southern U.S. This title more appropriately fits the American Brahman, however, as it was also developed in this country, and is part of the breed make-up of the Santa Gertrudis. Two strains of Brahman cattle were developed (Gray and Red), somewhat independently, and are today both registered by the American Brahman Breeders Association (ABBA), in Houston, Texas. According to Sanders (1980) Zebu cattle first entered this country in the early 1800s, and the first organized importation was made in 1849, by Dr. J.B. Davis of South Carolina. Small importations, such as this one, continued through the turn of the century, primarily into Louisiana and Texas, and interest grew among prominent cattlemen of the region. The only major importation (51 head), directly from India was in 1906 by A.P. Bordon, who with the help of then President Theodore Roosevelt, was able to release the surviving 30 bulls and 3 females from quarantine and move them to Texas. As most of the Zebu cattle imported earlier had been utilized in "grading up" breeding programs, this importation, primarily Nellore with some Gir and Guzerat, represents the foundation of straightbred Indian cattle contributing to the development of the Brahman breed. During the 1920s, large scale importations of Zebu cattle from Brazil, through Mexico, included 90 bulls imported in 1924, and 120 bulls and 18 heifers (7 safe in calf) in 1925. These cattle were primarily Guzerat descent, but some Gir bulls were also imported. Although some gray and red herds had been established by this time, two Guzerat bulls from these importations (Aristocrata and Imperator) had a major impact on the development of the Gray Brahman breed. Additionally, the Gir-Guzerat offspring by a red Gir bull named Red Imes (out of the 7 heifers safe in calf when imported), and the imported Gir bull, Estrella, were greatly influential in the establishment of several prominent Red Brahman herds. One other major importation was made in 1946 from Brazil. Cattle imported at this time were primarily of the Gir breed, and the Brazilian composite, Indu-Brazil breed. At that time, these two breeds were apparently quite similar in their characteristics, and there was some disagreement as to the breed origin of several prominent bulls imported. Nonetheless, several of these bulls are quite common in Red Brahman pedigrees. The ABBA was established in 1924, about the same time as the first Brazilian importations, and as mentioned earlier registers both Gray and Red Brahman cattle. A second breed association, the Pan American Zebu Association (now International Zebu Breeders Association; IZBA) was formed in 1946, primarily to promote the Indu-Brazil breed. Today, the IZBA maintains registries on six Zebu breeds: American Gray Brahman, American Red Brahman, Gir, Guzerat, Indu-Brazil and Nellore.

The development of the American Brahman appears to have been a haphazard process, as opposed to other composite breeds formed in this country. This history has resulted in the breeds greatest attributes and possibly its greatest downfall, its diversity. It has been reported that there are relatively few highly influential individuals in the breed, especially within the two types (Sanders, 1980; Wythe, 1970). One example of an individual with a tremendous impact on the breed is Manso, a son of Aristicrator, which is represented in more than ¾ of the pedigrees of registered Gray Brahman cattle. Due, however, to the wide base from which the breed was developed, and breeding practices that limited inbreeding, very few of Manso's offspring were related to this prominant sire by more than 50%, and most were somewhat outcrossed out of Guzerat-Nellore dams. This may give an indication of the genetic diversity that existed within the breed during its formation and early development.

This diversity may also be a factor in the negative image that Zebu breeds, in general, may have among scientists and producers, especially outside of the Gulf Coast region. This negative image has been supported by research results from breed comparisons of carcass characteristics (Crockett et al., 1979; Crouse et al., 1989; Wheeler et al., 1990), and a general market bias against "eared" cattle among feeder and packer buyers. Research in the area of meat science has indicated that Brahman and Brahman-influenced cattle have lower marbling ability and produce meat that is less palatable with higher shear force values than many of the Taurine breeds. These comparisons are based on mean values, and most scientists and producers have accepted this as established fact. The diversity of the breed and the history of its development, however, would suggest the possibility of greater variability among individuals in the breed for a wide variety of characteristics, including carcass characteristics. Personal experience has provided the author several examples of individual and possibly lines of sires that produced crossbred calves with desirable carcass characteristics. Although these are by no means the norm for the Brahman breed, there exists the possibility for a high degree of response to selection for the improvement of these characteristics, if indeed a large amount of variability exists within the breed, and if the superior individuals and possibly lines can be accurately identified.

Effects of the Brahman-cross Dam

Numerous studies have been conducted to evaluate the utility of the Brahman breed in crossbreeding programs. According to Long (1980), relatively few studies on the effects of crossbreeding were published prior to 1960. Early studies (Black et al., 1934; Baker and Black, 1950; McCormick and Southwell, 1957; Damon et al., 1959a,b, 1960; Cartwright et al., 1964) tended to concentrate on the estimation of breed effects and levels of heterosis in growth and carcass characteristics of crossbred calves. More recently, an interest in the attributes of the Brahman crossbred female has resulted in studies comparing the productivity of Brahman-British crossbred cows with that of straightbred and British crossbred cows. A majority of the research done in this area has been conducted in Florida, Georgia, Louisiana and Texas, but results from Nebraska, Nevada and Alberta, Canada, indicate that a certain level of Brahman influence in breeding females may have some advantages outside the Gulf Coast region.

Results from Florida and Georgia

One of the earliest studies comparing characteristics of crossbred cows was conducted at Tifton, Georgia, and reported by McCormick and Southwell (1957). In this study, a comparison was made between Angus-Hereford and Brahman-Hereford crosses for weaning, slaughter and brood cow characteristics. As calves and slaughter cattle, differences due to breed group were found only in birth weight; Brahman-Hereford calves weighed approximately 4 kg more than Angus-Hereford calves. Performance as brood cows, however, indicated that there was little difference in birth or carcass characteristics of their calves, but that the Brahman-cross cows weaned calves that were slightly more than 31 kg heavier than the Angus-cross cows. Although these results were based on a limited number of observations (90 birth, 57 weaning and 29 carcass), this study represented a beginning for findings in the eastern Gulf

Coast states in which Brahman-cross females were superior to British-cross cows in weaned calf production.

Several studies in Florida have compared the productive efficiency of various crosses between Brahman and Shorthorn (Koger et al., 1962; Peacock et al., 1971; Koger et al., 1975). Results reported from the first study (Koger et al., 1962) indicated that Brahman-Shorthorn F_1 cows weaned from 17.1 to 24.1% more calves per cow bred than straightbred Brahman and Shorthorn, and crossbred ¾ Brahman and ¾ Shorthorn cows. Peacock et al. (1971) later reported weaning rates of 71, 80, 76 and 75% for straightbred, ¾, ½ and ¼ Brahman cows, respectively, vs. 64% for straightbred Shorthorn cows, indicating not only a striking advantage for cows containing Brahman breeding, but a 16.3% advantage for crossbred cows over the average of the two purebred groups. In this study, the effects of pasture programs (native and two levels of improved pasture) interacted with cow breed type as the advantage for crossbred cows was greater on improved pastures than on native forages. In the third study, Koger et al. (1975) reported percentages of F_1 individual and maternal heterosis for calf age at weaning (3 and 1%, respectively), 205-d adjusted weight (21 and 21%, respectively), weaning rate (4 and 17%, respectively) and annual production per cow (26 and 44%, respectively). Individual breed additive effects for Brahman were negative for calf age at weaning, and positive for calf growth; maternal breed additive effects were positive for Brahman in all traits, except calf age at weaning.

Another report from Florida investigated the question of age at puberty in Brahman and Brahman-cross heifers (Plasse et al., 1968). In this study, straightbred Brahman heifers reached puberty 2.4 months later than Brahman-Shorthorn crossbred heifers (19.4 vs. 17 months of age). Additionally, the straightbred Brahman heifers were more variable in the age at which they reached puberty (14 to 24 months of age) than were the crossbred heifers (15 to 20 months of age). The authors also reported a negative correlation between 205-d adjusted weaning weight and age at puberty that ranged from -.46 in the straightbreds to -.41 in crossbreds. This study provided early evidence that the problems of later puberty observed in straightbred Brahman heifers could at least be partially overcome by crossbreeding Brahman with British breeds.

Rotational crossbreeding systems were investigated in Florida by Crockett et al. (1978a,b). In this two-part study, two-breed rotational crossbreeding systems were set up for all three combinations of Angus, Brahman and Hereford, and were compared to straightbred contemporaries of the three breeds. The results presented were from the first three generations of rotational crosses, and contemporary generations of the straightbred groups. For pregnancy rate, the crossbred cows averaged a 4% advantage over straightbred cows, with a range of 3 to 5% advantage within generations. This result was somewhat deceiving, as the lesser performance of the straightbreds was completely attributable to the straightbred Brahmans. Among the individual breed groups, straightbred Angus and Hereford groups, and Angus-Hereford crossbreds averaged 1.2 to 6.1% greater pregnancy rates than the Angus-Brahman and Brahman-Hereford crossbred groups. When the straightbred Brahman group was excluded (63.2% weaning rate), the remaining groups were similar in their weaning rates, ranging from 77.5% (Brahman-Hereford crossbreds) to 82.7% (Angus-Hereford crossbreds). This improvement in performance was attributed to superior calf survival among crossbred calves. Birth weights were higher among the Brahman crossbred groups (30.4 and 32.4 kg for Angus-Brahman and Brahman-Hereford, respectively) than among any of the other groups (ranged from 23.9 kg for straightbred Angus to 28.8 kg for straightbred Brahmans), and heterosis for birth weight was estimated to be 15, -3 and 14% for Angus-Brahman, Angus-Hereford and Brahman-Hereford crosses, respectively. Similar breed group rankings were observed for weaning weight, except that Angus-Hereford calves were heavier at weaning than any of the straightbred calves (182.1 vs. 171.2 to 174.9 kg) and heterosis for weaning weight was estimated to be 17, 5 and 18% for Angus-Brahman, Angus-Hereford and Brahman-Hereford calves, respectively. Cow production efficiency was calculated as the product of pregnancy rate, calf survival rate, and weaning weight, divided by cow weight at weaning. Overall, the weaning efficiency of crossbreds was superior to that of straightbreds (37 vs. 32%, respectively), and all crossbred groups exceeded straightbred groups (36 to 39% vs 26 to 35%, respectively). These results demonstrated that even if Brahman crossbred cows did not perform as well from a reproductive standpoint, efficiency of weaning was greater among these groups because the additional weight weaned was greater than the losses due to reproductive failure.

In another series of papers from Florida, a diallel incorporating Angus, Brahman and Charolais was used to study the effects of crossbreeding systems utilizing a continental European breed. Reproductive performance among first cross matings and preweaning performance of first cross calves were reported in Peacock et al. (1977) and Peacock et al. (1978). Female calves resulting from these matings were kept for breeding, and mated to sires of each of the three breeds. Calving rate and weaning rate were greater in Angus-Brahman (92 and 87%, respectively) and Brahman-Charolais crossbreds (90 and 84%, respectively) than for any of the straightbreds or the Angus-Charolais cows (Peacock and Koger, 1980). Maternal heterosis among Angus-Brahman cows was 8.7 and 12.2% and among Brahman-Charolais cows was 9.2 and 6.9% for calving and weaning rates, respectively. Among the crossbred dam groups, calves sired by Charolais bulls had the greatest 205-d adjusted weights, and mating system means were 184.0, 199.1, 205.2 and 211.8 kg for straightbred, first-cross, backcross and three-breed cross calves, respectively (Peacock et al., 1981). Individual heterosis estimates for 205-d weight among calves out of Angus-Brahman and Brahman-Charolais cows were 20.7 and 17.5 kg, respectively. Maternal heterosis estimates for Angus-Brahman, Angus-Charolais and Brahman-Charolais cows were 24.3, 8.6 and 9.9 kg, respectively. Mating systems ranked the same for production efficiency as for 205-d weight, and ranged from 34% for straightbreds to 43% for three-breed crosses. Among the backcross groups, Angus-Brahman cows ranked the highest with efficiency rates of 45 and 46% for Angus- and Brahman-sired calves, respectively, but Angus-Charolais cows were more efficient among the three-breed systems, although Angus-Brahman and Brahman-Charolais cows were comparable (45 vs. 44 and 40%, respectively). These results indicated that Brahman-cross cows were similar or superior in performance when compared to crossbred cows containing continental European breeding.

The most recent series of papers from Florida were reports on individual and maternal genetic effects among Brahman and Angus, straightbred and crossbred dams. Using the Angus effect as a base, Olson et al. (1990) reported an additive breed effect on pregnancy rate of 6% for Brahman dams. Heterosis for this trait was estimated from various crosses between the two breeds to be 25%. The Brahman breed effect and heterosis for calf age at weaning were both negative (7.24 and 6.41 d, respectively), indicating that Brahman and crossbred dams tended to calve later in the season. Estimates for birth and weaning weights were reported by Elzo et al. (1990a). The individual and maternal additive effects of Brahman on birth weight were 2.99 and -2.71 kg, and individual and maternal heterosis effects were .52 and 2.85 kg, respectively. Corresponding effects on weaning weight were 4.80, 13.56, 9.47 and 20.95 kg, respectively. These results indicate that compared to individual genetic effects, maternal genetic effects are generally of greater magnitude for birth and weaning weights of calves resulting from crosses between these two breeds.

<u>Results from Louisiana</u>

During the 1960s, a four-breed diallel was constructed using Angus, Brahman, Brangus and Hereford and experimental results were reported by the Louisiana beef cattle group. Turner et al. (1968) studied heterosis expressed by crossbred cows for calving rate, and reported that crossbred cows exceeded straightbreds by 9.6%, overall, and that breed group differences in death loss of calves were non-significant. In the determination of the level of heterosis expressed for the individual crosses, no differences between reciprocal cross groups were detected. Heterosis for calving rate was statistically different from zero for the crossbred groups involving Brahman (12.1, 11.6 and 18.8% for Angus-Brahman, Brahman-Brangus and Brahman-Hereford cows, respectively), but not for the other three groups (5.6, 6.6 and 8.4% for Angus-Brangus, Angus-Hereford and Brangus-Hereford cows, respectively).

Respective calving and weaning rates were 66.0 and 60.8% for straightbred cows, and 75.6 and 70.3% for crossbred cows.

During this experiment, a total of five sire breeds (Angus, Brahman, Brangus, Charolais and Hereford) were utilized to produce calves out of crossbred cows that were the result of either backcrosses or three-breed crosses. Turner and McDonald (1969) reported on the performance of the different crossbred dam groups with respect to birth and weaning characteristics of their calves. Data from steer and heifer calves were analyzed separately due to an apparent breed group × sex of calf interaction, but this effect was generally a magnitudinal difference between the sexes among the different breed types. Although no specific comparisons were made, some general observations were noted. Charolais-sired calves were heaviest and Angus-sired calves were the lightest at birth and weaning, and crossbred cows containing Brahman weaned heavier calves than cows of the other breed groups. Turner (1969) compared the birth and weaning characteristics of calves out of reciprocal cross cows among the breed types represented in this herd. He reported that, in general, calves were heavier at birth and weaning if their dams were out of Brahman or Brangus cows, but that differences were small and non-significant. Maternal heterosis effects were reported by McDonald and Turner (1972). For birth weight, significant heterosis was detected among individual crosses, within specific calf sire breed groups, but overall, the effect was reported to be non-significant. Significant levels of maternal heterosis were detected in all dam groups except among Angus-Brangus cross cows. The reported effects were 18.1, 8.1, 13.7, 28.8 and 9.9 kg for Angus-Brahman, Angus-Hereford, Brahman-Brangus, Brahman-Hereford and Brangus-Hereford cross cows, respectively. These studies provided evidence that in brood cows, crosses between Brahman and British breeds generally resulted in higher levels of preweaning calf performance than crosses among British breeds. Variability in the comparative performance among specific crosses involving Brahman, however, indicated that breed selection in a crossbreeding system was an important consideration.

Results from Texas

Cartwright et al. (1964), Ellis et al. (1965) and Roberson et al. (1986) reported on a 20 year study in Texas, begun in 1950, involving straightbred Brahman and Hereford matings, first crosses with straightbred sires and dams, backcrosses using F_1 sires and dams, and F_2 crosses. Results from the first 11 years of the study indicated a 6.5% (8.1% maternal heterosis) advantage for crossbred dams in calving rate (Long, 1980, adapted from Cartwright et al., 1964). A negative maternal heterosis effect was noted on birth weight, as crossbred backcross calves out of crossbred dams were 5.5% heavier at birth than the average of the two straightbred groups, but their contemporaries out of straightbred dams were 8.2% heavier (Ellis et al, 1965). Weaning weight information from the same time period, however, indicated a 15.5 kg (8.7%) overall advantage for calves out of crossbred dams when compared to the average of contemporaries out of straightbred dams (Long, 1980, adapted from Cartwright et al., 1964). Roberson et al. (1986) reported results from the entire duration of the study, and described direct and maternal additive effects of Brahman as deviations from Hereford means for birth weight, preweaning gain and weaning weight (adjusted to 180 d). Levels of individual and maternal heterosis were also reported. The Brahman direct additive effects were 4.6, -17.7 and -12.9 kg for birth weight, total preweaning gain and weaning weight, respectively. Maternal additive effects were -7.5, 20.0 and 13.1 kg, respectively for the same traits. Levels of individual and maternal heterosis for birth weight were 2.2 and .6 kg, respectively (both less than 10%). For preweaning gain and weaning weight, levels of heterosis were considerably greater at 19.6 and 21.6 kg, respectively for individual and 19.5 and 19.8 kg, respectively for maternal heterosis (all greater than 10%). An additional result from this study included the effect of season of calving. Calving took place during early spring (January to March), late spring (April to June) and late fall (October to December). Overall, birth weights were greater in late spring (34.2 kg) than in either early spring (32.5 kg) or late fall (32.1 kg). Season effects were opposite for total preweaning gain (144.2, 154.3

and 154.3 kg, respectively) and for weaning weight (179.7, 188 and 187.5 kg, respectively). Results presented in these papers provided evidence that the individual and maternal heterosis effects were greater for preweaning growth and weaning weight than for birth weight, indicating that systems utilizing Brahman-cross cows should result in high calf growth rates, without substantially affecting calving difficulty.

Another long term study from Texas incorporated a five-breed diallel breeding design to obtain cows of diverse biological types. The breeds utilized in the diallel were Angus, Brahman, Hereford, Holstein and Jersey. Twenty-five cow types were established, five straightbred and 20 crossbred, and cows were bred and calved year-round, so that differences in calving interval and other reproductive characteristics could be determined from a "physiological standpoint," rather than introducing the artificial effects of a breeding season (McElhenney et al., 1985). Calves for the first three cow parities were produced by *inter se* matings (McElhenney et al., 1985), and subsequent matings were by Charolais and Red Poll sires (McElhenney et al., 1986). Results indicated non-significant differences among reciprocal cross cow types for all characters measured, so results were reported on a breed cross basis (15 total types, 5 straightbred and 10 crossbred). Heterosis was reported only as averaged over all crossbred types, so provides little useful information for the purposes of this review. Some notable observations were reported, however, indicating differences in performance of crosses involving Brahman as contrasted to other types of interest in this review.

McElhenney et al. (1985) reported results from *inter se* matings during the first three parities of cows. Angus-Brahman and Brahman-Hereford cows were older and heavier at first calving than Angus-Hereford cows (940, 1012 and 816 d of age, and 433, 499 and 409 kg for breed groups, respectively). Among these three groups, calving interval to the second and third parities was also longer for the Brahman-cross groups than for Angus-Hereford cows (447 and 450, respectively vs. 406 d). For young cows, a comparison of crossbred and straightbred means revealed no difference in calving difficulty. When Brahman and Brahman-cross cows were excluded, however, an increase in cow size was associated with an increase in calving difficulty, indicating a positive Brahman influence on this character. Young Brahman cows had the least calving difficulty among the groups, and their calves were lighter at birth than any of the groups except straightbred Jersey. Angus-Brahman and Brahman-Hereford cows produced calves that were comparable in birth weight to Angus-Hereford cows (29.9, 32.1 and 32.2 kg, respectively), however, the percent of difficult births was higher among the young Angus-Hereford cows (8.4% vs. 5.0 and 4.0% for young Angus-Brahman and Brahman-Hereford cows, respectively). Preweaning daily gain and weaning weight differences between these three breed groups were observed. Calves out of Angus-Brahman (803 g) and Brahman-Hereford cows (812 g) had greater daily gains than calves out of Angus-Hereford cows (755 g). This resulted in age-adjusted weaning weights (185 d) of 193.8, 198.0 and 186.7 kg for the breed groups, respectively. Calves by ½ Brahman cows were also taller at weaning than those out of Angus-Hereford cows (106.6 and 107.7, respectively vs. 101.4 cm). As mature cows (fourth and greater parities), an interesting change was observed in the reproductive performance of cows in these three breed groups. During this phase of the study, cows were bred to sires of two outside breeds; Charolais, to represent a breed of large mature size, or Red Poll to represent a breed of moderate size (McElhenney et al., 1986). The length of the mean calving interval increased to 436 d among Angus-Hereford cows, whereas among Angus-Brahman and Brahman-Hereford calving interval decreased to 375 and 391 d, respectively. Additionally, Brahman-cross cows in general had calving intervals that were 32 d shorter than the mean of the other crossbred cow groups. The maternal influence of Brahman on calf birth weight was maintained, as both Angus-Brahman and Brahman-Hereford groups bore calves with a 32.0 kg mean birth weight, but calves by Angus-Hereford cows averaged 34.6 kg at birth. Differences in calf weaning characteristics were similar to those observed when the cows were younger. For Angus-Hereford, Angus-Brahman and Brahman-Hereford cow groups, mean weaning weights were 204.9, 213.7 and 219.5 kg, mean preweaning average daily gains were 843, 892 and 921 g, and mean weaning hip heights were

105.1, 109.2 and 109.6 cm, respectively. Results from this segment of this study revealed that significant levels of heterosis are maintained in inter se matings among a wide variety of crossbred types of cattle. Additionally, and more importantly for the purposes of this review, poor reproductive performance (expressed as longer calving intervals) observed in some young Brahman-cross cows, was not continued into maturity, and in fact the two groups discussed in this review actually performed better than the British beef breed crossbred cow group (had shorter calving intervals).

Rohrer et al. (1988a) defined productive longevity as the "age at which a cow dies or is culled because she presumably is incapable of weaning another calf due to physical weakness or subfertility." For this character, Rohrer et al. (1988b) reported an average advantage of 829.2 d for crossbred dams over straightbred dams, among groups involved in the diallel. The additive breed effects for Angus, Brahman and Hereford were 497.5, 407.9 and 384.3 d, respectively, using the average of all straightbreds as a base (both dairy breeds had negative additive breed effects). Levels of heterosis for longevity were 666.0, 866.6 and 781.6 d, resulting in a general combining ability of 85.5, 241.4 and 144.5 d for crosses involving the three beef breeds, respectively. Specific combining abilities were 13.3, -104.7 and -350.7 d for Angus-Brahman, Angus-Hereford and Brahman-Hereford crosses, respectively. Productive life spans of straightbred Angus, Brahman and Hereford cows were estimated to be 10.29, 9.66 and 9.79 yr, respectively. Among the crossbred groups, Angus-Brahman cows were estimated to have the longest productive life (14.65 yr), followed by Brahman-Hereford (13.22 yr) and Angus-Hereford (11.68 yr). Using the number of cows in each breed group at the beginning of the study as a base, 37.5, 21.7 and 38.5% of Angus-Brahman, Angus-Hereford and Brahman-Hereford cows, respectively, remained in the herd after 14 yr. These results indicated that Brahman-cross females were productive longer than British beef breed-crosses.

Another study in Texas was designed to evaluate different Zebu breeds for effects on crossbred cow productivity. Angus, Gray Brahman and Red Brahman bulls (along with Gir, Indu-Brazil and Nellore bulls) were mated to Hereford cows to produce F_1 females for comparisons among crossbred cow groups (Elizondo, 1989). Although all Gray and Red Brahman bulls were registered by the ABBA, these two groups were treated as different breeds, because of differences in their development in this country (Sanders, 1980). Results reported, to date, are from cows that were six years of age, or younger (Elizondo, 1989). Calves out of crossbred cows were sired by Charolais or Salers bulls, but results of interest in this review were pooled across sire breeds, as the interaction between dam and sire breed groups was non-significant. As was indicated in the diallel study discussed previously, differences in calf birth weight among the dam breed groups were small (37.6, 37.5 and 34.8 kg for Angus-, Gray Brahman- and Red Brahman-Hereford dams, respectively). Although not analyzed statistically due to low numbers of observations, the incidence of calving difficulty among first parity heifers was reported to be greater in the Angus-Hereford dams (60% assisted) than in any of the Zebu-cross groups (25 and 10% of Gray and Red Brahman-Hereford dams assisted, respectively). Differences in weaning characteristics were substantially greater, however, as calves out of all Zebu-Hereford dams were heavier and taller at weaning than those out of Angus-Hereford dams. Gray and Red Brahman-Hereford dams weaned calves that weighed 248.8 and 252.0 kg, and were 115.4 and 116.5 cm, respectively, whereas calves out of Angus-Hereford dams weighed 218.3 kg and were 109.9 cm tall at weaning. These results provided supporting evidence for the desirable birth and weaning characteristics of calves out of Brahman-cross cows, and demonstrated that even when continental European breeds of sire are mated to first parity heifers, calving difficulty is greatly reduced in Zebu-cross females, compared to Angus-Hereford cows.

Results from Nebraska, Nevada and Alberta

Results from the Germ Plasm Evaluation Program conducted at the USDA R.L. Hruska Meat Animal Research Center, Clay Center, Nebraska, comprise the most extensive cattle breed comparison study conducted in this country. Cundiff et al. (1985) presented observations on maternal performance among crossbred dams by diverse breeds of sire. All cows in this phase of the study were out of Angus and Hereford dams, and the breeds of sire compared were Angus, Hereford, Jersey, Red Poll, South Devon, Tarentaise, Pinzgauer, Sahiwal, Brahman, Brown Swiss, Gelbvieh, Simmental, Maine Anjou, Limousin, Charolais and Chianina. Sahiwal is a Zebu breed. Considerably smaller in mature size than Brahmans, this breed is known for its high milk production in females, as it was developed as a dual purpose breed (draft and dairy). The matings made to produce the F_1 cows used in these comparisons were conducted in three cycles, with the same Angus and Hereford sires used in all three cycles, and the remaining breeds distributed among the cycles. All calves used for comparisons were three-breed-crosses by a variety of sire breeds. Performance means for the characters considered were simply corrected for differences among the cycles in the reference dam breed group (Angus-Hereford), therefore comparisons are observational descriptions, and not necessarily statistically sound. Brahman- and Sahiwal-cross dams were found to be among the most favorable in reproductive performance, with calving rates of 94 and 95% and weaning rates of 86 and 89% for the breed crosses, respectively. These compared to rates for Angus-Hereford dams of 91 and 84%, respectively. Calving difficulty was extremely low in the Brahman-cross group, with only 1% assisted births, compared to 13% assisted in the Angus-Hereford group, and 7 to 17% among the other non-Zebu breed crosses (Sahiwal-crosses had 2% assisted births). The mean birth weight for progeny of Brahman-cross cows was 37.7 kg, ranking them third from the lowest, and was comparable to progeny of Angus-Hereford cows (39.1 kg). Sahiwal-cross dams had calves that were the lightest at birth (34.5 kg). Brahman-cross cows ranked second in daily milk production (4.1 kg), behind Jersey-cross cows (4.2 kg), and slightly above crosses containing dual-purpose breeds (Brown Swiss, Gelbveih and Simmental, 3.8 kg for all three breeds, and Sahiwal, 3.9 kg). These were all well above the Angus-Hereford dams which produced 2.8 kg per day. Mean cow weight for the Brahman-cross cows (583.6 kg) was intermediate to other crossbred groups, but slightly greater than Angus-Hereford (556.4 kg) and Sahiwal-cross cows (508.6 kg). Progeny of the Brahman-cross dams had the greatest adjusted 200-d weights (245.0 kg), and were considerably heavier than calves out of Angus-Hereford dams (215.9 kg). Sahiwal-cross dams weaned calves that had adjusted weaning weights of 228.2 kg. Combining weaning weight information with weaning rate, Brahman-cross dams also produced the most calf weight per cow exposed (210.5 kg). Although these results are simple observations, they indicate that Brahman-cross females may be effectively utilized and improve production efficiency over other crossbred types in regions more temperate than the Gulf Coast.

Setshwaelo et al. (1990) compared three-breed cross cows out of ten types of F_1 crossbred cows, by Brahman, Devon, Holstein, Brangus and Santa Gertrudis sires, that were produced as offspring in the Germ Plasm Evaluation Program. Effects of breeds of sire and maternal grandsire were discussed, but for this review, only the effects of sire breeds were germane. Expressed as estimated deviations from the mean of Angus- and Hereford-sired dam breed groups, ½ Brahman cows had a 1.3% greater conception rate, but weaned 0.5% fewer calves, neither of which were significantly different from zero. Progeny of ½ Brahman dams were 1.6 kg lighter at birth, and the incidence of calving difficulty was 14.7% less frequent in this group. The calf weaning weight effect was estimated to be a 24.7 kg advantage for ½ Brahman cows, and 21.4 kg more calf weight was produced in this group, per cow exposed to breeding; these two deviations were exceeded only by the ½ Holstein dam group. The ½ Brahman cows were 35.6 kg heavier than Angus- and Hereford-sired cows. The authors surmised that larger size observed and greater milk production potential assumed for dams in the Brahman- and Holstein-sired groups would result in greater nutrient requirements to maintain the level of production that was observed. They therefore suggested that these crossbred types may be less efficient from an economic standpoint. Results, however, did support earlier evidence that Brahman-sired cows may express high levels of productivity in a temperate environment.

Another study comparing the maternal performance of Brahman-cross cows to that of various other crossbred types was conducted in Nevada. Bailey et al. (1988) reported the reproductive performance and weaned calf production of young cows through their third parity. Straightbred Hereford and Red Poll, and crossbred Angus-Hereford, Angus-Charolais, Brahman-Angus, Brahman-Hereford and Hereford-Red Poll groups were used for comparisons. First parity heifers produced progeny by Red Angus sires, while progeny from the second and third parities were by Santa Gertrudis sires. As straightbred Hereford and crossbred Angus-Hereford cattle are commonly produced in the area, linear contrasts were made for selected crossbred types with straightbred Herefords and with Angus-Hereford crossbreds. Brahman-Angus cows were heavier than Hereford cows by 15 kg, but lighter than Angus-Hereford cows by 8 kg (non-significant), at the end of the breeding season following their third parity. Brahman-Hereford cows were heavier than cows in both comparison groups by 37 and 14 kg, respectively. Both of the Brahman-cross groups were similar to the Angus-Hereford group for calving and weaning rates, but Angus-Brahman cows were superior to the Hereford group by 17% at calving and 11% at weaning; Brahman-Hereford cows were superior by 17 and 16%, respectively. Calves out of Angus-Brahman and Brahman-Hereford cows weighed 5.4 and 2.7 kg less at birth, respectively than progeny of Hereford cows. Mean weaning weights were similar for all three groups in this comparison. Angus-Hereford cows had calves that were heavier than progeny of Angus-Brahman cows by 5.2 and 11.8 kg at birth and weaning, and progeny of Brahman-Hereford cows by 2.6 and 6.0 kg, respectively. Cow efficiency, defined as weaning weight multiplied by weaning rate, was greatest for Brahman-Hereford dams (185 kg), followed by Angus-Hereford dams (182 kg) and Brahman-Angus dams (168 kg). Straightbred Hereford cows were the least efficient of all groups, producing 147 kg of calf weaning weight per cow exposed to breeding. Bailey (1991) reported on the productive longevity of the cows in the study, and found that after 10 yr, 87% of Brahman-Hereford cows and 75% of Angus-Brahman cows were still productive, whereas only 48.5 and 70.7% of Hereford and Angus-Hereford cows, respectively, remained in the herd. Additionally, Angus-Brahman and Brahman-Hereford cows, on average, weaned 6.22 and 6.96 calves respectively, before they were removed, compared to 4.54 and 5.98 calves for Hereford and Angus-Hereford cows, respectively.

Finally, an older report was made by Peters and Slen (1967) on the performance of Brahman-British cross cows in Alberta, Canada. For this study, Angus, Hereford and Shorthorn cows were mated to Brahman bulls to produce F_1 calves. Levels of performance of these calves were compared to straightbred Hereford calves as generation 1. Of interest in this review, however, was generation 2, where the three types of crossbred females and Hereford cows were mated to Hereford sires to produce straightbred, backcross and three-breed-cross calves. In generation 3, ¼ Brahman cows were compared to straightbred Herefords. In generation 2, Angus-Brahman and Brahman-Shorthorn cows exhibited weaning rates of 80 and 89%, respectively, compared to the Hereford and Brahman-Hereford cows which had weaning rates of 62 and 63% respectively. The poor performance of the Brahman-Hereford crossbred cows indicated a large individual heterosis effect for this trait, as the calves produced by these cows were the result of a backcross. Birth weights were similar among all breed types, but crossbred cows weaned calves that weighed 191, 184 and 195 kg for Angus-Brahman, Brahman-Hereford and Brahman-Shorthorn cows, respectively. These weights compared very favorably to the weights of straightbred Hereford calves (150 kg). Combining weaning weights with weaning rates, Brahman-Shorthorn, Angus-Brahman and Brahman-Hereford cows were 87, 64 and 25% more efficient than Hereford cows. Results from generation 3 indicated that the crossbred advantage remained, even with only ¼ Brahman represented in the cows, as cows out of Brahman-Shorthorn, Brahman-Hereford and Angus-Brahman dams were respectively 54, 47 and 38% more efficient than Hereford cows. Although the comparisons between straightbred Herefords and the crossbred groups were completely confounded with heterosis, these results indicated that Brahman-cross cows could adapt and be extremely productive even under the environmental conditions of Western Canada.

A Perspective on Future Research Needs

From the literature reviewed, it is obvious that breed effects of the Brahman and levels of heterosis among Brahman-crosses result in highly productive brood cows, and that their adaptability ranges far outside the Gulf Coast region. Many questions, however remain unanswered in the scientific literature. Among those most obvious concerns the economic consequences of incorporating Brahman into a crossbreeding program. Several authors of reports reviewed raised this question. Setshwaelo et al. (1990) even went so far as to compare Brahman-cross cows to Holstein-cross cows and commented that the extremely high level of production in these two crosses may have a negative impact on the economic feasibility of their practical use. Due to the experimental design and practical management practices used in most breed comparison studies, different breed groups involved in the studies are generally maintained together, making differential determination of inputs required an impossible task. Rohrer et al. (1988a) indicated that some of the cows from each of the breed types in the five-breed diallel were removed for a period of time to determine differences in nutritional maintenance requirements, but reports of results have not been published at this time. This information would be of considerable value in the investigation of economic aspects of production efficiency, but a more practical approach may be of greater value. One possible approach would be to manage different breed groups separately, and attempt to maintain a similar (or at least an acceptable) level of reproductive performance, and measure the level of inputs required compared to the level of total production attained. Computer simulation is another approach, but without accurate information on the differential requirements of the various breed types, this approach leaves something to be desired. This lack of information becomes even more important when Zebu-crosses are involved, as evidence suggests differences in the nutritional physiology of Zebu and Taurine cattle, especially in stressful environments (Turner, 1980; Leng, 1990).

Differences in the disposition of Zebu and Taurine cattle undoubtedly exist and are an important consideration for many producers. This has long been a contributing factor to the negative image of Zebu and Zebu-cross cattle in this country, and is probably one of the most evident reasons that Zebu cattle are not more common in crossbreeding programs (Turner, 1980). Contrary to popular belief, Zebu cattle are generally quite docile. They tend, however, to be easily excited and respond to psychological and physical stresses much differently than Taurine cattle. Some behavioral aspects are believed to be heritable, suggesting that selection may be able to reduce the incidence of extreme cases. This may be an expensive alternative for producers, however, as this adds one more characteristic on which one must select, reducing the efficiency of overall selection for other economically important traits. A better understanding of the behavioral characteristics of Zebu cattle is undoubtedly needed, if these breeds are to be more generally accepted for their desirable aspects.

Finally, Zebu cattle, in general, and the Brahman breed, more specifically, are recognized in this country as a cattle that are utilized to improve the production efficiency in warm, humid, subtropical environments. This is due to unique physiological characteristics that do not exist in the Taurine breeds. A better understanding of these physiological differences is needed, especially as they relate to the reproductive process and the adaptability to temperature extremes. Zebu cattle, especially straightbreds, are considered to be less reproductively efficient than Taurine breeds. They also respond differently to treatments that alter the reproductive process (e.g. estrus synchronization, and multiple ovulation and embryo transfer). Research in this area could result in more efficient techniques for managing these cattle for improved reproductive performance. Due to the adaptability of these cattle to hot and humid environments, they also provide a unique model for understanding the physiology of temperature tolerance.

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CHAPTER III

PRODUCTIVITY OF MATURE CROSSBRED FEMALES WITH VARIOUS PROPORTIONS OF BRAHMAN IN SPRING AND FALL CALVING SYSTEMS

Abstract

Comparisons among mature (5 to 8 yr of age) crossbred cows containing different proportions of Brahman (0, ¼ and ½) were made on the basis of calf and cow characteristics related to production efficiency under spring and fall calving management systems. A total of 773 breeding (457 spring and 316 fall), 640 birth and 596 weaning records were produced from 1986 through 1991. Breeds of calf sires included Limousin (1986-88), Salers (1987-88), Angus (1989-91) and Polled Hereford (1989-91). Calves were born from late February to early May and from early September to late November for spring and fall calving, respectively. Calf characteristics considered were birth weight, age at weaning, preweaning ADG, age-adjusted weaning weight, age-adjusted hip height and weaning conformation. Cow characteristics included calving and weaning rates, condition at breeding and weaning, and cow weight. Calf weight produced per cow-year was calculated by the product of weaning rate and weaning weight least squares means. Spring-born calves were 2.1 and 14.6 kg heavier than fall-born calves at birth ($P < .01$) and weaning ($P < .01$), respectively; they were also 2.3 cm taller at weaning ($P < .05$). Calves out of ¼ Brahman cows gained 0.1 kg/d more ($P < .01$) and were 21.9 kg heavier ($P < .01$) at weaning than those from the 0 Brahman group. The comparative advantages to the calves out of ¼ Brahman cows were 0.04 kg/d gain ($P < .1$) and 13.9 kg weaning weight ($P < .05$) under fall versus spring calving management. Cows of these two breed groups were similar in the percentages of cows exposed to breeding that bore and weaned calves, but a slight numerical advantage was noted for 0 Brahman cows. Estimates of cow weight averaged over the production cycle were similar among the breed groups, but ¼ Brahman cows calving in the spring were lighter ($P < .01$) than those in any other calving season-breed group combination. Under spring calving management, 0 and ¼ Brahman groups weaned similar calf weight per cow exposed (208.1 and 210.3, respectively), but ¼ Brahmans were superior to the 0 Brahmans when calves were born in the fall (192.4 and 178.6 kg, respectively). Comparisons were also made with the ½ Brahman cow group, but due to differential removal practices applied to this group, these comparisons are of limited value. These results indicate that percentage Brahman cows may be effectively utilized with improved efficiency in weaned calf production among mature cows over British crossbred cows in temperate environments. The advantages among mature Brahman-cross cows were also greater under fall calving management.

(Key Words: Cattle, Crossbreeding, Cow Productivity, Breeds, Angus, Brahman, Hereford.)

Introduction

In the beef cattle industry, crossbreeding has become a common method of producing commercial cattle because of its advantages over straightbreeding systems. Realizing the expression of heterosis is often considered to be the greatest advantage in crossbreeding, but other aspects merit consideration. When breeding systems are thoughtfully designed, the blending of desirable breed effects in crossbred individuals allows the producer to develop a herd that is not only well adapted to a specific production environment, but also produces calves that are extremely desirable at the market. Additionally, crossbreeding systems can take advantage of breed or type complementarity, as those traits that are desirable in breeding females can be concentrated in the cow herd, while those characteristics that are antagonistic to maternal ability, but desirable for efficiency and carcass characteristics in the market animal can be concentrated in the sire lines (Cartwright, 1970).

In the Gulf Coast region of the United States, the use of Zebu breeds, of which the Brahman is most common, has become extremely popular in crossbreeding programs due primarily to their tolerance of heat and humidity (Franke, 1980). Other advantages of these types of cattle that make them desirable in this subtropical environment are their resistance to parasites, superior maternal ability and a genetic distinction from the cattle of European origin (Turner, 1980). Although straightbred Zebu cattle are often criticized for their carcass characteristics, temperament and advanced age at puberty, crossbreeding with *Bos taurus* breeds allows for the dilution or elimination of these undesirable characteristics, while contributing breed effects desirable to the crossbred individual. Additionally, the extreme genetic differences between *Bos indicus* and *Bos taurus* cattle results in the expression of high levels of heterosis (Willham, 1970; Koger, 1980; Turner, 1980).

Research on the effects of Brahman in crossbred individuals dates back to the early part of this century in Texas (Lush, 1927; Black et al., 1934). Most of the studies conducted in this country, however, have been under the warm and humid conditions of the South. A general bias against Brahman and Brahman-crosses has limited their use in other regions (Koger, 1980), and reports of their performance in more temperate areas of the country are limited. In one study conducted in Canada, Peters and Slen (1967) found that Brahman-cross steers and cows performed better than British cattle common to the area. Researchers in Nebraska have evaluated the performance of numerous breed crosses, including Brahman-crosses, in a long-term breed characterization study, and have reported some advantages in the productivity of Brahman-cross cows (Cundiff et al., 1985). The limited information available gives some indication that these crossbred cattle may offer advantages in beef production other than their well documented adaptability to subtropical environments.

The current study is part of a long-term project conducted to evaluate the productivity of six crossbred cow types, containing different proportions of Brahman and English breeding, under production conditions in North-central Oklahoma. The primary comparisons of interest were between crossbred cow types, and their relative productivity under spring and fall calving management systems. The specific objectives of this segment of the study were to evaluate the productivity characteristics of mature cows in the 0, ¼ and ½ Brahman breed groups and to compare these breed types under both spring and fall calving systems. These results, combined with those previously reported from this project by Bolton et al. (1987a,b) and McCarter et al. (1990, 1991a,b,c) will provide additional information on the performance of Brahman-cross cattle in a relatively temperate environment.

Materials and Methods

The females evaluated in this study were born in 1981, 1982 and 1983, out of Angus (A) and Hereford (H) cows that had been randomly assigned (within breed) to spring and fall calving herds. Sires used in these initial matings were purebred A, H and Brahman (B) bulls, and crossbred ½B-½A and ½B-½H bulls. The resulting calves had the following breed makeup: 1) ½A-½H and reciprocals, containing no B (0B); 2) ¼B-¼H-½A and ¼B-¼A-½H, containing ¼B; and 3) ½B-½A and ½B-½H, containing ½B. All calves were born at the Southwest Livestock and Forage Research Laboratory, near El Reno, Oklahoma. Bolton et al. (1987a) reported on the performance of these calves from birth to weaning. Heifer calves were retained and developed at El Reno, and were maintained there until the calves produced in 1986 were weaned. Postweaning growth, sexual development and reproductive performance as heifers were reported by Bolton et al. (1987b). Productivity of two- to five-year-old cows, milk production and effects of breed type by season of calving interactions were reported by McCarter et al. (1990, 1991a,b,c).

Following weaning of spring-born calves in October, 1986, and fall-born calves in June, 1987, cows were transferred to the Lake Carl Blackwell Experimental Range, west of Stillwater, Oklahoma, and were maintained there until they were removed from the herd. At both stations, the forages grazed were primarily native, and included species predominant in the southern mid-grass prairies (*Schizacharium scoparious*, *Bothriochloa saccharoides*, *Bouteloua curtipandula* and *Andropogon gerardii*). Additionally, some periods of spring and summer grazing were on available bermudagrass (*Cynadon dactylon*) monoculture pastures. Supplemental protein and hay were generally fed to the cows during the winter and early spring. The amount and type of supplement and the period of time for which it was fed varied from year to year, depending on cost of ingredients, forage availability and weather conditions. In general, however, protein supplementation began in late November or early December, and continued through early to mid-April. Additionally, fall calving cows were supplemented with approximately 0.1 to 0.2 kg hd^{-1} d^{-1} more crude protein than were spring calving cows, as the timing of critical winter weather coincided with the breeding season for the fall calving cows.

Both spring and fall calving groups were allowed a 75-d breeding season each year, resulting in calves born from late January through mid-April and from early September through late November, respectively. The breeding program varied slightly across years in the breeds of sire utilized and the method of breeding. In 1985, estrus synchronization was used at the beginning of the breeding season, and cows were exposed once by AI to Limousin sires, then turned out into single sire breeding pastures with Limousin bulls. In 1986 and 1987, no estrus synchronization was used, and cows were allowed two services by AI to either Limousin or Salers sires, followed by cleanup exposure to Limousin bulls in single sire pastures. From 1988 through the end of the study, all matings were by AI to either Angus or Polled Hereford sires, and no cleanup bulls were used. In years where more than one sire breed was utilized, each breed of sire was equally distributed among cows in breed groups, and in all years, sires within breeds were distributed approximately equally among cows in breed groups. The only exception to this practice was when approximately half of the ½B cows were mated to Gelbvieh sires in 1989; calf performance data resulting from these matings was not included in any of the analyses. Prior to 1988, spring- and fall-born cows were maintained in separate herds, calving exclusively in their respective seasons. Following pregnancy determination at the end of the 1988 breeding seasons, open cows that had an acceptable reproductive history were moved to the alternate calving group to reduce the cost of holding them open for a full year. This practice was continued through the end of the study. A distribution of the number of cows calving from each breed group by season and age is presented in Table 1.

Cows were weighed and body condition scores were recorded twice each year. Breeding season weights and scores were taken between the time that the last calf was born, and the third week of the breeding season. Cows were again weighed and scored at weaning time. Body condition scores were assigned on a nine point scale: 1 = emaciated, 5 = moderate condition, and 9 = extremely obese. An average cow weight for the current production cycle was calculated as the average of the two weights taken during that year. All condition scores recorded were the average of those assigned by two or three individuals scoring independently as the cows were weighed.

Calf management was consistent across years. All calves were weighed, calving difficulty scores were recorded and male calves were castrated within 24 h of birth. Calving difficulty scores were assigned as follows: 1 = no difficulty; 2 = slight difficulty, no mechanical assistance required; 3 = moderate difficulty, mechanical assistance required; 4 = extreme difficulty, excessive mechanical assistance or fetotomy required; 5 = Caesarean section; and 6 = abnormal presentation. As the incidence of calving difficulty was rare among all cow breed groups, these scores were reassigned for the purpose of analysis as no difficulty for scores of 1 or 2, and assistance required for scores of 3, 4 or 5. Abnormal presentations were not included in the analysis of calving difficulty, as they were considered to be random events, not associated with genetic differences among the cows or calves.

Calves were not provided a creep feed supplement at any time during the study, however, fall-born calves were often observed consuming protein supplement supplied to the cows, especially as the period of supplementation progressed. Spring-born calves were generally too small to be able to gain access to the supplement prior to the end of winter feeding. Weaning occurred in early October and early June, when calves reached an average age of 205 and 240 d for spring- and fall-born calves, respectively. Weaning of fall-born calves was delayed (approximately 35 d) to allow cows and calves to take advantage of spring forage production prior to weaning, and because it is a common practice among Oklahoma beef producers. At weaning time, weights, body condition scores (same scale as cows), muscling or conformation scores (12 = low choice, 13 = average choice and 14 = high choice, under old USDA feeder grading system) and hip heights were recorded on each calf. Calf weights and hip heights were adjusted to 205 and 240 d for spring- and fall-born calves, respectively. As with the cows, all scores recorded on calves were averages of those independently assigned by two or three individuals. Dams were assigned a reproductive status code which described the results of the current production cycle (1 = no calf born, 3 = calf born dead, 4 = calf born alive, died prior to weaning, 5 = calf culled prior to weaning, sick or unsound, 6 = calf weaned, and 7 = raised twins).

Although all cow breed groups were managed together, there were incidents of differential treatment of the groups. The most notable was the removal of all ½B cows following weaning of the 1990 calf crop. This action was necessitated by drought conditions resulting in a lack of sufficient forage to support all of the cows in this and other studies being conducted at the Lake Carl Blackwell Range. Actual culling practices were applied somewhat differently across years, partially due to fluctuations in forage conditions. For this reason, the data were edited, applying a strict culling practice of cows being removed following the second year during which they did not carry a calf to term. Any records produced subsequent to that time were deleted from the data. A keep/reason for removal code was also assigned to each record (0 = not removed; 1 = reproductive failure, 2 = poor udder conformation or no milk, 3 = bad temperament, 4 = prolapsed or Caesarean section, 5 = sick or diseased, 6 = structurally unsound, 7 = terminated segment (½B), 8 = removed for other or unspecified reason, 9 = died). Of the 363 cows in the study, 114 were removed for reproductive failure, while 72 were removed for other or unspecified reasons. Of the latter group, 54 were in the ½B group, and approximately half of these were open for only the first time.

Traits included in these analyses were divided into two categories: 1) characteristics of the calf, for which only those records were included that contained birth or weaning weights and scores; and 2) characteristics of the cows, for which information on all breeding records were included. Characteristics of the calf included birth weight, age at weaning, age-adjusted weaning weight, preweaning ADG, calf muscling (conformation) at weaning and age-adjusted weaning hip height. Age at weaning was used to indicate the point during the calving season at which cows tended to calve. Characteristics of the cow included percent calf crop born, percent calf crop weaned, dam body condition at breeding, dam body condition at weaning and dam weight. Calf traits were analyzed using least squares procedures with a full model that included fixed effects of dam breed group, season of calving, sex of calf, age of dam, year of calving, sire of calf within year and two-factor interactions for which all sub-classes were adequately represented. Age of dam and year were somewhat confounded, therefore, no attempt was made to separate the effects of these two sources of variation. Cow trait models included the same effects with the following exceptions: 1) sex and sire of calf were excluded; 2) age of dam/year combinations were included as a single fixed effect for dam condition score and weight analyses; and 3) current reproductive status was included in models for dam weight and body condition. Sire of dam nested within breed group was included in all models as a random effect, and the mean square of this term was used to test the effect of dam breed group. Crossbred cow group was classified by the proportion of Brahman breeding in the dams (0B, ¼B, ½B), therefore, sires of dams were grouped accordingly (0B, ½B, B).

Reported least squares means were computed using reduced models including main and nested effects, and applicable interactions ($P < .2$). Due to the differential treatment of the ½B dams, comparisons between the 0B and ¼B groups were most appropriate. Where applicable, however, comparisons were made between the ¼B and ½B groups to determine a general advantage to one type or the other.

Results and Discussion

Mean squares and levels of significance from full model analyses of variance on calf traits are presented in Table 2. Birth weight was affected by sire of dam, calving season, sex of calf and sire of calf nested within year (P < .01); dam breed group accounted for little of the total variation in birth weight (P > .2). Calf age at weaning was affected by dam breed group (P < .05), sire of dam (P < .01), season of calving (P < .01), age of dam (P < .01), year and sire of calf nested within year (P < .01). For age at weaning, the effects of dam breed group were found to be dependent on calving season, as there was an interaction between these two sources of variation (P < .05). All weaning traits and preweaning ADG were affected by dam breed group, sex of calf, age of dam, year and sire of calf nested within year (P < .05). Calving season also had a significant effect on the weaning traits measured (P < .05), with the exception of weaning conformation (P > .2). The effects of dam breed group on age-adjusted weaning weight, preweaning ADG and hip height were dependent on calving season (P < .1). For all of the traits measured on calves, the effects of sex of calf were not dependent on dam breed group or calving season (P > .2), except for a calving season by sex of calf interaction on weaning conformation (P < .01).

For the characteristics measured on the dams, mean squares and levels of significance from full model analyses of variance are presented in Table 3. The majority of variation observed in both measures of dam reproductive performance, percent calf crop born and percent calf crop weaned, was associated with the effects of age of dam and year (P < .01). Sire of dam nested within breed group also affected percent calf crop born (P < .05), and tended to affect percent calf crop weaned (P < .1). Body condition of the dam at breeding was affected by sire of dam nested within breed group, calving season, reproductive status of the dam, and age of dam and year (P < .01); dam breed group effects were dependent on calving season (P < .01). Body condition of the dam at weaning was affected by sire of dam nested within breed group (P < .01), calving season (P < .05), reproductive status of the dam (P < .01) and year (P < .01); breed group and season effects were dependent on reproductive status of the dam (P < .05). The main effects of sire of dam nested within breed group (P < .01), calving season (P < .01), reproductive status of the dam (P < .01) and year (P < .01) affected average cow weight. The effect of dam breed group on this trait was dependent on calving season ($P < .01$), and the calving season effect was dependent on reproductive status of the dam ($P < .05$).

Effects on Traits Measured on Calves

Dam breed group, calving season, season by group interaction and sex of calf least squares means and standard errors for traits measured on calves are presented in Table 4; appropriate linear contrasts are presented in Table 5. No differences associated with dam breed group were detectable in birth weight, as the range of the three adjusted means was 0.8 kg. This is somewhat in contrast to results reported by McCarter et al. (1991b) on the same cows as 3-, 4-, and 5-year olds, where a significant negative linear effect was reported for increasing the proportion of B in the dams from 0 to ½. Among spring-born calves out of Angus-Hereford, Gray Brahman-Hereford and Red Brahman-Hereford dams, however, Elizondo (1989) reported no difference in birth weight among these three dam breed types, although other types of Zebu-Hereford cross females had lighter calves at birth. In the present study, however, there was a difference observed in birth weight that was associated with calving season; spring-born calves weighed 2.0 kg more than fall-born calves ($P < .01$). The effect of sex of calf on birth weight was similar to that of season, as male calves were 2.2 kg heavier than females ($P < .01$). These simple effects of calving season and sex of calf are slightly less than those reported by McCarter et al. (1991b) on the same cows at a younger age (3.0 kg and 3.2 kg, respectively). Roberson et al. (1986) reported on Hereford, Brahman and reciprocal cross females and found similar differences in birth weight associated with sex of calf (34.2 vs. 31.7 kg for males and females, respectively), however, the difference between calves born during similar times of the year were less (32.5 vs. 32.1 kg for early spring- and fall-born calves, respectively). Differences in seasonal effects could be attributed to the inclusion of calves out of straightbred Brahman dams for the seasonal means in the latter study, as straightbred Brahman dams would be expected to better tolerate the summer heat during the last trimester of pregnancy. Calving difficulty data were analyzed, however, results are not presented since no estimated effects were statistically different from zero (P > .1). This was not unexpected due to the low incidence of difficult births during the six years in which data were collected for this study.

Age of calf at weaning was used to determine differences in the point at which dams calved, relative to the beginning of their respective calving seasons. Since calves were all weaned on the same date for a given calving season, a lower age at weaning indicated a later calving date for a particular season. Calving season, year and age of dam effects were therefore all expected to be large, because there were obvious and inherent differences in these three sources of variation; these effects were of little interest. There were breed group differences and a group by calving season interaction for age at weaning. Linear contrasts show that 0B and ¼B dams were not different (P > .1) in the average age at which there calves were weaned, but ½B dams calved 8.5 d later than ¼B dams (P < .05). Within season, the estimated differences in mean calving dates of 2.7 and 3.3 d in ¼B vs. 0B dams for spring and fall calving, respectively, were not significant (P > .1). Although these results do not support conclusive statements on the ½B dams, the estimated age at which their fall-born calves were weaned was more than 9 d less than for either of the other two dam breed groups. This would indicate that the ½B dams never overcame the causes of poor reproductive performance observed in fall calving two-year olds (McCarter et al., 1990), since even those maintained in the herd through maturity continued to calve later in the fall than dams in either of the other two groups.

Fall-born calves gained 0.208 kg/d less (P < .01) and were 14.58 kg lighter at weaning (P < .01) than spring-born calves, even though fall-born calves were weaned at and adjusted to 240 rather than 205 d of age. This season effect is in contrast to the non-significant effect reported on the same groups of cows at younger ages (McCarter et al., 1990, 1991b). Calves out of ¼B dams gained 0.099 kg/d more (P < .01) and were 21.91 kg heavier (P < .01) at weaning than those out of 0B dams. These results are consistent with those reported by Elizondo (1989), in which F_1, Gray and Red Brahman-Hereford dams weaned calves that were more than 30 kg heavier than those out of Angus-Hereford dams. Steer calves were 18.9 kg heavier than heifer calves ($P < .01$). Roberson et al. (1986) observed that steers were more than 14 kg heavier than heifers at weaning, in agreement with McCarter et al. (1991b), but other studies have generally reported less than a 10 kg difference in weaning weight due to sex of calf (Elizondo, 1989; Turner and McDonald, 1969).

The effect of calving season on preweaning ADG was 0.044 kg/d greater ($P < .1$) in calves out of 0B dams than in those out of ¼B dams. Likewise, the season effect was 13.89 kg greater ($P < .05$) for age-adjusted weaning weight when the same dam breed group comparison was made. Translated to a direct comparison of least squares means, 0B dams weaned spring-born calves that were 24.9 kg heavier than fall-born calves, whereas the difference was only 11.0 kg in ¼B dams. Furthermore, the difference between spring- and fall-born calves out of the ½B dams was only 7.93 kg ($P < .1$). These results, combined with similar effects reported by McCarter et al. (1991b) indicate that the reduction in the preweaning growth rate of fall-born calves in Oklahoma may at least partially be overcome when Brahman is part of the breed composition of the dam.

Age-adjusted hip height results were consistent with gain results; in general, calves that were heavier were also taller. Spring-born calves were 2.28 cm taller at weaning than fall-born calves ($P < .05$), and males were 3.64 cm taller than females ($P < .01$). Calves out of ¼B dams, however, were not significantly taller than those out of 0B dams ($P > .1$). Calves out of ½B dams, however, were 6.89 cm taller than those out of ¼B dams ($P < .01$). As was reported for weaning weight, the difference in hip height between spring- and fall-born calves was 4.05 cm greater among those out of 0B dams than among those out of ¼B dams ($P < .05$), but the difference between spring- and fall-born calves out of ½B dams was not statistically significant ($P > .1$). These results are in stark contrast to earlier results of McCarter et al. (1991b) where it was reported that fall-born calves were taller than spring-born calves. One possible explanation for this discrepancy is that breeds of sires to which the cows were bred changed from Limousin and Salers, to Angus and Polled Hereford in 1989.

Therefore, approximately half of the data analyzed in this study was from three-breed terminal cross calves; the remainder was from calves that were some proportion of a backcross. This cannot be substantiated, however, as direct comparisons between Continental European and British breeds of sire are not possible in these data.

Calves out of ¼B dams tended to be more heavily muscled than those out of 0B dams ($P < .1$), as reflected by a 0.23 grade greater weaning conformation score, and calves out of ½B dams were similar in score to those out of ¼B dams. Calving season mean conformation scores, averaged across other effects in the model were not different from each other ($P > .1$). Steer calves were generally more heavily muscled than heifer calves by 0.40 grade ($P < .01$). The dam breed group by sex of calf interaction was explained by a greater divergence between steers and heifer among the calves out of ½B dams ($P < .01$), as the difference between the two sexes was similar for the 0B and ¼B dams.

<u>Effects on Traits Measured on Dams</u>

Least squares means and standard errors for dam traits are presented in Table 6. Birth and weaning percentages were based on the number of cows exposed. A dam breed group effect was indicated by the analyses of variance for both measures of reproductive performance (Table 3), however, comparisons made between ¼B and 0B dams and between ¼B and ½B dams were not statistically different from 0 ($P > .1$) for percent calf crop born. For percent calf crop weaned, a tendency was observed for ¼B dams to have a weaning percentage that was 8.9% better than ½B dams ($P < .1$). Season effects were not large enough to be detected within these data. These results do not agree with those reported on the same cows as three-, four- and five-year olds (McCarter et al., 1991b), where a significant positive linear effect on percent calf crop weaned was found for increasing the proportion of B in cows from 0 to ½. Since records from the last three years of the present study were on calvings from exclusively AI matings (no clean-up bulls were used), this discrepancy may be the result of dam breed influences on adaptability to an AI program. It should be noted that the ½B cows were observed to be considerably more excitable than the cows from the other groups, which may have resulted in poorer conception rates than would be expected when they were exposed by natural service.

A large proportion of the observed variation in both percent calf crop born and percent calf crop weaned were explained by age of dam and year. The performance of these two correlated variables in the models for these traits was somewhat unexpected. It was considered that during the last three breeding seasons from which data were collected for this study, all breeding was by AI, and a reduction in reproductive performance in the cows was anticipated. Upon review of the estimated effects, however, age of dam appeared to overcompensate for this reduction, as older cows appeared to have significantly poorer reproduction. This overestimation appeared then to be corrected by the estimated year effects, resulting in least squares means for 1990 and 1991 to be well over 100% for percent calf crop born. The original models for these two traits had age of dam and year effects combined into a single variable, however, this resulted in inflated estimated means for dam breed groups and calving seasons. Therefore the effects were separated for the final analyses, in order to determine their functions mathematically. This effect of colinearity among dependent variables was not apparent in analyses for any of the other traits.

Estimates of the overall calf weight produced per cow-year were produced by the multiplication of estimated weaning rates (adjusted for seasonal effects) with estimated adjusted weaning weights. Averaged across calving seasons, ¼ Brahman group weaned 201.2 kg of calf per cow exposed, whereas 0 and ½ Brahman groups weaned 193.2 and 186.8 kg of calf per cow exposed. Due to seasonal effects on calf adjusted weaning weight within dam breed groups, comparisons of apparent productivity was different for spring and fall calving. Under spring calving management, 0 and ¼ Brahman groups were similar (208.1 and 210.3 kg calf weaned per cow-year), and ½ Brahman cows were less efficient (194.4 kg). When calves were born in the fall, however, the ¼ Brahman cows were considerably more efficient than both 0 and ½ Brahman cows (192.4 vs. 178.6 and 179.4, respectively). These results are in slight contrast to those reported by McCarter et al. (1991c), where it was reported that calf weight weaned per cow exposed was increased as percentage Brahman increased, however, in the current study, the proportion of records on ½ Brahman cows was greatly reduced over what would have been expected due to the removal of this group in 1990, and differential culling for two years prior to that. Therefore, comparisons between the 0 and ¼ Brahman groups are most appropriate in this study.

Overall, dam body condition scores were similar across dam breed types at the beginning of the breeding season, and again at weaning. There was an effect of calving season on body condition, as fall calving cows were, on average, scored higher than those calving in the spring, by 0.62 points at breeding time (P < .01), and by 0.16 points at weaning (P < .05). The difference between spring and fall calving cows at breeding was 0.36 points greater (P < .01) among ¼B dams as compared to 0B dams. The smaller difference in cow condition associated with calving season was found to be consistent across dam breed groups. Cows that did not wean a calf at the end of the cycle being considered were scored in heavier condition at breeding by 0.44 points (P < .01), and at weaning by 0.84 points (P < .01). It also appears that ¼B dams took greater advantage of a year during which they did not wean a calf, as there was a 0.37 point greater difference in weaning condition scores between those that weaned a calf and those that did not, compared to 0B dams (P < .05).

The analyses of cow weight was based on the average of the weights taken at the beginning of the breeding season and when the calves were weaned. There was an overall trend for ¼B dams to be lighter than 0B dams, by 22.5 kg (P < .1). Fall calving cows were 14.4 kg heavier than spring calving cows (P < .05). This effect was completely attributable to the ¼B and ½B cows, since estimated means on the 0B cows were greater in the spring calving group. Averaged across the production cycle, cows that did not wean a calf were 39.9 kg heavier than those that suckled calves through weaning (P < .01). There was also a tendency for the effect of reproductive status to be greater in the fall calving system, as the difference in the weight of cows that weaned calves and those that did not was approximately twice as large (51.3 vs. 26.8 kg) in the fall calving group ($P < .1$). Breed group and calving season effects are similar to those found in the earlier report on this project (McCarter et al., 1991b). As pointed out in this paper, the heavier weights observed in the fall calving cows were at least partially attributable to their poorer reproductive performance as two-year olds (McCarter et al., 1990). These results indicate that the effect of the lower calving percentage during the first year of production is maintained through maturity, probably resulting in increased production costs throughout the productive life of the cows.

Implications

For many years, Brahman-cross females have been utilized in the southern United States to improve the efficiency of weaned calf production. Results from the current and previously published reports on a long term beef cattle breeding project in central Oklahoma suggest that crossbred females containing up to ½ Brahman may also increase production efficiency under the conditions of a more temperate environment. In the current study, factors that influenced the degree to which efficiency was increased over British crossbred cows included the percentage Brahman in the cows (¼ or ½), calving season employed (spring of fall) and the interaction between these two factors. Spring calving was more efficient than fall calving, as weaning rates were greater and calves were heavier at weaning. As mature cows (five to eight years of age), weaned calf production per cow-year was greatest among the ¼ Brahman cows calving in the spring, but the advantage in utilizing this breed type was expressed to a greater extent under the fall calving management system. Although there were greater advantages for ¼ and ½ Brahman breed types when cows were evaluated at a younger age (McCarter et al., 1991c), these results indicate that the weaning efficiency is maintained through maturity only in the ¼ Brahman cows. Further research is needed to determine the economic implications on the entire production system.

TABLE 1. NUMBER OF COWS CALVING IN PERCENTAGE BRAHMAN BREED GROUPS, SEASONS, AND AGE OF DAM CLASSES.

Crossbred dam breed group	Spring calving cows[a]					Fall calving cows					Total
	Ages of dams, yr										
	5	6	7	8	Sub-total	5	6	7	8	Sub-total	
0 Brahman	31	17	26	23	97	28	21	21	20	90	187
¼ Brahman	73	51	67	58	249	48	28	28	27	131	380
½ Brahman	66	28(1)	14(7)	3(4)	111(12)	47	25	16	7	95	206
Total	170	96	107	84	457	123	74	65	54	316	773

[a] Numbers in parentheses represent cows bred to Gelbvieh sires; calf data not included in performance analyses.

TABLE 2. FULL MODEL MEAN SQUARES AND LEVELS OF SIGNIFICANCE[a] ASSOCIATED WITH MAIN EFFECTS AND INTERACTIONS FOR CHARACTERISTICS OF THE CALF.

		Calf traits					
Source of variation	df	Birth wt, kg	Age at wng, d	ADG to wng, kg	Age-adjusted wng wt, kg	Age-adjusted wng ht, cm	Wng conformation
Dam breed group	2	25.2	1419.7*	0.591**	28623.0**	1950.3**	2.998*
Sire in Group	43	35.7**	400.7**	0.019**	1105.5**	129.6**	0.840
Season	1	441.7**	126415.5**	3.782**	18924.4**	467.7*	1.090
Sex of calf	1	579.5**	74.2	0.704**	42843.6**	1703.5**	20.667**
Group x Season	2	1.7	844.5*	0.028+	2686.2*	491.0**	0.732
Group x Sex	2	30.3	64.3	0.002	243.2	10.0	0.886
Season x Sex	1	5.8	5.3	0.017	226.3	20.3	8.085**
Age of dam	3	29.1	1069.5**	0.141**	6966.6**	273.3*	4.586**
Year	5	33.1	2340.7**	0.097**	4741.9**	1157.0**	4.360**
Calf sire in Year	73	33.0**	952.5**	0.018**	983.5**	221.3**	0.810**
Residual (df)		19.4 (639)	225.8 (595)	0.011 (595)	610.0 (595)	73.4 (595)	0.736 (595)
R^2		0.349	0.720	0.660	0.520	0.515	0.353

[a] ** = P < .01, * = P < .05, and + = P < .10.

TABLE 3. FULL MODEL MEAN SQUARES AND LEVELS OF SIGNIFICANCE[a] ASSOCIATED WITH MAIN EFFECTS AND INTERACTIONS FOR CHARACTERISTICS OF THE DAM.

		Cow traits				
Source of variation	df	Calf crop born, %	Calf crop weaned, %	Breeding body cond	Weaning body cond	Average cow wt, kg
Dam breed group	2	0.733*	0.727**	1.618	0.110	6939.8
Sire in Group	43	0.181*	0.195+	1.058**	1.243**	10454.0**
Season	1	0.143	0.075	27.638**	1.755*	10631.0*
Group x Season	2	0.074	0.065	4.323**	0.224	11962.6**
Reproductive status	1	NA	NA	10.632**	28.747**	47149.4**
Group x Repro stat	2	NA	NA	0.051	1.415*	767.2
Season x Repro stat	1	NA	NA	0.105	1.698*	8671.6*
Age of dam	3	1.009**	0.623**	0.374	0.154	2695.5
Year	5	0.468**	0.618**	3.981**	2.865**	8817.5**
Residual (df)		0.124 (880)	0.140 (880)	0.452 (736)	0.379 (737)	2337.9 (666)
R^2		0.140	0.125	0.362	0.364	0.390

[a] ** = P < .01, * = P < .05, + = P < .10, and NA = not applicable.

TABLE 4. REDUCED MODEL LEAST SQUARES MEANS AND STANDARD ERRORS FOR CHARACTERISTICS OF THE CALF.

	Calf traits					
Effect	Birth wt, kg	Age at wng, d	ADG to wng, kg	Age-adjusted wng wt, kg	Age-adjusted wng ht, cm	Weaning conformation
Dam breed group						
0 Brahman	36.7 ± 0.6	228.8 ± 2.2	0.85 ± 0.02	224.4 ± 3.7	107.6 ± 1.3	12.8 ± 0.1
¼ Brahman	36.0 ± 0.5	231.7 ± 1.8	0.94 ± 0.01	246.3 ± 3.0	109.9 ± 1.0	13.0 ± 0.1
½ Brahman	35.9 ± 0.8	223.2 ± 2.9	1.00 ± 0.02	257.0 ± 4.8	116.7 ± 1.6	13.1 ± 0.1
Calving season						
Spring	37.2 ± 0.4	208.9 ± 1.3	1.04 ± 0.01	249.8 ± 2.1	112.5 ± 0.7	13.0 ± 0.1
Fall	35.2 ± 0.4	246.9 ± 1.6	0.83 ± 0.01	235.3 ± 2.6	110.3 ± 0.9	12.9 ± 0.1
Group x Season[a]						
0 Brahman in Spring	NA	208.4 ± 2.0	0.97 ± 0.01	236.8 ± 3.4	110.7 ± 1.2	NA
0 Brahman in Fall	NA	249.1 ± 2.2	0.73 ± 0.02	211.9 ± 3.7	104.5 ± 1.3	NA
¼ Brahman in Spring	NA	211.2 ± 1.4	1.05 ± 0.01	251.8 ± 2.3	111.0 ± 0.8	NA
¼ Brahman in Fall	NA	252.3 ± 2.0	0.85 ± 0.01	240.8 ± 3.3	108.7 ± 1.2	NA
½ Brahman in Spring	NA	207.0 ± 2.3	1.09 ± 0.02	261.0 ± 3.7	115.9 ± 1.3	NA
½ Brahman in Fall	NA	239.3 ± 2.8	0.91 ± 0.02	253.0 ± 4.6	117.6 ± 1.6	NA
Sex of calf						
Male	35.1 ± 0.4	227.4 ± 1.4	0.97 ± 0.01	252.0 ± 2.2	113.2 ± 0.8	13.1 ± 0.1
Female	37.3 ± 0.4	228.4 ± 1.3	0.89 ± 0.01	233.1 ± 2.2	109.6 ± 0.7	12.7 ± 0.1

[a] NA = not applicable, dam breed group × calving season not significant in full model ($P > .2$).

TABLE 5. REDUCED MODEL LINEAR CONTRASTS AND LEVELS OF SIGNIFICANCE[a] FOR CHARACTERISTICS OF THE CALF.

	Calf traits					
Contrast	Birth wt, kg	Age at wng, d	ADG to wng, kg	Age-adjusted wng wt, kg	Age-adjusted wng ht, cm	Weaning conformation
Dam breed group						
¼B - 0B	NS	NS	0.099**	21.91**	NS	0.23+
¼B - ½B	NS	8.54*	-0.051*	-10.72+	-6.89**	NS
Calving season						
Spring - Fall	2.05**	-38.04**	0.208**	14.58**	2.28*	NS
Group x Season						
¼B(S - F) - 0B(S - F)	NA	NS	-0.044+	-13.89*	-4.05*	NA
½B(Spr - Fall)	NA	-32.30**	0.186**	7.93+	NS	NA
Sex of calf						
Male - Female	2.23**	NS	0.077**	18.94**	3.64**	0.40**

[a] ** = P < .01, * = P < .05, + = P < .10, NS = P > .20, and NA = not applicable.

TABLE 6. REDUCED MODEL LEAST SQUARES MEANS FOR CHARACTERISTICS OF THE DAM.

Effect	Cow traits: Calf crop born, %	Calf crop weaned, %	Breeding body condition	Weaning body condition	Average cow wt, kg
Dam breed group					
0 Brahman	90.0 ± 3.8	86.1 ± 4.0	5.68 ± 0.11	6.02 ± 0.15	536.4 ± 12.1
¼ Brahman	85.0 ± 2.8	81.7 ± 2.9	5.67 ± 0.08	6.08 ± 0.11	513.9 ± 9.5
½ Brahman	77.0 ± 4.3	72.7 ± 4.5	5.98 ± 0.14	5.99 ± 0.22	537.9 ± 16.9
Season					
Spring	85.6 ± 2.2	81.5 ± 2.4	5.47 ± 0.06	6.11 ± 0.07	522.2 ± 5.2
Fall	82.4 ± 2.6	78.8 ± 2.8	6.09 ± 0.06	5.95 ± 0.07	536.6 ± 5.7
Group x Season[a]					
0 Brahman in Spring	NA	NA	5.53 ± 0.09	NA	538.9 ± 7.3
0 Brahman in Fall	NA	NA	5.81 ± 0.09	NA	533.9 ± 7.1
¼ Brahman in Spring	NA	NA	5.35 ± 0.06	NA	506.4 ± 5.2
¼ Brahman in Fall	NA	NA	5.99 ± 0.07	NA	521.4 ± 6.2
½ Brahman in Spring	NA	NA	5.51 ± 0.10	NA	521.2 ± 8.4
½ Brahman in Fall	NA	NA	6.45 ± 0.11	NA	554.6 ± 10.2
Reproductive status[b]					
Calf weaned	NA	NA	5.56 ± 0.04	5.61 ± 0.04	509.9 ± 3.6
No calf weaned	NA	NA	6.00 ± 0.08	6.45 ± 0.10	549.0 ± 6.9

[a] NA = not applicable, dam breed group × calving season not significant in full model (P > .2).
[b] NA = not applicable, reproductive status not included in full model.

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CHAPTER IV

SUMMARY AND PROJECT OVERVIEW

As part of a long term study (Oklahoma Agric. Exp. Sta. Project 1777), results presented in Chapter III constitute the beginning of the end of 14 years of research on the productivity characteristics of crossbred cattle. The information gathered from this project has been analyzed and reported in an M.S. Thesis (Bolton, 1986) and a Ph.D. Dissertation (McCarter, 1989), as well as the current Dissertation. To date, this project has also been the source of data for six publications in the Journal of Animal Science (Bolton et al., 1987a,b; McCarter et al., 1990, 1991a,b,c), 15 articles published in the Animal Science Research Report (Aaron et al., 1983; Aaron et al., 1984; Bolton et al., 1986; Frahm et al., 1987a,b; McCarter et al., 1987a,b; McCarter et al., 1988; McCarter et al., 1989a,b; McPeake et al., 1989; Selk and Buchanan, 1990; Tinker et al., 1988; Ziehe et al., 1991; Ziehe et al., 1992) and numerous abstracts presented at scientific meetings. The purpose of this Chapter is to summarize those results and provide some insight into what has been learned about the use of Brahman-cross females for calf production in Oklahoma.

The mating systems and management programs were designed so that comparisons could be made between breed types, as well as between management systems. Breed types varied in the proportion of Brahman represented (0, ¼ or ½), and in the base cow breed (Angus or Hereford). Management systems were based on either spring or fall calving. Spring calving has traditionally been the preferred system in Oklahoma, but fall calving systems also common among producers because weaned calves can usually be marketed at more favorable prices. The interaction between breed type and management system was also of interest, since there would likely be differences in the adaptive abilities of the breed types.

Production of Crossbred Calves

In order to obtain crossbred females to utilize in a breeding program, a crossbreeding program must be employed at least a generation in advance. In this project, straightbred Angus and Hereford cows were mated to Angus, Brahman, Hereford, Angus-Brahman and Brahman-Hereford bulls, to produce crossbred calves that were 0, ¼ or ½ Brahman in such a manner that calves were either ½ Angus or ½ Hereford. Under commercial production conditions, it would have been more practical to utilize crossbred dams (and straightbred sires) to produce the ¼ Brahman calves, in order to take advantage of maternal heterosis in this phase of production. Straightbred cows were used in this case, however, in order that calf performance within the different breed groups could be compared without confounding the effects of maternal heterosis. Calves produced for this segment of the project were born in 1981, 1982 and 1983.

Results presented here are taken from Bolton et al. (1987a). Of the primary effects of interest, breed type was the only source of variation that was associated with birth weight; 0, ¼ and ½ Brahman calves weighed 33.9, 35.3 and 37.7 kg, respectively. For the traits measured at weaning, the interaction between breed type and calving season was important. In general, spring-born calves performed better than fall-born calves, however, differences were increased as percentage Brahman increased. Even though spring-born calves were weaned at a younger age, their weaning weights were 195, 204 and 213 kg, as compared to those of fall-born calves, which were 184, 183 and 185 kg for 0, ¼ and ½ Brahman calves, respectively. As for the other weaning characters analyzed, hip height increased with percentage Brahman among spring-born calves, and tended to do so among fall-born calves. Conformation and condition scores were similar among the three breed types with a spring calving system, but decreased as percentage Brahman increased with fall calving.

Calving difficulty was not considered in this report because base cows were relatively mature and the frequency of difficult births was low. Although not a problem in this study, birth weight results indicated that the likelihood of calving difficulty would increase as percentage Brahman in the sire increases. This would be an important consideration for producers that wished to start from an established base cow herd in which calving difficulty had been a problem, or if they wanted to utilize heifers for the production of Brahman-cross calves. From results on weaning performance, it is apparent that the advantages of including Brahman in a breeding program, expressed in a spring calving system, are lost under fall calving management. Apparently, the genetic potential of all three breed types was not fully expressed, possibly due to a less than adequate maternal environment combined with the climatic stress of winter conditions during the period of rapid development and growth. The reduced conformation and condition scores among fall-born percentage Brahman calves, along with reduced weight gain indicated that the negative environmental effects increased in severity as genetic potential for growth increased. These results indicate that in the production of percentage Brahman calves in Oklahoma, there are relatively substantial advantages to spring calving systems. If fall calving is desired, however, the use of Brahman in a breeding program does not appear to be of any advantage, at least in the production of weaned calves out of straightbred British dams.

Puberty and Reproductive Performance

Reproductive performance is the most important aspect of calf production from the standpoint of profitability. The simple facts are that an open cow incurs costs, but produces no income, and a small calf is worth more than no calf. Age at puberty is generally not a major problem in well managed herds, but Brahman heifers have a scientifically supported reputation for reaching puberty at a later age than those of most Taurine breeds. In order for a heifer to produce a calf at 24 months of age, she must be pubertal by the age of 15 months. Age at puberty was measured in this study by recording the date at which heifers were first detected in estrus, but observation ceased when the heifers were turned out into breeding pastures. Therefore, only those heifers that reached puberty prior to the beginning of the breeding season were recorded. For this reason, the percentage of heifers reaching puberty prior to the beginning of the breeding season may give a better indication of breed type differences.

Bolton et al. (1987b) reported the results from the analyses of puberty. Of the heifers detected in estrus, age at puberty was not affected by breed type, but spring-born heifers reached puberty approximately 14 d earlier than fall-born heifers. This seasonal difference is probably a reflection of the differences in preweaning performance of the heifers, as fall-born heifers were lighter at weaning even though they were older. The percentages of heifers detected in estrus prior to the beginning of the breeding season were dependent on calving season and breed type combinations, but there was a general decrease with an increasing proportion of Brahman. The breed type effect was far more apparent among fall-born heifers, as 78.8 % of 0 Brahman heifers had reached puberty, whereas only 31.5 and 17.8% of the ¼ and ½ Brahman heifers had reached puberty. Among spring-born heifers, 69.2, 63.9 and 50.0% of 0, ¼ and ½ Brahman heifers had reached puberty by the beginning of the breeding season. Pregnancy rates among the spring-born heifers were similar for all three breed types (86.4, 97.2 and 86.8% for 0, ¼ and ½ Brahman heifers, respectively), but were less than the pubertal rates among fall-born heifers (62.9, 37.7 and 13.5% for 0, ¼ and ½ Brahman heifers, respectively).

Results on subsequent reproductive performance are from McCarter et al. (1990, 1991b,d) and the present study. Obviously from the breeding performance of the virgin heifers, there were differences in the weaning rates as two-year-old heifers, associated with the interaction between breed type and calving season. There was also an apparent breed of dam effect, as crossbred heifers out of Angus cows had a better weaning rate than those out of Hereford cows. A major component of this effect, however, was a pregnancy and weaning rate of 0% for the fall-calving, ½ Brahman heifers, out of Hereford cows. Averaged across their second, third and fourth calving years, the performance of the breed types was similar within seasons, but spring-calving cows weaned calves at a rate of 92.3%, as compared to the rate among fall-calving cows of 45.9%. Additionally, crossbred cows out of Angus dams weaned 23.8% more calves per cow exposed than did those out of Hereford dams. This effect decreased as percentage Brahman increased to the point that Brahman-Angus and Brahman-Hereford cows were very similar in their weaning rate (75.7 and 74.8%, respectively) across the three calving years. Lifetime levels of performance through six years of age combined the effects observed on the two-year-olds, with those observed on the three-, four- and five-year-olds and added limited information from some of the six-year-old cows. Up to this point, There were no differences observed among the breed types in the weaning rates of spring calving cows, as 0, ¼ and ½ Brahman cows had lifetime weaning rates of 85.4, 86.5 and 91.3%, respectively. Among fall-calving cows, rates were lower, and differences among breed types were small (76.3, 71.4 and 70.5% for 0, ¼ and ½ Brahman cows, respectively). Calving intervals were similar among the percentage Brahman breed types (390, 399 and 378 d for 0, ¼ and ½ Brahman cows, respectively), and calving season did not affect this trait. This measurement, however, fails to account for lost production from those cows that did not calve at two years of age, and was apparently affected by the culling procedures that were practiced for reproductive failure. As mature cows (five to eight years of age), calving season effects were not important in weaning rate (81.5 and 78.8% for spring and fall calving, respectively), but ½ Brahman cows tended to wean fewer calves per cow exposed (72.7%) than 0 and ¼ Brahman cows (86.1 and 81.7%, respectively). These results were possibly affected by some differential selection applied to the different breed types (Chapter III), and the fact that the ½ Brahman cows were not allowed to continue in production through the end of the study, resulting in fewer observations on this group.

Considering all of this information combined, it is apparent that seasonal effects on reproductive performance decreased as the cows matured. This was especially true among the percentage Brahman cows, calving in the fall, as the overall productivity of this group was undoubtedly affected in a negative way, by their poor performance as two-year-olds. This result stresses the importance of heifer development, but comments made about the economic impact, or the costs involved in the development of percentage Brahman heifers in a fall calving system are purely speculative. An alternative management practice that could potentially increase the overall productivity of fall calving systems, especially when percentage Brahman cows are desired, would be to produce replacement heifers in a spring calving system, and delay their first parturition to 30 months. From the results on the crossbred calf production phase, the increased productivity of cows producing replacement females, observed in the spring calving system, could possibly overcome the cost of maintaining the heifers for an additional six months prior to the production of their first calf. The appropriate comparison, yet to be investigated, would be against the added costs associated with development of heifers to the degree to which an acceptable breeding performance would be obtained in their first year of production.

Cow Size and Milk Production

Cow size and milk production potential can have profound effects on the efficiency of calf production, both biologically and economically. Larger cows tend to pass on to their offspring a greater genetic potential for growth. Cows with high milk production potential can provide a superior maternal environment that allows their calves to fully express their growth potential. These attributes do not come without costs, however, as increased productive potential for either growth or milk is also associated with increased nutritional requirements. Therefore, if the potential of cows does not match the production environment, efficiency is not optimized. Too great a production potential generally results in either poor reproductive performance, or a greater requirement for nutritional supplementation. Too low a potential results in a less than optimal utilization of feed resources. Cow condition can be used to determine the degree to which the potential of the cows has been matched to the feed resource environment; cows that are over-conditioned are generally too low in production potential, whereas cows that are thin may be overproductive for the level of feed and management that have been provided. Throughout the study, cows were weighed and scored for condition, twice each year; once at the beginning of the breeding season and again at the time of calf weaning. Milk production potential was estimated on two-, three- and four-year-old cows by averaging the six monthly estimates on each cow.

Results on cow weight and condition presented here are from McCarter et al. (1990, 1991b,c) and the present study, and milk production information is from McCarter et al. (1991a). At first breeding, heifers among the different breed types were similar, within calving season, with an overall mean of 308 kg. Fall-calving heifers were 46 kg heavier than spring-calving heifers. Cow weight increased, as would be expected, until the cows reached five years of age. As young cows (three to six years of age), the seasonal difference in weight was maintained (453 and 485 kg for spring and fall, respectively), and a breed type difference was expressed that was observed throughout the study; ¼ Brahman cows were lighter (445 kg) than 0 Brahman (483 kg) and ½ Brahman cows (480 kg). As mature cows, the mean weights of cows were 514, 536 and 538 kg for the three groups, respectively. The only noted association of breed type with body condition was that mature, fall-calving ½ Brahman cows tended to be in better condition at breeding, but were similar in condition at weaning when compared to the other two groups. At breeding time, spring-calving cows carried less condition than fall-calving cows (mean scores of 4.7 and 5.8 as young cows; 5.5 and 6.1 as mature cows). As mature cows, the weaning condition scores indicated that spring-calving cows were able to regain body condition through the summer up to a score of 6.1, and fall-calving cows maintained condition at a score of 6.0 through the late spring. These observations would not be unexpected, as breeding condition scores were recorded on spring-calving cows at the beginning of the normal spring green-up (April or early May), and on fall-calving cows prior to harsh winter conditions (late November or early December). Weaning condition scores (and personal observation) indicated that spring-calving cows tended to increase steadily in condition between the two dates, but fall-calving cows tended to lose condition through the winter, but regain most of what was lost by the time calves were weaned in June. Milk production estimates indicated no differences in this trait that were attributable to either breed type, or calving season. An interesting observation was noted, however, in the mean lactation curves of spring and fall calving cows. The spring group tended to follow a typical lactation curve, with a peak in the second month and a gradual decline to weaning. The fall group, however, tended to peak in the first month and decline through the fourth month, then there was a slight peak coinciding with spring green-up through the sixth month of lactation.

Part, if not all of the seasonal differences in cow weight may be attributable to the differences in cow condition, however, the reason for the breed type effects are unclear. Other studies (Chapter II) have reported that percentage Brahman cows tend to be larger than Angus-Hereford crossbreds. That tendency was not observed in this study after the heifers reached one year of age. The reason for this disagreement with other work is unclear. The similarity in body condition among the cow groups within calving seasons and the relatively moderate level of condition observed in most cows indicated that all groups were relatively adaptable to the nutritional environment provided. As no differences associated with breed type were observed in the level of milk production, and because there were no large differences in mature weight, there does not appear to be reason to expect that the cost of production would be greatly affected by breed type, among the groups studied, once the cows were in production. Therefore, differences in weaned calf production efficiency should reflect differences in profitability among mature cows under Oklahoma conditions.

Characteristics of Offspring

Weaned calves are the primary source of income in any cow/calf production system. Therefore, weaning weight must be considered the most important calf trait considered in any comparison of cow productivity. Birth weight is important because of its association with calving difficulty, especially in heifers and young cows. Other characteristics measured include preweaning average daily gain, weaning hip height, calf condition score and conformation (or muscling) score. Preweaning average daily gain is a better indicator of calf preweaning performance than weaning weight because it is not confounded by the effects of birth weight. Weaning hip height and condition are indicators of post-weaning performance, and can often influence the selling price of calves since short, fat calves generally have less than desirable stocker and feedlot performance. Weaning conformation is used as an early indicator of carcass composition.

Results presented in this section are from McCarter et al. (1990, 1991b,c) and from the present study. Calving difficulty was a problem among two-year-old heifers, as 21% required assistance. Although no differences in calf birth weight were associated with breed type, ¼ and ½ Brahman heifers required assistance less frequently than 0 Brahman heifers, by 10 and 25 percentage points. Calf birth weight was found to be affected by cow breed type only in the three- to five-year-old cows. In this cow age group, birth weight decreased as percentage Brahman increased, but this was a relatively unimportant point as the overall incidence of calving difficulty among three- to five-year-olds was 0.8%, with the majority occurring among three-year-olds. In two-year-old heifers, calf weaning condition and conformation were similar among all breed types. As young cows, however, percentage Brahman cows weaned calves that were in slightly better condition and had a more muscular conformation than calves out of Hereford-Angus cows. In older cows, calves out of the different breed types were more similar in both condition and conformation. Seasonal effects were not observed for weaning conformation, but spring-born calves out of young cows were in slightly heavier condition than those born in the fall. Weaning hip height increased linearly with percentage Brahman in the cows, at all ages. In general, ½ Brahman cows weaned calves that were 1.5 cm taller than those out of ¼ Brahman cows, and 3.0 cm taller than those out of 0 Brahman cows. These differences were observed to be greater as the cows reached maturity. Fall-born calves were 13 cm taller than spring-born calves when cows were young, but as the cows matured, spring-born calves were observed to be 2.2 cm taller than those born in the fall. In this cow age group, differences between breed types were greater in fall-born calves than in spring-born calves. Preweaning average daily gain and weaning weight were affected by breed type at all cow ages. As two-year-olds, ½ Brahman heifers weaned calves that gained .14 kg/d faster and were 28.5 kg heavier at weaning than 0 Brahman heifers. Seasonal effects were not important for either daily gain or weaning weight in this age group, but spring-born calves must have grown slightly faster as their weaning weights were similar to fall-born calves, yet they were, on average, 35 d younger at weaning. For the three- to five-year-old cows, the higher rate of gain among spring-born calves was more evident at .12 kg/d, yet no differences in weaning weights were associated with season. Weaning weights of calves by 0, ¼ and ½ Brahman cows were 220, 236.5 and 243 kg, respectively for this age group. In the mature cows, these weights increased to 224.4, 246.3 and 257 kg, respectively. Seasonal effects were observed in this age group, as spring-born calves gained .21 kg/d faster and were 14.4 kg heavier at weaning. In addition, the observed interaction between cow breed type and calving season resulted in smaller seasonal differences as percentage Brahman increased.

Through the utilization of Brahman-cross heifers and cows, calving difficulty was reduced in heifers, and overall preweaning performance of the calf was enhanced among cows of all ages. Seasonal effects on calf performance were not as prevalent in younger cows, but became important as cows reached maturity. In mature cows, there was a negative effect of fall calving on all measures of calf performance, when compared to spring calving. In general, however, these seasonal effects were less dramatic among the percentage Brahman breed groups, indicating that these breed types may be more adaptable to the harsher nutritional and climatic environment incurred on the cows during the period of peak lactation. This is not to suggest that the Brahman-cross cows were more cold tolerant. They may, however, express the ability to better utilize available forage during the dormant season, as long as the climatic conditions during the winter are relatively temperate, as is generally the case in Oklahoma.

Summary and Conclusion

In the production of Brahman-cross replacement females, spring calving systems had significant advantages over fall calving systems. In general, spring-born calves out of straightbred Angus and Hereford cows performed better than fall-born calves. Brahman-cross calves had better preweaning performance, expressed as heavier weaning weights, than Angus-Hereford calves under spring calving conditions, but there was no advantage observed in Brahman-crosses in the fall calving system. The less than optimal performance of all fall-born calf breed types, apparently caused by a less than adequate maternal environment, was of greater magnitude in the percentage Brahman calves, as compared to Angus-Hereford calves. This effect of calving season apparently carried over to postweaning performance, and may at least partially explain the comparatively poor breeding performance of ¼ and ½ Brahman virgin heifers. Prior to their first breeding season, a greater proportion of 0 Brahman heifers had been detected in estrus than either of the Brahman-cross breed type heifers. This effect was far more apparent among fall-born heifers, as only 18% of the ½ Brahman heifers had been in estrus before the breeding season began, as compared to 79% of the 0 Brahman heifers. Pregnancy rates among spring-born virgin heifers ranged from 86% (0 Brahman) to 97% (¼ Brahman) among spring-born heifers, and from 14% (½ Brahman) to 63% (0 Brahman) among fall-born heifers.

After calving for the first time, reproductive performance was similar among the three breed types, within calving season, but fall calving cows had lower weaning rates than those calving in the spring (46 vs. 92%). This seasonal effect on weaning rate was reduced considerably in mature cows (79 vs. 82%, respectively), which was probably due to culling practices employed. Differences in cow weights were not as expected from the results of other studies. The 0 and ½ Brahman cows were similar in weight throughout their reproductive life (483 and 480 kg, respectively), and ¼ Brahman cows were approximately 35 kg lighter than the other two groups at maturity. Cows of all three breed types maintained similar condition within spring and fall calving groups, throughout the study, although seasonal fluctuations were observed. Milk production estimates were similar across breed types and calving seasons in young cows, but there was a noted tendency for the shape of lactation curves to vary with calving season. Calving difficulty was less frequent among first calf Brahman-cross heifers, especially among the ½ Brahman group, but calf birth weights were generally similar across cow breed types. Calf preweaning performance was positively affected by increasing percentage Brahman in the dam, and weaning weights were 23 to 33 kg greater among calves out of ½ Brahman cows compared to 0 Brahman cows.

Upon review of the entire study, it is obvious that the efficiency of weaned calf production may be increased through the use of Brahman-British crossbred females. This is especially true under spring calving management systems. When spring calving was employed, the overall system was more efficient due to advantages in heifer development, virgin heifer conception, and calf preweaning performance for all breed types over fall calving systems. Additionally, the system efficiency increased as the percentage of Brahman in the females was increased from 0 to ½, using spring calving. Under fall calving systems, there were no advantages in the utilization of Brahman, with respect to the birth to weaning phase of replacement heifer production. It was also apparent that the costs associated with heifer development would have been higher than with spring calving, in general. Costs would most likely have increased for this phase of the system as the percentage of Brahman in the females increased, basing acceptable performance standards on the puberty and first season conception rates of the spring calving group. Although the breed types ranked ½ Brahman, ¼ Brahman, 0 Brahman from highest to lowest productivity in mature cows, regardless of calving season, the comparatively poorer reproductive performance of the Brahman-crosses as young heifers leads to considerable doubt as to the ranking of the breed types for overall system efficiency, under fall calving management systems.

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