USE OF BRAHMAN BREEDING IN CROSSBREEDING PROGRAMS UNDER SPRING OR FALL CALVING MANAGEMENT SYSTEMS TO INCREASE PRODUCTION EFFICIENCY

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NOMENCLATURE

adg	average daily gain
C	Celsius
cm	centimeters
d	days
g	grams
h	hours
kg	kilograms

CHAPTER I

INTRODUCTION

Crossbreeding is one of the major management techniques available for commercial beef cattle producers attempting to increase efficiency of production. Since additive and non-additive genetic variation are generally both important, improvement is maximized by combining systematic crossbreeding with selection among and within breeds (Cundiff, 1970). Willham (1970) lists heterosis, opportunity to incorporate desirable genetic material quickly and chance to combine desirable traits from several breeds into a market animal as desirable consequences of crossbreeding. Successful crossbreeding, however, requires the choice of appropriate breed combinations for the environment and production system (Koger, 1980).

Brahman cattle in the United States are the product of a breeding up process that began in the 1920's using Zebu cattle imported from India. The Brahman breed was established as such in 1924. American Gray Brahmans are primarily a mixture of Guzerat and Nellore breeding while American Red Brahmans are primarily Gir and Indu-Brazil with some Guzerat influence. The Gir, Guzerat and Nellore breeds are indigenous to India while the Indu-Brazil breed was developed in Brazil using breeds imported from India. Over 80% of the Zebu cattle imported into the US came either directly or indirectly from Brazil (Sanders, 1980). Brahman and Brahman crosses have the ability to adapt to the heat and humidity of the Gulf Coast region of the United States which has led to widespread use of this breed in that region (Franke, 1980). It is suspected that the optimum proportion of *Bos indicus* blood in crosses with *Bos taurus* cattle may vary with climate and production environment (Gregory and Cundiff, 1980). Different environments have been shown to have varying effects on different breed types due to genotype by environment interactions. Butts et al. (1971) reported significant genotype by environment interactions for birth, weaning and yearling traits among Hereford cattle in Florida and Montana, with cattle performing best at the location from which they originated.

Most studies involving Brahman cattle have been conducted in the Gulf Coast region of the United States, however, relatively few have been conducted in more temperate environments. Due to genotype by environment interactions, it is possible that Brahman and Brahman cross cattle may perform differently relative to other breeds in environments more temperate than the hot and humid South.

Many Oklahoma cattle producers have incorporated fall calving programs into to their production management systems. Therefore, evaluation of the production capabilities of Brahman cross cattle under both spring and fall calving systems is important.

The results presented in this study come from a long term research project at Oklahoma Agricultural Experiment Station designed to (1) compare productivity of six crossbred cow groups that are Hereford x Angus, Angus x Hereford, Brahman-Hereford x Angus, Brahman-Angus x Hereford, Brahman x Angus and Brahman x Hereford, (2) compare spring versus fall calving systems and (3) determine the effects of genotype (crossbred cow group) by environment (season of calving) interactions on cow productivity. Objectives of this portion of the study were to evaluate (1) the performance of females as two-year-olds, (2) the performance of females as three-, four- and five-year-olds, (3) milk production capabilities of crossbred cow groups and (4) the lifetime performance of these females through seven years of age of until they were removed from the herd.

CHAPTER II

REVIEW OF LITERATURE

Effects of Brahman Breeding

Reproductive Traits

Straightbred Brahman are typically lower in calf crop weaned than cows from British breeds. However, Brahman x British dams generally show increased levels of heterosis which results in calf crop weaned percentages that exceed British x British dams (Turner et al., 1968). Hereford, Red Poll, Angus and Brahman sires were mated to Hereford, Red Poll, Angus and Charolais dams to produce Hereford, Red Poll, Hereford x Red Poll, Red Poll x Hereford, Angus x Hereford, Angus x Charolais, Brahman x Angus and Brahman x Hereford females to be used to evaluate maternal characteristics of dams representing *Bos taurus* and *Bos indicus* x *Bos taurus* breed types in Nevada (Bailey et al., 1988). These workers reported significant (P<.05) differences between purebred Hereford and Brahman x British dams for pregnancy rate, calving rate and weaning rate in favor of the Brahman x British dams. However, no differences existed between Angus x Hereford and Brahman x British dams for these traits. Both Brahman- and Angus-sired dams exceeded the overall herd mean for these reproductive traits.

Several studies conducted in Florida have demonstrated significant advantages associated with using Brahman-cross dams. Peacock and Koger (1980) using Angus, Brahman, Charolais, Angus x Brahman, Angus x Charolais and Brahman x Charolais dams reported calving rates of 92 and 90% for Angus x Brahman and Charolais x Brahman reciprocal crosses, respectively. These percentages were significantly ($P<.05$) superior to those for purebred Angus, Brahman and Charolais but not significantly different from the 82% calving rate of Angus x Charolais reciprocal cross dams. Weaning rates followed similar patterns with Angus x Brahman and Charolais x Brahman crosses being superior with rates of 87 and 84% respectively. Weaning rates for five breed groups consisting of various proportions of Brahman and Shorthorn cows was reported by Koger et al. (1975). The five breed groups were purebred Brahman, 3/4 Brahman:1/4 Shorthorn, Brahman:Shorthorn F_1, 1/4 Brahman:3/4 Shorthorn and purebred Shorthorn. Weaning rate for these groups averaged across pasture management systems ranged from 76% for 3/4 Brahman:1/4 Shorthorn to 60% for purebred Shorthorns. The three crossbred groups were not significantly different from each other, however, all three crossbred groups were superior ($P<.05$) to both groups of purebreds.

In another Florida study, Crockett et al. (1978a) used Angus, Brahman, Hereford and all possible two-breed rotational crosses of these three breeds to determine breed group effects on pregnancy and weaning rates in a rotational crossbreeding system. Angus, Hereford and Angus x Hereford had the highest average pregnancy rates, ranging from 89.9% for Angus x Hereford to 86.9% for Herefords. Purebred Brahman had the lowest average pregnancy rate (72.0%). Angus x Brahman and Hereford x Brahman crosses averaged 85.7 and 83.8% pregnancy rates, respectively. Weaning rates averaged 79.1, 63.2 and 80.9%, respectively, for Angus, Brahman and Hereford cows. Angus x Brahman, Angus x Hereford and Brahman x Hereford averaged 80.8, 82.7 and 77.5%, respectively. As with pregnancy rate, Angus x Hereford were superior for weaning rate followed by purebred Hereford and Angus x Brahman cows.

Researchers in Louisiana have found evidence of significant advantages to using Brahman breeding in a crossbreeding program. Turner et al. (1968) reported significant ($P<.05$) heterosis effects for calving percent for Angus x Brahman, Brahman x Brangus and Brahman x Hereford reciprocal crosses. The percent advantage of crossbred over straightbred performance was 18.2, 17.4 and 28.1% for Angus x Brahman, Brahman x Brangus and Brahman x Hereford reciprocal crosses, respectively, compared with 6.6% for Angus x Hereford reciprocal crosses. Reynolds et al. (1979), in another Louisiana study, found heterosis to be nonsignificant for pregnancy rate in Brahman x Angus reciprocal crosses. However, pregnancy rate for Brahman x

Angus crosses was superior to that for Angus x Brangus, Brahman x Brangus and Brahman x Africander-Angus.

Canadian researchers, Peters and Slen (1967), bred Hereford, Angus and Shorthorn dams to Brahman bulls imported from California to produce F_1 females for evaluation of their productivity under Canadian range conditions. All F_1 females were bred to Hereford bulls, therefore, calves produced contained different levels of heterosis. The 1/4 Brahman females were also retained for evaluation. Brahman x Angus and Brahman x Shorthorn cows weaned more ($P<.05$) calves per hundred cows bred than Hereford and Brahman x Hereford dams. Generation three 1/4 Brahman dams, while not significantly different from Hereford dams, tended to wean a higher number of calves per 100 cows exposed. Weaning rate ranged from 69 to 79% for generation three 1/4 Brahman dams compared with 60% for Hereford dams.

Results from research conducted at the US Meat Animal Research Center (1979) at Clay Center, Nebraska using F_1 dams generated by breeding Angus and Hereford dams to Angus, Hereford, Pginzgauer, Tarentaise, Brahman and Sahiwal sires indicate that Brahman-sired F_1 dams are exceeded only by Sahiwal-sired dams for percentage calf crop born and percentage calf crop weaned. The Sahiwal breed is a Zebu breed known for high milk yield that originated in the area that is now Pakistan (Sanders, 1980). Brahman-sired dams averaged 86.5% calf crop born while Sahiwal-sired dams averaged 93.4% compared with 75.5% for Angus x Hereford reciprocal crosses. For calf crop weaned, Brahman-sired dams averaged 78.8% compared with 88.0 and 68.8% for Sahiwal-sired and Angus x Hereford reciprocal cross dams, respectively.

Use of Brahman breeding in crossbreeding programs is largely restricted to the Gulf Coast region of the US. However, research results from Nebraska, Nevada and Canada indicate that Brahman or other Zebu breeds can be effectively incorporated into crossbreeding programs in environments colder and less humid than those typical to the Gulf Coast region of the US to improve reproductive performance.

Birth traits

Birth weight of calves is important because of the relationship between birth weight and calving difficulty. Two studies from Florida yield conflicting results for birth weight of calves from Brahman-cross dams. Turner (1969) reported that bull calves from Brahman-cross dams tended to be lighter at birth than bull calves from Angus x Brangus, Angus x Hereford and Brangus x Hereford reciprocal cross dams. This trend was present to a lesser extent for dams producing heifer calves. Crockett et al. (1978b) reported birth weights for calves out of Angus, Brahman, Hereford and Angus x Brahman, Angus x Hereford and Brahman x Hereford rotational cross dams to be 23.9, 28.8, 28.0, 30.4, 25.3 and 32.4 kg, respectively. Purebred Brahmans produced the heaviest straightbred calves and dams in rotations involving Brahman breeding produced the heaviest crossbred calves. Neither of these two studies reported calving difficulty.

In the Nevada study, calves from Brahman-cross dams tended to be lighter at birth than those from other crosses. Bailey et al. (1988) reported birth weights for calves from Brahman x Hereford and Brahman x Angus dams to be 33.5 and 30.8 kg, respectively. Comparatively, calves from Angus x Hereford and Angus x Charolais dams were heavier ($P<.01$) as they averaged 36.0 and 36.9 kg, respectively, at birth. The frequency of calving difficulty was so low (14 cases out of 869 matings) that the data were not analyzed.

Research at US Meat Animal Research Center (1979) indicates that two-year-old Brahman-sired dams produce calves intermediate for birth weight when compared with other crosses. Calves from Brahman-sired dams were heavier than those from Hereford-, Angus- and Sahiwal-sired dams but were lighter than calves from Pinzgauer- and Tarentaise-sired dams. Two-year-old Sahiwal-sired dams produced the lightest calves (30.2 kg), Brahman-sired dams produced calves averaging 34.6 kg at birth and Pinzgauer-sired dams produced the heaviest calves at birth (36.9 kg). As three-year-olds, the ranking changed only slightly as Angus- and Hereford-sired dams produced calves heavier at birth than Brahman-sired dams. Pinzgauer-sired dams still produced the heaviest calves at birth (39.1 kg), Brahman-sired dams produced calves averaging 33.8 kg and Sahiwal-sired dams still produced the lightest calves (32.4 kg). For both age groups, Brahman- and Sahiwal-sired dams experienced less calving difficulty than other breed groups. As two-year-olds, Brahman-sired dams experienced calving difficulty only 13% of the time, compared with 11.2% for Sahiwal-sired dams and 52.2% for Angus- and Hereford-sired dams. The same trend was present for these groups as three-year-olds. Brahman-sired dams experienced 0% difficult births while Sahiwal-sired dams required assistance 3.5% of the time and Angus- and Hereford-sired dams experienced calving difficulty 13.4% of the time. As would be expected, three-year-olds required less assistance than two-year-olds for all dam breed groups.

In the Canadian study by Peters and Slen (1967), F_1 Brahman-cross dams produced calves lighter at birth than straightbred Herefords, 28.7 and 32.1 kg, respectively. Generation 3, 1/4 Brahman dams produced calves similar in birth weight to straightbred Herefords. As two-year-olds, none of the F_1 cows required assistance at birth which was attributed to the low birth weights of their calves. Forty-two percent of the straightbred Herefords required assistance and 3% of the 1/4 Brahman cows required assistance at birth as two-year-olds.

Roberson et al. (1986) reported Brahman-Hereford F_1 dams to be intermediate in birth weight of calves produced to straightbred Brahman and Hereford dams. In this study, conducted in Texas, Brahman, Hereford and Brahman-Hereford F_1 sires were bred to Brahman, Hereford and Brahman-Hereford F_1 dams. Calves produced by F_1 dams were intermediate to both purebred groups when bred to each of the three sire breeds. Calves from F_1 dams were heavier than those from Brahman dams and lighter than those from Hereford dams. Calving difficulty was not reported.

McDonald and Turner (1972) reported Brahman-cross dams produced calves lighter at birth than other crosses in a Louisiana study. In this study, dams of all possible two-breed combinations of Angus, Brahman, Brangus and Hereford were bred to Angus, Brahman, Brangus, Charolais and Hereford sires to produce three-breed cross calves. Across sire breeds, Angus x Brahman reciprocal crosses tended to produce the lightest calves (29.7 kg), followed by Brahman x Hereford reciprocal crosses (30.9 kg) and Brahman x Brangus reciprocal crosses (31.2 kg). The remaining breed groups, Angus x Hereford, Angus x Brangus and Brangus x Hereford produced calves averaging 34.5, 34.1 and 33.2 kg, respectively.

<u>Preweaning growth</u>

Turner (1969) in a study involving reciprocal groups of two-breed cross cows reported that calves nursing

Brahman-cross dams gained faster than those nursing other crossbred dams. Angus x Brahman, Brahman x Brangus and Brahman x Hereford reciprocal cross dams produced calves that gained faster than the overall average. On the other hand, Angus x Brangus, Angus x Hereford and Brangus x Hereford reciprocal cross dams produced calves that gained at rates below the overall mean.

Bailey et al. (1988) examined differences between cow groups for a preweaning weight taken at approximately 84 days of age. Calves from Brahman x Angus dams were lightest (105.3 kg), followed by calves from straightbred Red Poll dams (108.3 kg) and then Brahman x Hereford dams (110.3 kg). Both Brahman crosses produced lighter calves at 84 days of age than straightbred Hereford, Hereford x Red Poll reciprocal crosses, Angus x Hereford and Angus x Charolais dams. Angus x Charolais dams had the heaviest calves (118.0 kg).

Roberson et al. (1986) reported differences in preweaning growth of calves out of Brahman, Hereford and Brahman-Hereford F_1 dams indicating F_1 dams to be superior. Major differences in favor of F_1 dams were found when cows were bred to Brahman and Brahman-Hereford F_1 sires. When mated to Hereford sires, calves from F_1 dams were only slightly superior to those from Brahman dams, however, large differences existed between these two groups and straightbred Herefords.

Weaning Traits

Heterosis has been shown to be expressed to a high degree in weaning weight of calves from Brahman-cross dams. Weaning weight is generally a direct measure of the primary product of the cow herd (Long, 1980). Dinkel and Brown (1978) found weaning weight to be highly correlated with and thus the best single predictor of cow-calf efficiency to weaning.

Two Louisiana studies have shown advantages in weaning weight for calves out of Brahman-cross dams. Turner and McDonald (1969) reported Brahman-cross cows that weaned calves heavier than other two-breed cross cows. Angus x Brahman, Brahman x Brangus and Hereford x Brahman reciprocal cross cows produced calves averaging 205, 208 and 212 kg, respectively. Comparatively, Angus x Brangus, Brangus x Hereford and Angus x Hereford reciprocal cross cows produced calves averaging 193, 201 and 182 kg, respectively. The two crosses involving Brangus were significantly superior to the Angus x Hereford crosses. McDonald and Turner (1972), using the same six reciprocal crossbred groups as above in a different study, obtained similar results. Crosses involving Brahman weaned heavier calves than those not involving Brahman. Differences in condition scores were found between calves from Brahman-cross dams and calves from other crossbred cows. A score of 10 denoted a grade of average good with each unit change referring to 1/3 of a grade. Brahman x Angus, Brahman x

Hereford and Brahman x Brangus weaned calves averaging conditions scores of 10.1, 10.1 and 10.3, respectively. Calves from Brangus x Hereford, Angus x Brangus and Angus x Hereford reciprocal crosses received scores averaging 9.7, 9.7 and 9.5 respectively. Thus, an advantage for those calves out of Brahman-cross dams is indicated.

Three studies from Florida have indicated advantages similar to those found in Louisiana for Brahman-cross dams. Koger et al. (1975) reported adjusted 205 d weights for calves from Brahman, 3/4 Brahman-1/4 Shorthorn, Brahman-Shorthorn F_1, 1/4 Brahman-3/4 Shorthorn and Shorthorn dams, averaged across three different pasture programs, to be 180, 183, 195, 177 and 152 kg, respectively. These results indicated an advantage was held by 3/4 and 1/2 Brahman dams over the other breed groups with the F_1 dams being superior. Condition scores reflected a similar trend as they averaged 9.2, 9.3, 9.9, 9.1 and 8.9 for calves out of the five respective breed groups. Crockett et al. (1978), using Angus, Brahman and Hereford breeding in all possible two-breed rotations, found Angus-Brahman and Brahman-Hereford rotations produced heavier calves at weaning than Angus-Hereford rotations averaged across three generations. Calves from Brahman-Angus and Brahman-Hereford rotations averaged 202.2 and 205.9 kg, respectively, at weaning, compared with 182.1 kg for calves from Angus-Hereford rotations. Weaning condition scores followed a similar pattern as calves from Brahman-Angus, Brahman-Hereford and

Angus-Hereford rotations averaged 9.6, 9.3 and 9.2, respectively. Peacock et al. (1981) reported adjusted 205 d weaning weights for three-breed-cross calves out of Brahman x Angus dams to average 221.8 kg, compared with 207.0 and 206.7 kg for calves out of Brahman x Charolais and Angus x Charolais dams. Backcross calves from these F_1 dams were the lightest (188.6 kg) for Angus-sired calves out of Angus-Charolais F_1 dams and heaviest (222.7 kg) for Charolais-sired calves out of Brahman-Charolais F_1 dams. Other groups of backcross calves were similar as 205 d adjusted weaning weights ranged from 202.2 to 207.3 kg. Weaning condition scores were the highest among three-breed cross calves out of Brahman-Charolais F_1 dams. Angus-Charolais and Brahman-Angus F_1 dams produced similar three-breed cross calves as both groups averaged scores of 10.2. Backcross calves from Brahman-Angus F_1 dams were superior to calves from other groups as Brahman-sired and Angus-sired calves averaged 10.7 and 10.4, respectively. Backcross calves from other groups ranged from 9.6 to 9.8.

In the Texas study by Roberson et al. (1986), Brahman-Hereford F_1 dams weaned heavier calves than straightbred Hereford and Brahman dams when bred to Hereford, Brahman and Brahman-Hereford F_1 sires. Calves from F_1 dams averaged 196.4 kg at weaning across sire breeds, compared with 180.4 kg for Brahman dams and 175.0 kg for Hereford dams.

Average 180 d weaning weights for calves out of Brahman x Angus and Brahman x Hereford dams were reported to average 204.2 and 213.6 kg, respectively, in a Nevada study (Bailey et al., 1988). These averages were exceeded by all other breed groups in the study with the exception of calves produced by Hereford dams. Angus x Charolais dams weaned the heaviest calves (223.0 kg) and Hereford dams the lightest (202.8 kg).

Both two- and three-year-old Brahman-sired dams weaned heavier calves than other crossbred cow groups in US Meat Animal Research Center Germ Plasm Evaluation Program (1979). Two-year-old Brahman-sired dams, out of Angus and Hereford dams, weaned calves averaging 220.9 kg, compared with 202.7 kg for both Tarentaise- and Sahiwal-sired dams and 179.1 kg for Angus- and Hereford-sired dams. Three-year-old Brahman-sired dams weaned calves averaging 233.3 kg while Sahiwal-, Tarentaise-, Angus- and Hereford-sired dams weaned calves averaging 223.2, 225.0, 206.8 and 193.6 kg, respectively.

In the Canadian study by Peters and Slen (1967), weaning weight averages of 195, 191, 184 and 150 kg for Hereford-sired calves out of Brahman x Shorthorn, Brahman x Angus, Brahman x Hereford and Hereford dams, respectively, were reported. One-quarter Brahman dams with the remaining proportion being either Shorthorn, Angus or Hereford also weaned calves heavier than those from straightbred Hereford dams. Of the 1/4 Brahman dams, 3/4 Shorthorn dams produced calves averaging 186 kg, 3/4 Angus dams averaged 182 kg followed by 170 kg for 3/4 Hereford dams and 152 kg for straightbred Herefords. Thus the advantage due to Brahman-breeding is maintained with only 1/4 Brahman breeding.

Milk Production

Willham (1972) stated that the amount of milk produced by a cow being used for beef production is not as important as the response of the calf to the total maternal environment created by the cow. Several researchers have reported strong relationships between milk production of dam and performance of their calf. Neville (1962) reported 66% of the variation in calf weight at eight months due to milk consumption. Totusek et al. (1973) also demonstrated the importance of milk production of beef cows to optimize calf performance. However, only limited information is available as to the milk production capabilities of Brahman and Brahman-cross dams.

In a Venezuela study, Neidhardt et al. (1979) estimated 24 hr milk production from Brahman cows to be 6.2 kg using weigh-suckle-weigh procedures at 6 hr intervals on eight monthly test days. The eight month lactation curve for these straightbred Brahmans was similar to that found for British breeds of beef cattle. Milk production increased from the first to the second month, decreased slightly the third month and decreased steadily for the remainder of lactation.

Daley et al. (1987) measured 24 hr milk yield at 60, 105 and 150 d postpartum for Hereford, Red Poll, Hereford x Red Poll reciprocal cross, Angus x Hereford, Angus x Charolais, Brahman x Hereford and Brahman x Angus dams. At 60 d postpartum, Angus x Herefords produced the most milk (9.77 kg) and Brahman x Angus and Brahman x Hereford dams were the two lowest groups, 7.78 and 7.00 kg, respectively. On a weight basis, Brahman-cross dams also produced the least butterfat, protein, lactose and solids-not-fat. At 105 d postpartum, Angus x Charolais dams produced the most milk (10.15 kg) while Brahman x Hereford cows produced the least (7.60 kg),Hereford cows were second lowest (7.98 kg) and Brahman x Angus cows were third lowest (8.40 kg). Hereford, Angus x Hereford, Brahman x Hereford and Brahman x Angus had the lower daily yield of butterfat at d 105 than the other crossbred groups. No other differences were found at 105 d postpartum for the other milk components. At 150 d postpartum, Brahman x Angus produced the most milk (8.97 kg) while Herefords produced the least (5.81 kg) and Brahman x Hereford cows were second lowest as they averaged 7.28 kg. No differences were found for milk components. Thus results from this study indicated that Brahman-cross dams yield less milk per lactation than other crosses in a Nevada environment.

Studies in the Southeastern US and Nebraska, however, have found Brahman-cross dams to produce more milk than other crosses. Cundiff et al. (1984) reported that three-year-old Brahman x Angus and Brahman x Hereford dams had higher 12 hr milk yields than Hereford x Angus reciprocal cross dams. In a Louisiana study, Reynolds et al. (1967) reported milk production of three-year-old Angus, Africander-Angus, Brahman, Brangus and Brahman-Angus heifers to be 3.1, 2.9, 2.8, 3.4 and 4.3 kg, respectively after a 16 hr separation period. Dams four years of age and older produced 3.8, 3.6, 3.2, 3.8 and 5.0 kg for these respective groups. These authors stated also that measurements for Brahman cows may be inaccurate because of temperament of cow and some calves refused to nurse. Results from a Texas study indicated that Brahman-Hereford cross dams produced 6.08 kg of milk in a 24 hr period compared with only 3.36 and 3.45 kg for Hereford and Brahman dams, respectively (Todd et al., 1968).

Effects of Season of Birth

Reproductive Traits

Several researchers have demonstrated seasonal effects on age at puberty and reproduction of heifers. A study involving Holstein-Friesian heifers found age at puberty to be affected by season of birth (Hawk et al., 1954). These researchers found no difference between summer-, fall- and winter-born heifers, but spring-born heifers reached puberty at a younger age (P<.05) than heifers born in the other seasons. Grass et al. (1982) reported similar results in that few fall-born crossbred heifers reached puberty in the winter and were thus delayed until the following spring.

March- and September-born Angus x Holstein heifers were used in conjunction with environmental chambers to determine the effects of season on age at puberty by Schillo et al. (1983). After weaning (six months of age), heifers of each birth group were split into two groups. One group from each birth group was then placed in an environmental chamber which simulated the conditions expected to be present in a fall-spring sequence and the other group was placed in a chamber which simulated a spring-fall sequence. Heifers were maintained in these chambers for six months. Age at puberty was affected by date of birth and chamber sequence. September-born heifers reached puberty at a younger age then March-born heifers and heifers in the chambers simulating the spring-fall sequence were younger than those in the fall-spring chambers at puberty. Ages at puberty (in days) were 295 for September-born, spring-fall; 319 for September, fall-spring; 321 for March-born, spring-fall; and 346 for March-born, fall-spring heifers. These results indicated trends opposite to those found by other researchers under natural conditions.

Plasse et al. (1968) reported that Brahman and Brahman-crosses in Florida experienced anestrus-like behavior during the winter months. The average age at first corpus luteum was 19.4 months for straightbred

Brahmans and 17.0 months for Brahman-cross heifers. These ages were much greater than those reported for Bos taurus cattle. A depression in ovarian activity was observed in the Brahman heifers. Although 77 to 84% had reached puberty, only 29 to 44% of the heifers had a corpus luteum between November and January. Thus these results indicated that trying to use Brahmans in a fall-calving operation could result in decreased reproductive rates.

Calf Performance

Roberson et al. (1986) reported that calves born to Hereford, Brahman and Brahman-Hereford F_1 dams in January, February and March had average birth weights of 32.5 kg, those born in April, May and June averaged 34.2 kg and those born in October, November and December averaged 32.1 kg. Thus, calves born during the spring are indicated to be heavier at birth than those born in the fall and winter.

Cundiff et al. (1966) reported that spring-born (February-April), Hereford and Angus calves had higher 205 d weaning weights than calves born in all other seasons using Oklahoma field data. Calves born in August, September and October had the lowest 205 d weights. Marlowe and Gaines (1958), using Angus, Hereford and Shorthorn field data collected from herds in Virginia, evaluated the effects of season of birth on preweaning growth rate and type scores. Creep feeding of calves removed the effects of season of birth on growth rate and type score. Growth rate for calves born in June through December averaged .05 kg/d less than the growth rate of calves born in February through May. Calves born between June 1 and September 1 which were not creep fed averaged 1/3 of a grade lower than non-creep fed calves born other seasons. Brown (1960) reported that fall-born Hereford and Angus calves from herds in Arkansas averaged 16 to 18 kg lighter ($P<.05$) at 240 d than spring-born calves. Using Iowa field data, Sellers et al. (1970) reported that winter- and spring-born calves had heavier 205 d adjusted weaning weights than calves born in other seasons. Thus the overall trend obtained from these projects indicates that spring calving is advantageous to fall calving when comparing weaning weight of calves.

Effects of Genotype x Environment Interactions

Reproductive Traits

Butts et al. (1971) reported significant genotype x environment interactions for percent pregnant and percent weaned. These researchers used two herds of Hereford cattle, one originating at the US Range Livestock Experiment Station, Miles City, MT and the other originating at the Brooksville Beef Cattle Research Station, Brooksville, FL. These herds were subdivided and half of each was transferred to the opposite location. Percent pregnant and percent weaned were lower for the cattle originating in Montana and located in Florida than for the other three groups which were similar. Koger et al. (1979) analyzed an expanded version of the data used by Butts et al. (1971) and found similar results for both pregnancy and weaning rates.

In a Florida study, Peacock et al. (1971) reported pregnancy rate to be significantly influenced by pasture program x breed of cow interaction. A differential response to improved pasture was observed. Straightbred Brahman and Shorthorn cows averaged 61% pregnant on native range and 72% pregnant on highly improved pasture, a difference of 11%. Crossbred cows (3/4 Brahman-1/4 Shorthorn, Brahman-Shorthorn F_1 and 1/4 Brahman-3/4 Shorthorn) averaged 67 and 86% for native range and highly improved pasture, respectively, a difference of 19%. Thus, crossbred dams are indicated to have a greater response to improved nutrition than do straightbred dams. This same trend was present for weaning rate. Grass et al. (1982), however, found no breed or breed-of-sire x diet interaction for age at puberty in crossbred heifers out of Holstein dams, sired by Angus, Hereford, Simmental or Chianina bulls.

Calf Performance

Burns et al. (1979) using the same cow herds as Butts et al. (1971) and Koger et al. (1979) found significant line by location interactions for birth weight. For the lines located in Montana, cattle from Montana produced calves averaging 36.8 kg at birth compared to 35.0 kg for dams of Florida origin. The same trend was present for the Florida herd as cattle from Florida had calves averaging 29.8 kg at birth compared with an average of 29.0 kg for calves out of dams originating in Montana. Similar trends were found for daily gain, 205 d weaning weight and annual production per cow. Daily gain for calves produced by the Montana line in Montana averaged 744 g while the line originating in Florida averaged 724 g. In Florida, the Florida line produced calves averaging 744 g compared with 664 g for the Montana line. Weaning weights averaged 197.5, 182.9, 166.1 and 183.2 kg, respectively, for Montana and Florida lines in Montana and Florida. Annual production per cow averaged 145.6, 139.2, 108.0 and 146.0 kg, respectively, for local and Florida lines in Montana and Montana and local lines in Florida. The only trait not affected by a line by location interaction was condition score. Calves from cattle originating in Florida received higher scores at both locations.

Sellers et al. (1970) reported a significant season of birth by breed interaction on preweaning gains of Hereford and Angus calves in Iowa. Spring- and summer-born Angus calves gained faster to weaning than Hereford calves born in these same seasons. The reverse was true for calves born in the fall and winter.

Using Brahman x Angus, Santa Gertrudis crossbreds and Brahman x Hereford dams, Holloway et al. (1988) reported a significant breed type x management intensity interaction for calf weight at weaning. Calves from Brahman x Angus dams were heaviest for all three management intensities as they averaged 230, 234 and 226 kg, respectively, for high, medium and low management intensities. Under high intensity management, Santa Gertrudis crossbreds produced calves averaging 224 kg while Brahman x Hereford weaned calves averaging 221 kg. These two groups were similar under medium management intensity as Santa Gertrudis crossbreds averaged 228 kg and Brahman x Herefords averaged 229 kg. Under low management intensity, Brahman x Herefords averaged 225 kg compared with 214 kg for Santa Gertrudis crossbreds.

Bolton et al. (1987) reported significant proportion Brahman x season of calving interactions for preweaning average daily gain and weaning weight. Preweaning growth rate and subsequently weaning weight increased as proportion Brahman increased from 0 to 50% for spring-born calves. However, growth rate for fall-born 0 Brahman calves was greater than that of 1/4 and 1/2 Brahman calves. Due to differences in birth weight, weaning weights were similar for the three groups of fall-born calves.

Rollins et al. (1964) compared the postweaning growth of 3/4 Hereford-1/4 Brahman calves with that of straightbred Hereford calves in the Imperial Valley region of California. Crossbred calves outgained Hereford calves in the summer both on pasture and in the feedlot. During the fall and winter months Hereford cattle outgained crossbreds in the feedlot. Since the same cattle were used for both feeding periods, the authors felt that a portion of the differences may be attributable to compensatory growth.

Summary

The effects of Brahman breeding on cow productivity in the Gulf Coast region of the US is well documented (Turner 1969, Koger et al. 1975, Peacock et al. 1980 and Roberson et al. 1986). Brahman breeding has been shown to increase weaning weight which is an accurate measure of both the primary product and efficiency of a cow-calf operation. Therefore, use of Brahman breeding can increase efficiency of production and product output. Similar results have also been obtained in more temperate regions such as Nebraska and Alberta, Canada (US Meat Animal Research Center, 1979 and Peters and Slen, 1967). Thus, Brahman breeding may be useful in environments less hot and humid than those typically found in the Southeastern US. However, more research in temperate regions is needed to better evaluate the potentials of using Brahman-cross dams in a commercial cow-calf operation.

Studies examining the effects of season of birth or season of calving have generally indicated as advantage for spring-calving over fall-calving management systems (Marlowe and Gaines 1958, Cundiff et al. 1966, Sellers et al. 1970 and Roberson et al. 1986). Spring-born calves typically gain faster to weaning and thus have higher weaning weights than fall-born calves. Also, spring-born heifers generally reach puberty at a younger age than fall-born heifers. Therefore, spring-born heifers are able to begin their productive life sooner than fall-born heifers which results in lower replacement costs.

Few studies have evaluated the interaction of genotype with season of birth of season of calving. Even fewer studies have been published concerning any type of genotype by environment interaction involving Brahman or Brahman-cross cattle (Peacock et al. 1971, Bolton et al. 1987 and Holloway et al. 1988). Genotype by environment interactions have been shown to exist (Butts et al. 1971, Koger et al, 1979, Burns et al. 1979, Grass et al. 1982 and Schillo et al. 1983). Therefore, genotype x environment interactions need to be carefully evaluated in future experiments to better determine optimum crossbreeding systems for commercial beef production.

CHAPTER III

PRODUCTIVITY OF TWO-YEAR-OLD CROSSBRED COWS CONTAINING VARIOUS PROPORTIONS OF BRAHMAN BREEDING IN SPRING OR FALL CALVING SYSTEMS

Abstract

Productivity of two-year-old crossbred cows containing various proportions (0, 1/4 or 1/2) of Brahman breeding was evaluated using 203 spring-calving and 171 fall-calving heifers over a three year period. All heifers were mated to Limousin sires. Percentage of cows exposed to breeding that weaned a calf was the only trait for which a significant crossbred cow group X season of calving interaction was found. Preweaning ADG and age adjusted weaning weight tended to increase as proportion Brahman breeding increased. Spring-born calves outgained ($P<.05$) fall-born calves by .10 kg/d. However age adjusted weaning weight was similar for the two groups as spring-born calves were weaned at an average age of 205 d and fall-born calves were weaned at an average age of 240 d. Weaning condition scores were similar for all calves. Weaning conformation scores were greater ($P<.05$) for spring-born calves (13.1) than fall-born calves (12.7). Age adjusted weaning hip height increased as proportion Brahman breeding increased. These data indicate, based on reproductive rate, that spring calving is advantageous to fall calving. In both seasons weaning weight tended to increase as proportion Brahman increased.

(Key Words: Crossbreeding, Cow Productivity, Genotype X Environment Interaction, Angus, Brahman, Hereford.)

Intorduction

Crossbreeding is one of the major management techniques available for commercial beef cattle producers attempting to increase efficiency of production. Since additive and non-additive genetic variation are generally both important, improvement is maximized by combining systematic crossbreeding with selection among and within breeds (Cundiff, 1970). However, successful crossbreeding requires the choice of appropriate breed combinations for the environment and production management system (Koger, 1980). Different environments have been shown to have varying effects on different breed types due to genotype X environment interactions. Peacock et al. (1971) found significant cow breed group by type of pasture interactions for pregnancy rate among purebred Shorthorn, purebred Brahman, 1/4 Brahman-3/4 Shorthorn, 1/2 Brahman-1/2 Shorthorn and 3/4 Brahman-1/4 Shorthorn cows as pregnancy rate of crossbred cows increased 19% on improved pasture versus an 11% increase for purebred cows. Sellers et al.

(1970) reported significant season of birth by breed interaction as spring- and summer-born Angus calves gained faster to weaning than Hereford calves born in these seasons, whereas fall- and winter-born Hereford calves had higher preweaning gains than Angus calves born in these seasons.

Since different types of cattle may have varying levels of performance in different environments, a long-term study was initiated for the evaluation of the effects of genotype (crossbred cow group), environment (season of calving) and genotype X environment interactions on cow productivity using crossbred cows with different proportions of Angus, Brahman and Hereford breeding managed in either spring or fall calving systems. The objective of this portion of the study was to determine the effects of crossbred cow group, season of calving and the interaction between crossbred cow group and season of calving on productivity to weaning of two-year-old females.

Materials and Methods

Angus (A) and Hereford (H) dams were assigned at random to spring- and fall-calving groups and mated to A, H, Brahman (B), 1/2B-1/2A and 1/2B-1/2H bulls to produce crossbred calves that were 0 Brahman (1/2 H-1/2 A and 1/2 A- 1/2 H), 1/4 Brahman (1/4 B-1/4 H-1/2 A and 1/4 B-1/4 A-1/2 H) and 1/2 Brahman (1/2 B-1/2 A and 1/2 B-1/2 H) over a three year period (1981-1983). The mating system, origin of foundation breeding stock and growth performance of crossbred calves were reported by Bolton et al. (1987a). Postweaning growth, sexual development and pregnancy rate of heifers were reported by Bolton et al. (1987b).

Heifer calves, after weaning, remained at the Southwestern Livestock and Forage Research Laboratory, El Reno, Oklahoma and were managed to calve first as two-year-olds. Heifers were maintained on pastures consisting predominantly of big bluestem (Andropogon gerardii), little bluestem (Schizacharium scoparius), buffalograss (Buchloe dactyloides), sideoats grama (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon). Heifers in the spring-calving group were supplemented from mid-December through mid-April with approximately .8 kg/head/d of 41% cottonseed meal cubes and were provided access to hay (wheat, oat and Old World bluestem) based on range and weather conditions. Fall-calving heifers were supplemented with 1 kg/head/d of 41% cottonseed meal cubes from December through mid-April and were also provided hay based on range and weather conditions. The number of available heifers are presented by crossbred cow group, season of calving and year in Table 1.

Monthly average minimum and maximum temperatures and precipitation amounts for 1983 through 1986 are presented in Table 2. December and January were typically the coldest months with average minimum temperatures ranging from -9 to 0 C and average maximum temperatures ranging from 0 to 13 C. July and August were the warmest months with average maximum temperatures between 32 and 37 C. Yearly precipitation amounts ranged from 78.1 cm in 1984 to 116.7 cm in 1985.

Heifers were exposed to Limousin bulls, in single sire pastures, for a 75 d breeding season for 1983 and 1984 calf crops. For 1985 calf crop, heifers were synchronized and bred to Limousin bulls by artificial insemination once and then placed in single sire breeding pastures with Limousin bulls for a total breeding period of 75 d. Spring-calving heifers were bred to calve in February, March and April and fall-calving heifers were bred to calve in September, October and November.

Condition scores and weights were obtained for the heifers prior to breeding and at the time their calves were weaned. Calving difficulty scores were assigned by the herdsman using a scale of 1 to 6 (1 = no difficulty, 2 = little difficulty, 3 = moderate difficulty, 4 = major difficulty, 5 = caesarean section and 6 = abnormal presentation). Cows receiving a score of 6 were deleted from the analysis. Cows receiving a score of 1 or 2 were assigned a value of 0 whereas a score of 3 or more was considered a difficult birth which required assistance and was assigned a value of 1 for analysis. Birth weights were obtained and male calves were castrated within 24 h of birth. Calves remained with their dams on pasture and were not creep fed. Spring-born and fall-born calves were weaned at an average of 205 and 240 d, respectively. Fall-born calves were weaned at an older age as this is a common practice of Oklahoma producers. Calf weight, hip height, condition score and conformation score were determined at weaning. Calf condition scores (1 = very thin to 9 = very fat with 5 = average) and conformation scores, a measure of muscling, (12 = low choice, 13 = average choice and 14 = high choice) were determined by averaging scores assigned by two to four evaluators. Calf weaning weights and hip heights were adjusted to 205 and 240 d of age respectively, for spring- and fall-born calves.

Data were analyzed using Harvey's LSMLMW PC-1 Version (Harvey, 1987). The full model included effects for crossbred cow group, sire nested within crossbred cow group, sex of calf, season of calving, year of calving, sire of calf, prebreeding and weaning cow weight and condition score along with all two factor interactions. Least squares means were estimated using reduced models for each of the traits analyzed which contained appropriate effects ($P<.15$). Comparisons among means were made using least significant differences.

Results and Discussion

Significance levels for crossbred cow group (CG), season of calving (S), year, sex of calf and CG X S interaction are presented in Table 3. Crossbred cow group was a significant source of variation on percentage of cows exposed to breeding that weaned a calf (%W), calving difficulty (CD), preweaning average daily gain (ADG), age adjusted weaning weight (WW), weaning conformation score (WG), and age adjusted weaning hip height(WH). Season of calving significantly affected %W and birth weight (BW). Year of calving was a significant source of variation for WH. Sex of calf had a significant effect on CD, BW, ADG and WW. Percentage of cows exposed to breeding that weaned a calf was the only trait for which a significant CG X S interaction existed.

Least squares means and standard errors for percentage cows exposed to breeding that weaned a calf are presented in Table 4. Overall 60.3% of heifers exposed to breeding weaned a calf. This average is slightly lower than that found by Peacock et al. (1971) who reported a weaning rate of 71% for cows containing either 0, 25, 50, 75 or 100% of Brahman breeding with the remaining proportion being Shorthorn, crossbred groups ranged from 74% for F_1 cows to 76% for 3/4 Brahman cows. Percentage of cows exposed to breeding that weaned a calf ranged from 0% for fall-calving Brahman-Hereford to 88.5% for spring-calving 1/4 Brahman:1/4 Hereford:1/2 Angus. All spring-calving cow groups weaned a higher percentage of calves than did their fall-calving counterparts. No significant differences existed between CG in the spring-calving herd. Fall-calving Hereford-Angus (HA) were similar to all spring-calving groups. The large difference between HA and other crossbred groups in the fall season can be attributed to a larger proportion of the AH cycling at an earlier age. Within the fall-calving herd, Angus-Hereford (AH), 1/4 Brahman:1/4 Hereford:1/2 Angus (BHA), 1/4 Brahman:1/4 Angus:1/2 Hereford (BAH) and Brahman-Angus (BA) were similar and their weaning percentages ranged from 45.1 to 58.1 percentage points lower than their respective spring-calving counterparts. No fall-calving Brahman-Hereford cows weaned a calf as a two-year-old. The trend of %W decreasing as proportion Brahman increased was expected based on similar trends in percent detected in heat and percent pregnant as reported by Bolton et al. (1987b). The differences between spring- and fall-calving groups may in part be due to the anestrus-like behavior of Brahman and Brahman crosses during the winter months similar to that reported by Plasse et al. (1968).

Least-squares means and standard errors for CD, BW, ADG and WW are presented in table 5 by CG, S and sex of calf (SX). Calving difficulty or percentage of cows requiring assistance (those receiving a score of 3 or higher) ranged from 5.8% for BA to 31.9% for BAH (table 5). Overall, 21.0% required assistance at calving. Belcher and Frahm (1979) reported a similar average of 27.9% calving difficulty for two-year-old crossbred cows. Although not significantly different from Brahman-Hereford (BH) and Hereford-Angus (HA), BA required significantly less assistance than AH, BHA and BAH. No significant differences existed between AH, BHA and BAH. No significant differences in BW existed between CG with average BW across groups being 32.6 kg (Table 5). Spring-calving cows required 6.1 percentage points more ($P<.05$) assistance than did fall-calving cows. This difference is due in part to the 2 kg difference in BW for the two calving groups. Cows giving birth to male calves required 19.3 percentage points more assistance than those having female calves. Again, this difference may be attributable to differences in BW as male calves averaged 3.4 kg heavier ($P<.05$) at birth than female calves. These findings tend to agree with those of Roberson et al. (1986) who reported significant seasonal effects on birth weight as calves born in January-March averaged 32.5 kg, those born in April-June averaged 34.2 kg and calves born in October-December averaged 32.1 kg. Bull calves were reported to be 2.5 kg heavier at birth than heifer calves.

No differences in ADG and WW existed between calves from 1/4 and 1/2 B dams (Table 5). Calves from 1/4 and 1/2 B cow groups were faster ($P<.05$) gaining and thus heavier ($P<.05$) at weaning than calves from 0 B dams. Although spring-born calves gained an average of .10 kg/d faster ($P<.05$) than fall-born calves, the two groups had similar WW due to the age differences at weaning. Preweaning ADG of male calves averaged .03 kg/d more ($P<.05$) than female calves resulting in a 9.3 kg advantage at weaning.

No differences in conformation scores were found between crossbred cow groups. Conformation score least-squares means for spring- and fall-born calves were 13.1 ± .1 and 12.7 ± .1, respectively, thus indicating spring-born calves to be heavier ($P<.10$) muscled than fall-born calves at weaning. The overall mean condition score was 5.30 with no differences attributable to the effects included in the model.

Age adjusted weaning hip height least squares means and standard errors are presented in Table 6 by CG and year x season (Y x S) interaction. Calves within each proportion B group were similar with WH increasing ($P<.05$) as proportion B increased. Age adjusted weaning hip height was significantly affected by Y x S interaction. The reason for this interaction is an unexplainable increase ($P<.05$) in WH by the fall 1985 calves. All other Y x S groups were similar.

Since crossbreeding is used to increase production efficiency, performance of females as two-year-olds is important from an economic standpoint. The earlier in life a heifer becomes productive, the lower the cost of replacements. The data presented in this study indicate relatively large differences in the producing ability of two-year-old crossbred cows in spring- and fall-calving systems. These differences, in part, may be attributable to rate of development and sexual maturity of the different crossbred groups. Thus, as these cows mature, the relative ranking of these groups may change.

TABLE 1. NUMBER OF AVAILABLE RECORDS BY CROSSBRED GROUP, SEASON AND YEAR

Crossbred cow group[a]	1983 Spring	1983 Fall	1984 Spring	1984 Fall	1985 Spring	1985 Fall	Total
HA	10	12	9	6	7	5	49
AH	6	7	6	7	0	0	26
BHA	21	16	18	11	9	13	88
BAH	16	14	12	8	10	6	66
BA	13	17	13	10	16	11	80
BH	10	13	20	10	7	5	66
Total	76	79	78	52	49	40	374

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

TABLE 2. RAINFALL AND AVERAGE MINIMUM AND MAXIMUM DAILY TEMPERATURES BY MONTH FOR 1983 THROUGH 1986.

Month	1983 Temperature[a] Min	1983 Temperature[a] Max	1983 Rain[b]	1984 Temperature Min	1984 Temperature Max	1984 Rain	1985 Temperature Min	1985 Temperature Max	1985 Rain	1986 Temperature Min	1986 Temperature Max	1986 Rain
January	-3	7	.8	-5	7	.5	-6	5	7.7	-5	13	0.0
February	0	9	7.7	1	15	1.8	-4	7	11.7	0	13	2.0
March	2	14	7.8	2	13	13.0	6	17	12.7	5	19	2.7
April	5	17	4.1	7	19	7.3	11	23	13.6	10	22	14.1
May	12	24	18.9	13	25	6.8	14	27	4.3	14	25	12.8
June	17	29	9.3	20	32	13.5	18	30	16.2	20	30	8.8
July	21	35	0.0	20	34	1.6	20	33	6.2	22	35	4.9
August	22	37	2.2	20	35	2.6	20	33	5.8	19	32	17.9
September	16	31	5.2	16	29	3.0	17	29	15.2	19	28	21.3
October	11	23	19.3	10	22	12.3	9	21	11.7	10	21	16.9
November	5	16	5.5	3	16	5.6	2	14	7.2	1	12	10.7
December	-9	0	1.0	0	12	10.1	-7	6	4.5	-1	9	3.7
Average or total	8	20	81.8	9	21	78.1	8	20	116.7	10	22	115.6

[a] Temperature averages given in C.
[b] Total precipitation, given in cm.

TABLE 3. SIGNIFICANCE LEVELS OF CROSSBRED COW GROUP, SEASON OF CALVING, YEAR, SEX OF CALF AND CROSSBRED COW GROUP BY SEASON OF CALVING INTERACTION[a]

	Source					
Trait	CG[b]	Sire(CG)	Season	Year	Sex	CG x Season
% weaned[c]	**	*	**	NS	NA	+
Calving Difficulty[d]	**	NS	NS	NS	**	NS
Birth weight	NS	**	**	NS	**	NS
Preweaning average daily gain	**	NS	**	NS	+	NS
Age adjusted weaning weight[e]	**	NS	NS	NS	**	NS
Weaning conformation grade[f]	NS	*	*	NS	NS	NS
Weaning condition score[g]	NS	NS	NS	NS	NS	NS
Age adjusted weaning hip height[e]	**	NS	**	**	NS	NS

[a] **=p<.01, *=.01<p<.05, +=.05<p<.10, NS=p>.10 and NA=not applicable.
[b] CG=Crossbred cow group.
[c] Percentage cows exposed to breeding that weaned a calf.
[d] Calving difficulty scores: 1 = no difficulty, 2 = little difficulty, 3 = moderate difficulty, 4 = major difficulty and 5 = Caesarian. A score of 3 or more is considered a difficult birth.
[e] Adjusted to 205-day basis for spring-born calves and to 240-day basis for fall-born calves.
[f] Conformation score: 12 = low choice, 13 = average choice and 14 = high choice.
[g] Condition score: 1 = thin to 9 = fat with 5 = average.

TABLE 4. LEAST-SQUARES MEANS AND STANDARD ERRORS FOR PERCENTAGE OF COWS EXPOSED TO BREEDING THAT WEANED A CALF BY CROSSBRED COW GROUP x SEASON OF CALVING.

	Percentage weaned	
	Season	
Cow Group[a]	Spring	Fall
HA	82.3 ± 11.2[b]	77.0 ± 11.9[b]
AH	88.1 ± 15.4[b]	30.0 ± 14.5[c]
BHA	88.5 ± 9.6[b]	41.4 ± 10.4[c]
BAH	85.1 ± 10.1[b]	40.0 ± 11.5[c]
BA	85.9 ± 10.4[b]	33.4 ± 10.6[c]
BH	74.5 ± 11.5[b]	-2.4 ± 12.2[d,e]

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[b,c,d] Means not sharing at least one common superscript differ ($P<.05$).

[e] No fall-calving Brahman x Hereford weaned a calf as a two-year-old.

TABLE 5. LEAST-SQUARES MEANS AND STANDARD ERRORS FOR CALVING DIFFICULTY, BIRTH WEIGHT, PREWEANING AVERAGE DAILY GAIN AND AGE ADJUSTED WEANING WEIGHT BY CROSSBRED COW GROUP, SEASON OF CALVING AND SEX OF CALF.

Comparison	Percentage requiring assistance at birth[a]	Birth weight, kg	Preweaning ADG, kg/d	Age adjusted weaning weight, kg[b]
Crossbred cow group[c]:				
HA	15.7 ± 6.6[d,e]	32.0 ± .9[d]	.70 ± .02[d]	187.5 ± 3.0[d]
AH	30.6 ± 10.8[d,f]	33.2 ± 1.3[d]	.71 ± .02[d]	193.0 ± 4.9[d]
BHA	26.8 ± 5.1[d,f]	32.9 ± .8[d]	.82 ± .02[e]	212.8 ± 2.6[e]
BAH	31.9 ± 6.0[f]	33.2 ± .9[d]	.82 ± .02[e]	213.8 ± 3.0[e]
BA	5.8 ± 5.8[e]	31.4 ± .9[d]	.85 ± .02[e]	218.2 ± 2.8[e]
BH	15.1 ± 7.8[d,e]	32.8 ± 1.2[d]	.85 ± .02[e]	219.3 ± 3.9[e]
Season of calving:				
Spring	22.5 ± 3.4[d]	33.6 ± .6[d]	.84 ± .08[d]	205.7 ± 17.4[d]
Fall	16.4 ± 5.6[d]	31.6 ± .7[e]	.74 ± .08[e]	209.2 ± 19.0[d]
Sex of calf:				
Male	30.6 ± 4.5[d]	34.3 ± .6[d]	.81 ± .01[d]	212.1 ± 2.5[d]
Female	11.3 ± 4.5[e]	30.9 ± .6[e]	.78 ± .01[e]	202.8 ± 2.6[e]

[a]Percentage of cows receiving a calving difficulty score of 3 or higher.
[b]Adjusted to 205 and 240 d basis for spring- and fall-calving groups, respectively.
[c]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[d,e,f]Means in same column within the same comparison not sharing a common superscript differ ($P<.05$).

TABLE 6. LEAST-SQUARES MEANS AND STANDARD ERRORS FOR AGE ADJUSTED WEANING HIP HEIGHT BY CROSSBRED COW GROUP AND YEAR x SEASON OF CALVING.

Comparison		Age adjusted weaning weaning hip height, cm[a]
Crossbred cow group[b]:		
HA		108.3 ± .7[c]
AH		106.6 ± 1.3[c]
BHA		111.7 ± .5[d]
BAH		112.2 ± .6[d]
BA		115.1 ± .6[e]
BH		114.8 ± .8[e]
Year x Season:		
1983:	Spring	109.1 ± 1.9[c]
	Fall	110.9 ± 2.1[c]
1984:	Spring	105.4 ± 1.9[c]
	Fall	106.8 ± 2.5[c]
1985:	Spring	104.1 ± 2.3[c]
	Fall	132.4 ± 2.5[d]

[a]Adjusted to 205 and 240 d basis for spring- and fall-calving groups, respectively.
[b]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman- Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[c,d,e]Means in same column within the same comparison not sharing a common superscript differ ($P<.05$).

CHAPTER IV

PRODUCTIVITY OF THREE-, FOUR- AND FIVE-YEAR-OLD CROSSBRED COWS CONTAINING VARIOUS PROPORTIONS OF BRAHMAN BREEDING IN SPRING OR FALL CALVING SYSTEMS

Abstract

Productivity of three-, four- and five-year old crossbred cows containing various proportions (0, 1/4 or 1/2) of Brahman breeding was evaluated using 520 spring-calving and 428 fall-calving records collected over a four year period. Cows were bred to Limousin sires for the first three years and to Limousin and Salers sires the fourth year. Percentage of cows exposed to breeding that weaned a calf was the only trait for which a significant (P<.05) crossbred cow group x season of calving interaction existed. Preweaning average daily gain and age adjusted weaning weight tended to increase as proportion Brahman breeding increased. Spring-born calves gained faster (P<.05) than fall-born calves by .11 kg/d, however age adjusted weaning weight was similar for the two groups as spring-born calves were weaned at an average age of 205 d while fall-born calves were weaned at an average age of 240 d. Weaning condition scores were similar across breed groups, however, spring calves received higher (P<.05) scores than did fall calves, 5.72 and 5.53, respectively. Weaning conformation grades were similar for all calves. Age and sex adjusted weaning hip height increased as proportion Brahman breeding increased and fall calves were taller (P<.01) than spring calves. These data indicate that Brahman cross dams can be used to increase preweaning growth rate and thus weaning weight. A slight advantage for spring-calving over fall-calving systems is also indicated.

(Key Words: Crossbreeding, Cow Productivity, Genotype X Environment Interaction, Angus, Brahman, Hereford.)

Introduction

Crossbreeding is a management technique widely used by commercial beef producers attempting to improve production efficiency. The desirable consequences of crossbreeding are heterosis, incorporation desirable genetic material quickly and combining desirable traits from several breeds into a market animal (Willham, 1970). Successful crossbreeding requires the choice of appropriate breed combinations for the environment and production management system (Koger, 1980). Brahman and Brahman crosses have the ability to adapt to the heat and humidity of the Gulf Coast region of the United States which has led to widespread use of this breed in that region (Franke, 1980). Production capabilities of Brahman cross cows in the Southeastern and Gulf Coast regions are widely documented (Turner et al, 1968; Turner and McDonald, 1969; Peacock et al., 1971; and Peacock et al., 1981). Since it is suspected that the optimum proportion of Bos Indicus breeding in crosses with Bos Taurus cattle may vary with climate and production environment (Gregory and Cundiff, 1980), research under different conditions needs to be conducted. Different environments have been shown to have varying effects on different breed types due to genotype x environment interactions. Peacock et al. (1971) found significant cow breed group by type of pasture interactions for pregnancy rate. Sellers et al. (1970) reported significant season of birth by breed interaction for preweaning growth.

Different types of cattle may have varying levels of performance in different environments, therefore a long-term study was initiated for the evaluation of the effects of genotype (crossbred cow group), environment (season of calving) and genotype X environment interactions on cow productivity using crossbred cows with different proportions of Angus, Brahman and Hereford breeding managed in either spring or fall calving systems. The objective of this portion of the study was to determine the effects of crossbred cow group, season of calving and the interaction between crossbred cow group and season of calving on productivity of three-, four- and five-year old crossbred cows.

Materials and Methods

Angus (A) and Hereford (H) dams were assigned at random to spring- and fall-calving groups and mated to A, H, Brahman (B), 1/2B-1/2A and 1/2B-1/2H bulls to produce crossbred calves that were 0 Brahman (1/2 H-1/2 A and 1/2 A- 1/2 H), 1/4 Brahman (1/4 B-1/4 H-1/2 A and 1/4 B-1/4 A-1/2 H) and 1/2 Brahman (1/2 B-1/2 A and 1/2 B-1/2 H) over a three year period (1981-1983). The mating system, origin of foundation breeding stock and growth performance of crossbred calves were reported by Bolton et al. (1987a). Postweaning growth, sexual development and pregnancy rate of heifers were reported by Bolton et al. (1987b). Management and productivity of these cows as two-year olds was reported by McCarter et al. (1989).

Cows were maintained on pastures consisting predominantly of big bluestem (Andropogon gerardii), little bluestem (Schizacharium scoparius), buffalograss (Buchloe dactyloides), sideoats grama (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon) at the Southwestern Livestock and Forage Research Laboratory, El Reno, Oklahoma for the 1984 through 1986 calf crops. After weaning the 1986 calf crops, cows were moved to Stillwater, Oklahoma and maintained on pastures similar in composition to those at the El Reno research station. Spring-calving cows were supplemented from mid-December through mid-April with .8 kg/head/d of cottonseed meal cubes (41% CP) and were provided access to hay (wheat, oat and Old World bluestem) based on range and weather conditions while in El Reno. Fall-calving cows were fed 1 kg/head/d of cottonseed meal cubes and provided access to hay based on range and weather conditions from December through mid-April. After being moved to Stillwater, the same basic feeding regime was used with the exception of the hay being bermudagrass and prairie hay. The number of records available for analysis are presented by crossbred cow group, season of calving and age of dam in table 1.

Monthly average minimum and maximum temperatures and precipitation amounts for 1984 through 1987 are presented in table 2. Average minimum temperatures for the winter months ranged from -7 to 1 C while average maximum temperatures ranged from 5 to 15 C. Average maximum temperatures for the summer months ranged from 30 to 35 C. Yearly rainfall amounts ranged from 78.1 cm in 1984 to 116.7 cm in 1985 with most of the precipitation occurring during the spring and fall seasons.

Cows were exposed to Limousin bulls, in single sire pastures, for a 75 d breeding season for 1984 calf crop. For 1985 and 1986 calf crops, cows were synchronized and bred to Limousin bulls by artificial insemination once and then placed in single sire breeding pastures with Limousin bulls for a total breeding period of 75 d. Calf crops were produced in 1987 by breeding cows to Limousin and Salers bulls artificially twice, if second insemination was required, and then placed in single sire pastures with Limousin clean-up bulls for a total breeding period of 75 d. Cows within each breed group were randomly assigned to sire breed groups and then to sires within the breeds. Spring-calving cows were bred to calve in February, March and April and fall-calving cows were bred to calve in September, October and November.

Condition scores and weights were obtained for the cows prior to breeding and at the time their calves were weaned. Calving difficulty scores were assigned by the herdsman using a scale of 1 to 6 (1=no difficulty, 2=little difficulty, 3=moderate difficulty, 4=major difficulty, 5=caesarian section and 6=abnormal presentation). Calving scores of 6 were deleted from the analysis. A score of 3 or more was considered a difficult birth which required assistance. Birth weights were obtained and male calves were castrated within 24 h of birth. Calves remained with their dams on pasture without access to creep feed. Spring-born and fall-born calves were weaned at an average of 205 and 240 d, respectively. Fall-born calves were weaned at an older age as this is a common practice of Oklahoma producers. Calf weight, hip height, condition score and conformation score were determined at weaning. Calf condition scores (1=very thin to 9=very fat with

5=average) and conformation scores, a measure of muscling, (12=low choice, 13=average choice and 14=high choice) were determined by averaging scores assigned by a committee consisting of two or three evaluators. Calf weaning weights and hip heights were adjusted to 205 and 240 d of age respectively, for spring- and fall-born calves.

The full model for the analyses included effects for crossbred cow group, sire nested within crossbred cow group, sex of calf, season of calving, year of calving, age of dam, sire of calf, prebreeding and weaning cow weight and condition score along with all two factor interactions. Least squares means were estimated using reduced models containing appropriate effects (P<.15) for each trait.

Results and Discussion

Significance levels for crossbred cow group (CG), season of calving (S), year (Y), age of dam at calving (A), sex of calf (SX) and CG X S interaction are presented in table 3. Crossbred cow group significantly affected preweaning ADG (PWADG), adjusted weaning weight (AWW) and adjusted weaning hip height (AWH). Season of calving was a significant source of variation on percentage of cows exposed to breeding that weaned a calf (%W), birth weight (BW), PWADG, weaning condition score (WCS) and AWH. Effects attributable to A were non-significant for all traits. Year of calving significantly affected %W, percentage of cows requiring assistance at birth (CD), WCS and weaning conformation grade (WG). Birth weight, CD, PWADG and AWW were significantly affected by SX. Sire of dam nested within CG had significant effects on all traits with the exception of WG. Percentage of cows exposed to breeding that weaned a calf was the only trait for which CG x S interaction was significant. Sire of calf was a significant source of variation on all calf traits, however, no CG x sire of calf interactions were found. Prebreeding and weaning cow weight and condition scores were not significant for any trait examined and were therefore not included in reduced models.

Least squares means and standard errors for percentage cows exposed to breeding that weaned a calf are presented in table 4. Overall 87.1% of cows exposed to breeding weaned a calf. Bailey et al. (1988) reported similar percentages for Brahman x Hereford and Brahman x Angus cows, 88 and 82%, respectively, while Peacock et al. (1971) reported an average of 71% for cows containing 0, 25, 50, 75 or 100% Brahman breeding with the remaining proportion being Shorthorn. Within the spring-calving group, Brahman-Angus x Hereford (BAH) weaned the lowest percentage (79.7%), however, this percentage was significantly different from Brahman x Hereford (BH) only. No other significant differences existed in the spring-calving group. Within the fall-calving group Brahman x Angus (BA) weaned significantly more calves than 0 and 1/4 Brahman groups. Brahman x Hereford, while similar to BA, BAH and

Hereford x Angus (HA), weaned a significantly higher percentage than Angus x Hereford (AH) and Brahman-Hereford x Angus (BHA). All 0 and 1/4 Brahman groups were similar within the fall group. Across seasons, HA, AH and BHA weaned significantly more calves in the spring than in the fall. No significant differences existed for BAH, BA and BH across seasons. This trend in %W is different from that found for these same cows as two-year olds (McCarter et al., 1989), thus indicating a shift in performance as the cows mature in favor of the F_1 Brahman-cross dams.

Percentage of cows requiring assistance at birth (those receiving a score of 3, 4 or 5) and BW were significantly affected by CG x SX interaction as well as CG and SX main effects. Therefore, least squares means and standard errors for CD and BW are presented in table 5 by CG x SX interaction. For the entire herd, average CD was 0.8%. The CG x SX interaction is created by the large percentage (13.1%) of AH giving birth to bull calves requiring assistance while all other subclasses required assistance at birth 2.2% or less of the time. All groups except AH having bull calves were similar. The differences in CD are not reflected in BW differences. The significance of CG x SX interaction for birth weight may be attributable to changes in magnitude of differences between heifer and bull calves within each CG. Birth weights for heifer calves across breed groups were similar and averaged 35.0 kg. For all breed groups, bull calves tended to be heavier than heifers. Bull calves from AH dams were significantly heavier than those from BA and BH and tended to be heavier than HA, BHA and BAH. This could partially explain the large CD for AH. Season of calving was a significant effect on BW as spring-born calves outweighed fall-born calves by 2.7 kg. Roberson et al. (1986) reported significant seasonal effects on birth weight, however calves born in January-March were similar to calves born in October-December, 32.5 and 32.1 kg, respectively.

Preweaning ADG and AWW least squares means are presented in table 6 by CG, S and SX. Calves out of BA, BH and BAH were similar in preweaning growth rate and weight at weaning with BA and BH producing significantly faster gaining and thus heavier calves at weaning than HA, AH and BHA. Calves from the two groups of 1/4 Brahman dams were similar in PWADG and AWW. Likewise, calves from the two groups of 0 Brahman dams were similar for PWADG and AWW however, calves from these two groups tended to be slower growing than those from 1/4 Brahman dams. The trend of preweaning growth increasing as proportion Brahman increased is similar to that reported by Koger et al. (1975) in calves out of Shorthorn, 1/4 Brahman:3/4 Shorthorn and F_1 Brahman-Shorthorn dams. Spring-born calves outgained fall-born calves by .114 kg/d, however due to the difference in age at weaning of the two groups AWW was similar for spring- and fall-born calves. Steers outgained heifers by .01 kg/d resulting in a 16.7 kg advantage at weaning.

No differences in WCS were found between CG. Seasonal differences in WCS were significant as spring-born calves received higher scores than fall-born calves, 5.72 and 5.53, respectively. Overall average WG was 13.3 with only Y x A interaction being significant, however no trends could be identified in the Y x A least squares means.

Adjusted weaning hip height least squares means and standard errors are presented in table 7 by CG and S. Calves within each proportion Brahman group were similar. Calves from 1/2 Brahman dams were significantly taller than those from 1/4 and 0 Brahman dams. Brahman-Hereford x Angus cows weaned calves significantly taller than either of the 0 Brahman groups while BAH weaned calves similar to 0 Brahman calves. Fall-born calves averaged 17.1 cm taller at weaning than spring-born calves. This difference can be attributed to fall calves being an average of 35 d older at weaning than spring calves.

The results presented in this study indicate that Brahman-cross dams can be used effectively in a commercial crossbreeding system to increase preweaning growth rate and thus weaning weight when compared with AH and HA dams. Differences attributable to season of calving indicate a slight advantage for spring calving relative to fall calving based of %W and PWADG.

TABLE 1. NUMBER OF AVAILABLE RECORDS BY CROSSBRED GROUP, SEASON OF CALVING AND AGE OF DAM

Crossbred cow group[a]	Season of calving and age of dam: Spring 3	Spring 4	Spring 5	Fall 3	Fall 4	Fall 5	Total
HA	25	25	17	23	23	17	130
AH	8	8	7	14	14	9	60
BHA	47	46	37	39	39	21	229
BAH	38	38	27	27	25	13	168
BA	41	41	26	37	33	20	198
BH	32	32	25	28	23	15	155
Total	191	190	139	168	157	95	940

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

TABLE 2. RAINFALL AND AVERAGE MINIMUM AND MAXIMUM DAILY TEMPERATURES BY MONTH FOR 1984 THROUGH 1987.

	1984 Temperature[a]			1985 Temperature			1986 Temperature			1987 Temperature		
Month	Min	Max	Rain[b]	Min	Max	Rain	Min	Max	Rain	Min	Max	Rain
January	-5	7	.5	-6	5	7.7	-5	13	0.0	-7	7	6.4
February	1	15	1.8	-4	7	11.7	0	13	2.0	-1	13	13.7
March	2	13	13.0	6	17	12.7	5	19	2.7	3	16	8.6
April	7	19	7.3	11	23	13.6	10	22	14.1	7	24	1.6
May	13	25	6.8	14	27	4.3	14	25	12.8	16	29	17.2
June	20	32	13.5	18	30	16.2	20	30	8.8	19	31	17.5
July	20	34	1.6	20	33	6.2	22	35	4.9	21	32	7.4
August	20	35	2.6	20	33	5.8	19	32	17.9	21	34	5.4
Septembe	16	29	3.0	17	29	15.2	19	28	21.3	15	29	11.2
October	10	22	12.3	9	21	11.7	10	21	16.9	6	23	3.1
November	3	16	5.6	2	14	7.2	1	12	10.7	4	17	6.7
December	0	12	10.1	-7	6	4.5	-1	9	3.7	-3	9	9.7
Average/total	9	21	78.1	8	20	116.7	10	22	115.6	8	22	108.5

[a] Temperature averages given in C.
[b] Total precipitation, given in cm.

TABLE 3. SIGNIFICANCE LEVELS FOR MAIN EFFECTS INCLUDED IN PRELIMINARY MODEL AND CROSSBRED COW GROUP BY SEASON OF CALVING INTERACTION ON REPRODUCTIVE, BIRTH AND WEANING TRAITS[a]

	Source[b]						
Trait	CG	Sire(CG)	S	Y	DA	SX	CG x S
% weaned[c]	NS	**	**	**	NS	NA	**
Calving Difficulty[d]	NS	**	NS	NS	NS	**	NS
Birth weight	NS	**	**	NS	NS	**	NS
Preweaning average daily gain	**	**	**	NS	NS	**	NS
Age adjusted weaning weight[e]	**	**	NS	NS	NS	**	NS
Weaning conformation grade[f]	NS	NS	NS	**	NS	NS	NS
Weaning condition score[g]	NS	**	**	**	NS	NS	NS
Age and sex adjusted weaning hip height[e]	**	**	**	NS	NS	NS	NS

[a] **=P<.01, *=.01<P<.05, t=.05<P<.10, NS=P>.10 and NA=not applicable.
[b] CG=Crossbred cow group, Sire(CG)=Sire nested within CG, S=Season of calving, Y=Year of calving, DA=Age of dam, SX=Sex of calf.
[c] Percentage cows exposed to breeding that weaned a calf.
[d] Calving difficulty scores: 1 = no difficulty, 2 = little difficulty, 3 = moderate difficulty, 4 = major difficulty and 5 = Caesarian. A score of 3 or more is considered a difficult birth.
[e] Adjusted to 205-day basis for spring-born calves and to 240-day basis for fall-born calves.
[f] Conformation score: 12 = low choice, 13 = average choice and 14 = high choice.
[g] Condition score: 1 = thin to 9 = fat with 5 = average.

TABLE 4. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PERCENTAGE OF COWS EXPOSED TO BREEDING THAT WEANED A CALF BY CROSSBRED COW GROUP x SEASON OF CALVING.

	Percentage weaned	
	Season	
Cow Group[a]	Spring	Fall
HA	90.5 ± 5.9[b,c]	76.6 ± 6,3[d,e]
AH	87.1 ± 7.0[b,c,d,f]	65.6 ± 7.2[e]
BHA	88.1 ± 3.2[b,c,d]	70.5 ± 3.5[e]
BAH	79.7 ± 3.8[b,d,f]	74.8 ± 4.6[e,f]
BA	86.0 ± 3.6[b,c,d]	93.7 ± 4.3[c]
BH	90.8 ± 4.4[c]	85.0 ± 5.0[b,c,d,f]

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[b,c,d,e,f] Means not sharing at least one common superscript differ ($P<.05$).

TABLE 5. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PERCENTAGE OF COWS REQUIRING ASSISTANCE AT BIRTH AND BIRTH WEIGHT BY CROSSBRED COW GROUP X SEX OF CALF INTERACTION.

Crossbred cow group[b]	Calving Difficulty, %[a]		Birth Weight, kg	
	Heifers	Bulls	Heifers	Bulls
HA	-0.3 ± 1.6[c]	2.2 ± 1.6[c]	34.9 ± 0.9[c]	39.0 ± 0.9[d,e]
AH	-0.8 ± 1.8[c]	13.1 ± 2.2[d]	36.1 ± 1.0[c,f]	40.2 ± 1.2[d]
BHA	1.6 ± 1.0[c]	1.0 ± 1.0[c]	34.5 ± 0.5[c]	38.1 ± 0.5[d,f]
BAH	0.1 ± 1.2[c]	0.2 ± 1.2[c]	34.9 ± 0.6[c]	37.7 ± 0.6[d,f]
BA	0.1 ± 1.2[c]	1.1 ± 1.1[c]	35.3 ± 0.6[c]	35.8 ± 0.6[c,e]
BH	0.1 ± 1.3[c]	0.1 ± 1.2[c]	34.4 ± 0.7[c]	34.4 ± 0.6[e,f]

[a] Percentage of cows receiving a calving difficulty score of 3, 4 or 5.
[b] HA=Hereford x Angus, AH=Angus x Hereford, BHA= Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[c,d,e,f] Means within same trait comparison not sharing at least one common superscript differ (P<.05).

TABLE 6. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PREWEANING AVERAGE DAILY GAIN AND AGE ADJUSTED WEANING WEIGHT BY CROSSBRED COW GROUP, SEASON OF BIRTH AND SEX OF CALF.

Comparison	Preweaning ADG, kg	Age adjusted weaning weight, kg[a]
Crossbred cow group[b]:		
HA	.836 ± .023[c,d]	221.6 ± 5.7[c,d]
AH	.791 ± .027[c]	214.3 ± 6.8[c]
BHA	.882 ± .014[d,e]	229.8 ± 3.3[c,d]
BAH	.891 ± .014[e,f]	232.1 ± 3.7[d,e]
BA	.927 ± .014[f]	240.0 ± 3.8[e]
BH	.927 ± .018[f]	240.2 ± 4.2[e]
Season of birth:		
Spring	.932 ± .005[c]	228.3 ± 1.4[c]
Fall	.818 ± .009[d]	231.0 ± 1.6[c]
Sex of calf:		
Steer	.905 ± .005[c]	238.0 ± 1.5[c]
Heifer	.845 ± .005[d]	221.3 ± 1.5[d]

[a]Adjusted to 205 and 240 d basis for spring- and fall-calving groups, respectively.
[b]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[c,d,e,f]Means in same column within the same comparison not sharing a common superscript differ (P<.05).

TABLE 7. LEAST SQUARES MEANS AND STANDARD ERRORS FOR AGE AND SEX ADJUSTED WEANING HIP HEIGHT BY CROSSBRED COW GROUP AND SEASON OF BIRTH.

Comparison	Adjusted weaning hip height,cm[a]
Crossbred cow group[b]:	
HA	117.2 ± 0.9^{c}
AH	116.6 ± 1.1^{c}
BHA	119.2 ± 0.6^{d}
BAH	$118.6 \pm 0.6^{c,d}$
BA	120.9 ± 0.6^{e}
BH	121.9 ± 0.7^{e}
Season of birth:	
Spring	110.5 ± 0.3^{c}
Fall	127.6 ± 0.3^{d}

[a] Adjusted to 205 and 240 d, respectively, for spring and fall groups.
[b] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[c,d,e] Means within same comparison not sharing at least one common superscript differ (P<.05).

CHAPTER V

MILK PRODUCTION OF CROSSBRED COWS CONTAINING VARIOUS PROPORTIONS OF BRAHMAN BREEDING IN SPRING OR FALL CALVING SYSTEMS

Abstract

Estimates of 24 h milk yield were obtained on 160 spring-calving and 153 fall-calving crossbred cows containing various proportions (0, 1/4 or 1/2) of Brahman breeding. Milk production was measured using weigh-suckle-weigh procedures for the entire lactation period. Interactions between crossbred group and season of calving were not significant. Across seasons, milk production tended to increase as proportion Brahman breeding increased, however, these increases were rarely significant. Average 24 h milk yield estimates ranged from 5.5 kg for Hereford x Angus to 6.2 kg for Brahman x Angus. Lactation curves for the two seasons were different. Spring-calving cows had a typical lactation curve while the curve for fall-calving cows tended to follow forage quality and quantity. Phenotypic correlations between monthly measurements of 24 h milk yield and calf performance tended to be strong and positive within the spring group.

Correlations for the fall group, while positive, tended to be weaker than those found in the spring group. Therefore, milk yield is indicated to be an important consideration when selecting breeds to be used in a crossbreeding program.
(Key Words: Crossbreeding, Milk Yield, Angus, Brahman, Hereford.)

Introduction

Milk production of the beef cow has a major impact on efficiency of beef production. However, the amount of milk produced is not as important as the response of the calf to the total maternal environment created by the cow (Willham, 1972). Neville (1962) found that 66% of the variation in calf weight at weaning was due to milk consumption. Totusek et al. (1973) reported a similar relationship and found the weigh-suckle-weigh method to be a more precise estimator of actual milk yield which he attributed to the greater release of oxytocin caused by the nursing calf. Breed variation in milking ability has been demonstrated by various researchers (Notter et al., 1978, Chenette and Frahm, 1981, and Daley et al., 1987). However, only limited data is available concerning milk production of cows with various proportions of Brahman breeding as well as milk production of similar breed groups in spring versus fall calving systems. The objective of this study was to evaluate the effects of crossbred cow group, season of calving and the interaction of crossbred cow group and season of calving on 24 h milk yield measured using weigh-suckle-weigh procedures.

Materials and Methods

Angus (A) and Hereford (H) dams were assigned at random to spring- and fall-calving groups and mated to A, H, Brahman (B), 1/2B-1/2A and 1/2B-1/2H bulls to produce crossbred calves that were 0 Brahman (1/2 H-1/2 A and 1/2 A- 1/2 H), 1/4 Brahman (1/4 B-1/4 H-1/2 A and 1/4 B-1/4 A-1/2 H) and 1/2 Brahman (1/2 B-1/2 A and 1/2 B-1/2 H) over a three year period (1981-1983). The mating system, origin of foundation breeding stock and growth performance of crossbred calves were reported by Bolton et al. (1987a). Postweaning growth, sexual development and pregnancy rate of heifers were reported by Bolton et al. (1987b). Management and productivity of these cows as two-year-olds were reported by McCarter et al. (1989a) and as three-, four- and five-year-olds by McCarter et al. (1989b).

This research was conducted at the Southwestern Livestock and Forage Research Laboratory, El Reno, Oklahoma. Cows were maintained on pastures consisting predominantly of big bluestem (Andropogon gerardii), little bluestem (Schizacharium scoparius), buffalograss (Buchloe dactyloides), sideoats grama (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon). Spring-calving cows were supplemented from mid-December through mid-April with .8 kg/head/d of cottonseed meal cubes (41% CP) and were provided hay (wheat, oat and Old World bluestem) as deemed necessary by the herdsman based on range and weather conditions. Cows calving in the fall were supplemented with 1 kg/head/d of cottonseed meal cubes from December through mid-April. These cows were also given hay based on range and weather conditions.

Monthly estimates of 24 h milk production were obtained using weigh-suckle-weigh procedures on 160 spring-calving and 153 fall-calving cows randomly selected from the six crossbred breed groups over a two year period, 1984 and 1985 calf crops. Distribution of records by crossbred cow group, season of calving and year is presented in Table 1. Only those cows successfully weaning a calf were included. Cow-calf pairs were randomly assigned to one of four milk production groups. The order in which the groups were processed each month was randomly determined. Cows and calves were gathered from pastures and placed by groups into holding pens the afternoon prior to measurement. Calves were separated from cows around 1800 h. Cows were provided hay and water at all times. Calves were placed with dams and allowed to nurse at 545 h. Groups were staggered so that all groups could be properly observed. Calves were separated from dams as soon as most of the calves had finished nursing (20 to 30 min.). This procedure was repeated at 1145 h with the exception that calves were weighed prior to and after nursing. The difference between these two weights was considered to be the amount of milk produced by the dam in 6 h. Negative differences were set to zero for the analysis. The 1145 h procedure was repeated at 1745 h. Estimates obtained at 1145 h and 1745 h milkings were summed and doubled to estimate 24 h milk production.

Spring-calving cows were evaluated for six months (April through September) while fall-calving cows were evaluated for seven months (November through May). The discrepancy in the number of measurements taken was due to the fact that spring-born calves were weaned at an average age of 205 d while fall-born calves were weaned at an average age of 240 d. Six month average 24 h milk production was computed for both spring and fall groups using estimates for the first six months of lactation. Data were analyzed using least squares procedures to determine the effects of crossbred cow group (CG), season of calving (S), year, age of dam, sex of calf and all two-factor interactions on 24 h milk production. Sire of dam nested within CG was included in all models and was used to test CG. Calving date was also included as a covariate. Least squares means were estimated using reduced models containing CG, S and CG x S, as these were the variables of primary interest, along with any other appropriate effects ($P<.15$) for each trait.

Results and Discussion

Table 2 contains significance levels for main effects included in the preliminary model and cow group by season of calving interaction for monthly measurements of 24 h milk production and six month average 24 h milk production. Calving date was not significant for any trait examined and was therefore eliminated from reduced models. Effect of crossbred cow group (CG) was generally non-significant. Season of calving (S) was a significant source of variation for four of the six measurements. The interaction of CG x S was not significant for any of the monthly milk production measurements. Year of calving (Y) and age of dam (AGE) were generally not significant. Sex of calf (SX) was significant for the four of the six months as well as average 24 h milk production (AMP). Milk production in all months with the exception of the first month were significantly affected by S x Y interaction. Effects due to AGE x Y interaction were significant for 24 h milk production in the fourth month and AMP.

Least squares means and standard errors for monthly measurements of 24 h milk production and AMP are presented in Table 3 by CG. Means tended to be lower than those reported by Daley et al. (1987) in Bos taurus and Bos indicus x Bos taurus dams, similar to those reported by Chenette and Frahm (1981) in Hereford, Angus, Simmental, Brown Swiss and Jersy crossbred cows, and higher than those reported by Notter et al. (1978) in Hereford and Angus reciprocal crosses. No significant differences existed between CG for first, fourth, fifth and seventh months of lactation. Overall mean 24 h milk production for first month was 5.9 kg. In the second month of lactation Brahman-Angus x Hereford (BAH) produced more milk (P<.05) than did Hereford x Angus (HA), 7.4 and 5.7 kg, respectively. No other differences were found between CG for the second month of lactation. For the third month of lactation, BAH produced less (P<.05) milk than Brahman-Hereford x Angus (BHA), Brahman x Angus (BA) and Brahman x Hereford (BH), 5.4, 6.5, 6.5 and 7.1 kg, respectively. Overall mean for 24 h milk production during the fourth and fifth months of lactation was 5.2 kg. For the sixth month of lactation, BH produced more (P<.05) milk than did HA, BHA and BA, 6.3, 4.9, 4.6 and 4.9 kg, respectively, with all other groups being similar. Milk production during the seventh month of lactation for the fall-calving cows, across breed groups averaged 3.0 kg. For AMP, BA produced more (P<.05) milk than did HA, 6.2 and 5.5 kg respectively. No other significant differences were found between CG for AMP. For most months and AMP, milk yield tended to increase as proportion Brahman increased, however, this increase was generally not significant. Daley et al. (1987) reported a trend opposite to this as Brahman x Bos taurus crosses produced less milk than Bos taurus crossbred dams.

Seasonal effects on 24 h milk production are presented graphically in Figure 1. Season of calving significantly affected 24 h milk production in first, third, fourth and sixth month of lactation. Spring-calving cows (SC) produced less (P<.01) milk during the first month of lactation than fall-calving cows (FC), 4.1 and 7.3 kg, respectively. For the second month of lactation, SC tended to produced more milk than FC, 7.0 and 6.4 kg, respectively. During third and fourth months of lactation SC yielded more (P<.05) milk than FC. Spring-calving cows produced 6.8 and 6.3 kg, respectively, during third and fourth months compared with 5.9 and 4.2 kg for FC. Milk production during the fifth month was similar for the two groups. Fall-calving cows reversed the trend and produced more (P<.05) milk than SC in the sixth month, 6.0 and 4.6 kg, respectively. Six month average 24 h milk production was virtually the same for both groups. If seventh month 24 h milk production was used in calculation of average milk production for FC, SC would have higher AMP than FC due to the relatively low amount of milk given during the seventh month by FC. In a secondary analysis, the month of lactation by season of calving interaction was significant indicating different lactation curves for the two seasons. The lactation curve for SC was the more typical of the two curves as it was at its lowest point the first month, increased sharply the second month, slightly declined during the third and fourth months and decreased substantially the fifth and sixth months. This curve is similar to that reported by Clutter and Nielsen (1987) for spring calving crossbred cows and to that reported by Neidhardt et al. (1979) for Brahman beef cows. Lactation curve for FC was at its highest point the first month, steadily declined during the second and third months, sharply declined the fourth monthly, steadily increased the fifth and sixth months and then sharply declined in the seventh month. Differences in lactation curves may be attributable to the quantity and quality of available forages as they closely reflect trends in forage growth.

Sex of calf was a significant source of variation for 24 h milk production in second, fourth, fifth and sixth month of lactation as well as AMP. Cows raising steer calves produced .7, .5, .6 and 1.0 kg more ($P<.05$) milk in second, fourth, fifth and sixth months, respectively, than cows raising heifer calves. Six month average 24 h milk production differed ($P<.05$) for the two sexes as cows raising steers produced 6.2 kg compared with 5.6 kg for those raising heifer calves. Daley et al. (1987) reported similar findings for 24 h milk yield at 60 and 105 d postpartum.

Phenotypic correlations, calculated across breed groups, between monthly measurements of 24 h milk production and calf performance for spring- and fall-calving groups are presented in Table 4. Correlations were calculated by season of calving as previous results indicated different lactation curves for the two groups. Correlations within spring-calving group for 24 h milk production in first through fifth months of lactation were moderate to strong, ranging from .29 to .48. Correlations between sixth month and first through fifth months were not different (P>.10) from zero indicating a very weak to non-existent relationship. Correlations between milk production traits and calf weaning traits were positive and generally significant. Milk production during the earlier months of lactation was more highly correlated with weaning traits than milk production in later months. During later months of lactation, calves begin utilizing nutritional sources other than dam's milk, so the weaker relationship is expected. Chenette and Frahm (1981) reported correlations of .29 and .20, respectively, for calf ADG and calf weaning weight with milk yield. Correlations between 24 h milk production in the second month of lactation and calf weaning traits were stronger than those found for other months with calf weaning traits. This could be related to the second month of lactation being the month in which 24 h milk production peaked. Milk production was more highly correlated with weight traits than with weaning conformation (a measure of muscling), weaning condition and weaning hip height. Weaning traits were highly correlated with each other.

Phenotypic correlations for fall-calving cows are presented below the diagonal in Table 4. Monthly measurements of 24 h milk production were weakly correlated (range -.14 to .21). In general, correlations between milk production and calf weaning traits were weaker than those found for the SC. Third, fourth and sixth months were more highly correlated with calf traits than other months. The FC lactation curve was at one of its lowest points at the fourth month, so the trend found with SC is reversed with stronger correlations occurring between calf traits and months of lower milk production. Correlations between calf traits and first month of lactation were not significant except for a weak, positive correlation with weaning condition and a weak, negative correlation with weaning hip height. The stronger correlations between milk yield in the sixth month and calf weaning traits is also opposite of the trends present with SC. All correlations with seventh month milk production were weak. For four of the seven months, milk production and weaning hip height were negatively correlated.

In conclusion, this study indicates that only subtle differences exist between crossbred cows containing (0, 1/4 or 1/2) of Angus, Brahman and Hereford breeding in milk yield. However, the general trend is an increase in milk yield as proportion Brahman breeding increases. Differences between the lactation curves of spring- and fall-calving cows indicated that spring-calving cows had a more typical curve while milk production of fall-calving cows tends to follow forage availability and quality.

Phenotypic correlations between milk yield and calf performance were strong and positive for the spring group and, although generally positive, tended to be lower for the fall group. Therefore, milk producing ability is an important trait to be considered in selecting breeds for a crossbreeding program to maximize production efficiency.

TABLE 1. DISTRIBUTION OF RECORDS BY CROSSBRED GROUP, SEASON OF CALVING AND YEAR

Crossbred cow group[a]	Year and Season 1984 Spring	1984 Fall	1985 Spring	1985 Fall	Total
HA	7	11	14	9	41
AH	1	2	5	9	17
BHA	21	14	24	18	77
BAH	13	8	20	20	61
BA	8	15	19	21	63
BH	10	10	18	16	54
Total	60	60	100	93	313

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

TABLE 2. SIGNIFICANCE LEVELS FOR MAIN EFFECTS INCLUDED IN PRELIMINARY MODEL AND CROSSBRED COW GROUP BY SEASON OF CALVING INTERACTION ON MONTHLY MEASUREMENTS OF 24 HOUR MILK PRODUCTION AND AVERAGE 24 HOUR MILK PRODUCTION[a]

Source	Month[b]							
	1	2	3	4	5	6	7	AMP[c]
Crossbred cow group (CG)	NS	NS	+	NS	NS	NS	NS	NS
Sire of dam/CG	NS	NS	NS	NS	NS	NS	NS	**
Season of calving (S)	**	NS	*	**	NS	**	NA	NS
CG x S	NS	NS	NS	NS	NS	NS	NA	NS
Year	NS	**	NS	NS	NS	NS	NS	**
Age of dam	NS	NS	NS	NS	NS	+	NS	NS
Sex of calf	NS	+	NS	+	+	**	NS	**

[a] **=p<.01, *=.01<p<.05, +=.05<p<.10, NS=p>.10 and NA=not applicable.
[b] For spring-calving group Month 1 = April and Month 6 = September, for fall-calving group Month 1 = November and Month 7 = May.
[c] AMP= Average 24 h milk production for first 6 months of lactation.

TABLE 3. LEAST SQUARES MEANS AND STANDARD ERRORS FOR MONTHLY MEASUREMENTS OF 24-HOUR AND SIX MONTH AVERAGE 24 HOUR MILK PRODUCTION BY CROSSBRED COW GROUP[a].

Month of	Cow Breed Group[b]					
Lactation	HA	AH	BHA	BAH	BA	BH
First	6.4 ± 0.7[c]	4.4 ± 1.1[c]	5.7 ± 0.7[c]	5.6 ± 0.6[c]	6.6 ± 0.6[c]	5.5 ± 0.6[c]
Second	5.7 ± 0.6[c]	6.3 ± 1.0[c,d]	6.5 ± 0.7[c,d]	7.4 ± 0.6[d]	7.2 ± 0.6[c,d]	7.1 ± 0.6[c,d]
Third	6.0 ± 0.6[c,d]	6.5 ± 0.7[c,d]	6.5 ± 0.6[c]	5.4 ± 0.6[d]	6.5 ± 0.5[c]	7.1 ± 0.5[c]
Fourth	4.4 ± 0.7[c]	5.7 ± 0.8[c]	4.8 ± 0.7[c]	5.5 ± 0.7[c]	5.6 ± 0.6[c]	5.4 ± 0.6[c]
Fifth	5.3 ± 0.6[c]	5.7 ± 0.7[c]	5.3 ± 0.6[c]	4.8 ± 0.6[c]	5.4 ± 0.5[c]	5.3 ± 0.4[c]
Sixth	4.9 ± 0.8[c]	5.6 ± 0.9[c,d]	4.6 ± 0.8[c]	5.6 ± 0.8[c,d]	4.9 ± 0.7[c]	6.3 ± 0.6[d]
Seventh	2.2 ± 0.6[c]	2.3 ± 0.7[c]	3.0 ± 0.5[c]	3.1 ± 0.5[c]	3.2 ± 0.5[c]	2.6 ± 0.6[c]
Average	5.5 ± 0.4[c]	5.9 ± 0.5[c,d]	5.8 ± 0.4[c,d]	6.0 ± 0.4[c,d]	6.2 ± 0.4[d]	6.1 ± 0.3[c,d]

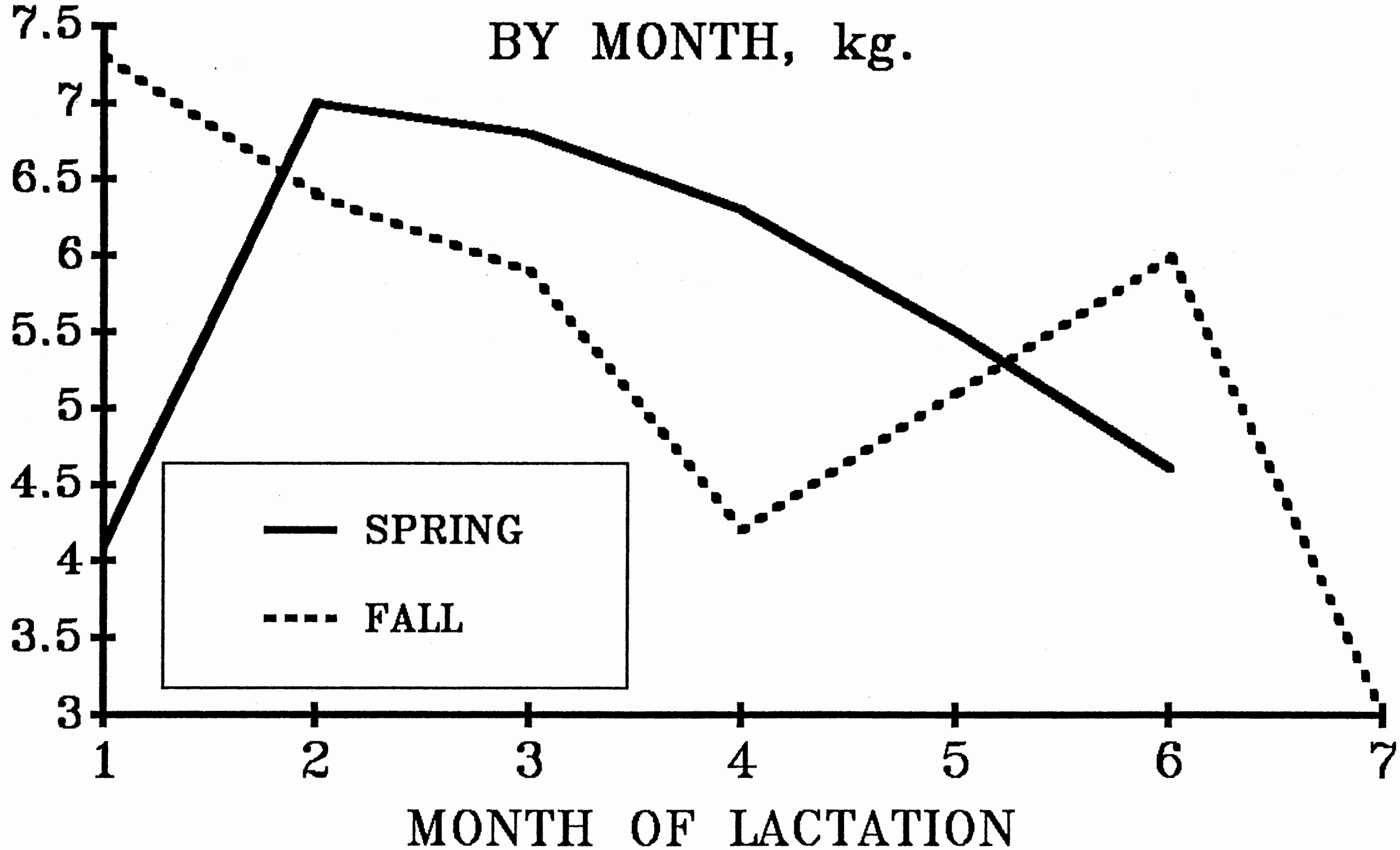
[a] Milk production in kg/24 h.
[b] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.
[c,d] Means with in same row not sharing a common superscript differ (P<.05).

TABLE 4. PHENOTYPIC CORRELATIONS[a] BETWEEN MONTHLY MEASUREMENTS OF 24 HOUR MILK PRODUCTION AND CALF PERFORMANCE FOR SPRING-CALVING AND FALL-CALVING GROUPS[b]

	Month										
Traits[c]	1	2	3	4	5	6	PWADG	AWWT	WG	WC	AWHT
Month 1		.40**	.37**	.31**	.37**	-.05	.23**	.21**	.15+	.18*	.14+
Month 2	.02		.48**	.45**	.29**	.02	.48**	.45**	.23**	.37**	.25**
Month 3	.07	.19*		.47**	.41**	.03	.32**	.25**	.17*	.25**	.12
Month 4	.03	.06	.25**		.34**	.09	.36**	.30**	.21**	.21**	.15+
Month 5	.07	-.14+	.10	.12		.06	.13+	.11	.10	.19*	.04
Month 6	.21**	-.01	.19*	.03	-.05		.11	.13+	.07	.05	.08
PWADG	.06	.10	.25**	.37**	.22**	.24**		.98**	.53**	.57**	.62**
AWWT	.03	.11	.24**	.35**	.22**	.22**	.98**		.52**	.57**	.69**
WG	.13	.26**	.28**	.22**	-.06	.38**	.57**	.57**		.68**	.19*
WC	.13+	.13	.23**	.16*	.03	.31**	.48**	.48**	.70**		.22**
AWHT	-.14+	-.16*	-.09	.02	.13	-.22**	.27**	.30**	-.14+	-.08	

[a] Product moment correlations.
[b] Spring-calving are above diagonal and fall-calving are below.
[c] Month 1 = April and Month 6 = September for spring group and Month 1 = November and Month 6 = April for fall group, PWADG = preweaning ADG, AWWT = age adjusted weaning weight, WG = weaning conformation grade, WC = weaning condition score and AWHT = adjusted weaning hip height.
+ P<.10.
* P<.05.
** P<.01.

FIGURE 1. 24-HOUR MILK PRODUCTION BY MONTH, kg.



CHAPTER VI

EFFECTS OF GENOTYPE BY ENVIRONMENT INTERACTION ON LIFETIME PRODUCTIVITY OF YOUNG CROSSBRED COWS CONTAINING VARIOUS PROPORTIONS OF BRAHMAN BREEDING IN SPRING OR FALL CALVING SYSTEMS

Abstract

Lifetime productivity of young (two- to six-year olds) crossbred cows containing various proportions (0, 1/4 or 1/2) of Brahman breeding was evaluated using 201 spring-calving and 172 fall-calving cows. Cows were mated to Limousin sires to produce 1983 through 1986 calf crops. The 1987 calf crops were produced using Limousin and Salers sires. Significant (P<.10) genotype (crossbred cow group) x environment (season of calving) interactions were found for age at first calf, lifetime percentage weaned and weight weaned per year. No significant differences were found between cow groups in either the spring- or fall-calving groups. All spring calving groups calved earlier in life than their respective fall calving counterparts. No differences attributable to effects included in the model used for analysis were found for calving interval

which averaged 389 d. All groups weaned a higher (P<.05) percentage of calves in the spring than in the fall. Average adjusted weaning weight was significantly affected by crossbred cow group as 1/2 Brahman cows produced heavier (P<.05) calves at weaning than did 0 Brahman and Brahman-Hereford x Angus. Weight weaned per year was less (P<.05) for fall-calving groups than for spring-calving groups with the exception of Hereford x Angus which were similar across the two seasons. These differences can be attributed to the lower levels of reproductive performance by fall-calving cows. Spring-calving breed groups were similar for weight weaned per year as were fall-calving breed groups.
(Key Words: Crossbreeding, Cow Productivity, Genotype x Environment Interaction, Angus, Brahman, Hereford.)

Introduction

Crossbreeding allows for use of different genetic types of cattle to increase the efficiency of beef production. Willham (1970) lists heterosis, opportunity to incorporate desirable genetic material quickly and chance to combine desirable traits from several breeds into a market animal as desirable consequences of crossbreeding. Successful crossbreeding, however, requires the choice of appropriate breed combinations for the environment and production management system (Koger, 1980). Crockett et al. (1978) reported heterosis levels for annual production to be higher for Brahman x British cows then for British x

British cows. Varying effects of different environments on different breed types due to genotype x environment interactions have been shown to exist by several researchers. Peacock et al. (1971) reported significant cow breed group x type of pasture interactions for pregnancy rate. Butts et al. (1971) reported significant genotype x environment interactions for birth, weaning and yearling traits among Hereford cattle in Florida and Montana, with cattle performing best at the location from which they originated.

Since different genetic types of cattle may have varying levels of performance in different environments, a long term study was initiated for the evaluation of the effects of genotype (crossbred cow group), environment (season of calving) and genotype x environment interactions on cow productivity using crossbred cows with different proportions of Angus, Brahman and Hereford breeding managed in either spring or fall calving systems. The objective of this portion of the study was to evaluate the effects of crossbred cow group, season of calving and the interaction between crossbred cow group and season of calving on annual productivity of crossbred females.

Materials and Methods

Angus (A) and Hereford (H) dams were assigned at random to spring- and fall-calving groups and mated to A, H, Brahman (B), 1/2B-1/2A and 1/2B-1/2H bulls to produce crossbred calves that were 0 Brahman (1/2 H-1/2 A and 1/2 A- 1/2 H), 1/4 Brahman (1/4 B-1/4 H-1/2 A and 1/4 B-1/4 A-1/2 H) and 1/2 Brahman (1/2 B-1/2 A and 1/2 B-1/2 H) over a three year period (1981-1983). The mating system, origin of foundation breeding stock and growth performance of crossbred calves were reported by Bolton et al. (1987a). Postweaning growth, sexual development and pregnancy rate of heifers were reported by Bolton et al. (1987b). Management and productivity of these cows as two-year olds were reported by McCarter et al. (1989a) and as three-, four- and five-year olds by McCarter et al. (1989b). Milk production and relationships between milk production and calf weaning traits for these cows were presented by McCarter et al. (1989c).

Cows were pastured at the Southwestern Livestock and Forage Research Laboratory, El Reno, Oklahoma for production of 1983 through 1986 calf crops. Cows were maintained on pastures consisting predominantly of big bluestem (Andropogon gerardii), little bluestem (Schizacharium scoparius), buffalograss (Buchloe dactyloides), sideoats grama (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon). Spring-calving cows were supplemented from mid-December through mid-April with .8 kg/head/d of cottonseed meal cubes (41% CP) and either wheat, oat or Old World bluestem hay when deemed necessary by the herdsman based on range and weather conditions.

Cows in the fall-calving group were supplemented with 1 kg/head/d of cottonseed meal cubes and provided hay when needed. After weaning the 1986 calf crops, cows were moved to Stillwater, OK. Pastures in Stillwater were similar to pastures in El Reno. The only change in the feeding regime was the use of bermudagrass and prairie hay in place of the hays used in El Reno. The number of records used for this analysis are presented in Table 1 by crossbred cow group and season of calving. Average annual rainfall for 1983 though 1987 was 100 cm. Winter temperatures typically ranged from minimums of -9 to 0 C to daily maximums of 0 to 13 C. Summer maximum temperatures ranged from 32 to 37 C.

Cows were exposed to Limousin bulls, in single sire pastures, for a 75 d breeding season to produce 1983 and 1984 calf crops. For 1985 and 1986 calf crops, cows were synchronized and bred to Limousin bulls artificially once and then placed in single sire pastures with Limousin bulls for a total breeding season of 75 d. Calf crops were produced in 1987 by breeding cows to Limousin and Salers bulls artificially twice, if second insemination was required, and then placing cows into single sire pastures with Limousin bulls for a total breeding period of 75 d. Cows within each crossbred cow group were assigned to sire breed groups at random and then to sires within breed at random. Spring-calving cows were bred to calve in February, March and April and fall-calving cows were bred to calve in September, October and November.

Age at first calf was computed in days using dam's birth date and her first calving date. Calving interval was computed using Beef Improvement Federation Guidelines (1986). Lifetime reproductive performance was computed by dividing parity of dam by the total number of possible calvings (age of dam in years minus one). Spring- and fall-born calves were weaned at an average age of 205 and 240 d, respectively. Fall-born calves were weaned at an older age as this is a common practice of Oklahoma producers. Calf weight was determined at weaning and adjusted to 205 or 240 d basis for spring- and fall-born calves, respectively. Weight weaned per year was computed by summing the adjusted weaning weights for each calf weaned and dividing by dam age in years minus one. Weight weaned per year estimated using calf weaning weight is a measure of the primary product for cow-calf producers.

Data were analyzed using least squares procedures. The model for analysis included effects for crossbred cow group, sire of dam nested within crossbred cow group, season of calving and crossbred cow group x season of calving interaction. Birth date of dam (Julian date) was entered as a covariate. Sire of dam was used to test differences between crossbred cow groups.

Results and Discussion

Significance levels for crossbred cow group (CG), season of calving (S) and CG x S interaction are presented in Table 2. Crossbred cow group was a significant source of variation for age at first calf (AFC), lifetime reproductive performance (LRP) average adjusted weaning weight (WWT) and weight weaned per year (W/Y). Season of calving significantly affected AFC, LRP and W/Y. Age at first calf, LRP and W/Y were significantly affected by CG x S. Calving interval was not significantly affected by any of the terms in the model.

Across CG and S, calving interval averaged 389. This interval is shorter than that reported by Plasse et al. (1968) who reported a calving interval of 409.9 d for Brahman and Brahman x British cows. Optimally, calving interval would be 365 d, however because cows were culled only when they failed to conceive for two consecutive years, the calving interval for this herd was extended by 24 d. Calving interval is an indicator of overall herd performance, however, the formula used in calculation of calving interval adjusts for the age at first calf which is of great economic importance. Heifers calving at a younger age represent lower costs for replacements. Least squares means for age at first calving in days are presented in Table 3. Within the spring calving group, no differences were found between CG. Within the fall-calving group, Hereford x Angus (HA) calved first earlier ($P<.05$) than all other fall-calving groups. Fall-calving Angus x Hereford (AH), Brahman-Hereford x Angus (BHA) and Brahman x Angus (BH) were similar. Fall-calving Brahman x Hereford (BH) calved first later (P<.05) than all other crossbred cow groups. This was expected since no fall-calving BH weaned a calf as a two-year-old. Spring-calving cows in all groups had their first calf earlier (P<.05) than their fall-calving counterparts.

Least squares means and standard errors for lifetime percentage weaned are presented in Table 4. All crossbred groups weaned significantly more calves in the spring than in the fall. Within the spring-calving group, HA, AH, BHA, BA and BH weaned similar percentages and only BHA were significantly superior to BAH. Bailey et al. (1988) reported similar weaning percentages for spring-calving Angus x Hereford, Brahman x Angus and Brahman x Hereford, ranging from 82 to 88%. Within the fall calving group, HA, AH, BHA and BA weaned similar percentages. Hereford x Angus and BA weaned higher (P<.05) percentages of calves than did BAH and BH.

Least squares means and standard errors for average adjusted weaning weight are presented in Table 5 by CG. Brahman x Hereford, BA and BHA were similar for WWT with BH and BA dams weaned calves heavier (P<.05) at weaning than HA, AH and BHA. Brahman-Angus x Hereford dams, while similar to BHA, produced calves heavier (P<.05) at weaning than did AH dams. Hereford x Angus, AH and BHA were similar for WWT. Turner and McDonald (1969) reported a similar trend as calves from Brahman-cross dams were heavier at weaning than those from British-cross dams.

Least squares means and standard errors for weight weaned per year are presented in Table 6 by CG x S interaction. Weight weaned per year combines reproductive performance with mothering ability of the dam to give a more precise estimate of a cows total productivity. Dinkel and Brown (1978) reported calf weaning weight to be highly correlated with and therefore important as a predictor of cow-calf efficiency to weaning. Within the spring group, no differences were found among the six crossbred groups. The same was true for the six fall-calving groups. With the exception of HA, spring-calving cows weaned more (P<.05) weight per year than their respective fall-calving counterparts. Hereford x Angus were similar across seasons. Frahm and Marshall (1985) reported calf weaning weight per cow exposed similar to those for spring-calving cows from this study, ranging from 158 kg for Angus x Hereford to 187 kg for Jersy x Angus.

These results indicate that spring calving is advantageous to fall calving as all breed groups with the exception of HA weaned significantly more weight per year under spring calving management than under fall calving management. Overall, productivity, measured as weight weaned per year, increased as proportion Brahman increased indicating that some Brahman breeding may be helpful in a commercial crossbreeding system to increase production efficiency. These differences, however, were not significant. Significant genotype x environment interactions were found. Thus, the need for considering environment and production management system when selecting breeds for use in a crossbreeding system cannot be overemphasized.

TABLE 1. DISTRIBUTION OF RECORDS BY CROSSBRED GROUP AND SEASON OF CALVING.

Crossbred cow group[a]	Season of Calving Spring	Fall	Total
HA	24	25	49
AH	12	13	25
BHA	48	40	88
BAH	38	28	66
BA	42	38	80
BH	37	28	65
Total	201	172	373

[a] HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

TABLE 2. SIGNIFICANCE LEVELS[a] FOR EFFECTS OF CROSSBRED COW GROUP, SEASON OF CALVING AND CROSSBRED COW GROUP x SEASON OF CALVING INTERACTION ON PRODUCTION TRAITS.

Trait	CG[b]	S[c]	CG x S
Age at first calf	**	**	**
Calving interval	NS	NS	NS
Lifetime reproductive performance	**	**	+
Average adjusted weaning weight, kg	**	NS	NS
Weight weaned/year	*	**	+

[a]** = P<.01, *= P<.05, + = P<.10 and NS = P>.10.
[b]CG = Crossbred cow group.
[c]S = Season of calving.

TABLE 3. LEAST SQUARES MEANS AND STANDARD ERRORS FOR AGE AT FIRST CALF IN DAYS BY CROSSBRED COW GROUP x SEASON OF CALVING INTERACTION.

Crossbred Cow Group[a]	Season of Calving: Spring	Season of Calving: Fall
HA	756 ± 28[b]	835 ± 34[c]
AH	745 ± 45[b,c]	966 ± 41[d]
BHA	730 ± 20[b]	909 ± 23[d]
BAH	746 ± 25[b]	964 ± 32[d]
BA	778 ± 22[b,c]	972 ± 24[d]
BH	777 ± 27[b,c]	1143 ± 35[e]

[a]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[b,c,d,e]Means not sharing at least one common superscript differ ($P<.05$).

TABLE 4. LEAST SQUARES MEANS AND STANDARD ERRORS FOR LIFETIME PERCENTAGE WEANED BY CROSSBRED COW GROUP X SEASON OF CALVING INTERACTION.

Crossbred Cow Group[a]	Season of Calving Spring	Fall
HA	90.2 ± 3.7[b,c]	78.3 ± 4.0[d,e]
AH	91.8 ± 5.3[b,c]	71.7 ± 5.1[d,e,f]
BHA	93.2 ± 2.3[b]	69.9 ± 2.6[d,f]
BAH	81.9 ± 3.0[c,e]	66.2 ± 3.6[f]
BA	88.6 ± 2.7[b,c]	75.8 ± 2.9[d,e]
BH	88.9 ± 3.2[b,c]	60.6 ± 3.4[f]

[a]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[b,c,d,e,f]Means not sharing at least one common superscript differ ($P<.05$).

TABLE 5. LEAST SQUARES MEANS AND STANDARD ERRORS FOR AVERAGE ADJUSTED WEANING WEIGHT FOR CALVES WEANED[a] BY CROSSBRED COW GROUP.

Crossbred Cow Group[b]	Average Adjusted Weaning Weight
HA	208.3 ± 7.0[c,d]
AH	199.3 ± 8.6[c]
BHA	212.2 ± 4.1[c,d]
BAH	222.9 ± 5.8[d,e]
BA	230.8 ± 4.6[e]
BH	233.9 ± 5.3[e]

[a]Total weight weaned during lifetime divided by number of calves weaned, in kg.

[b]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[c,d,e]Means not sharing at least one common superscript differ (P<.05).

TABLE 6. LEAST SQUARES MEANS AND STANDARD ERRORS FOR WEIGHT WEANED PER YEAR[a] BY CROSSBRED COW GROUP X SEASON OF CALVING INTERACTION.

Crossbred Cow Group[b]	Season of Calving: Spring	Season of Calving: Fall
HA	184.7 ± 9.6[c,d]	163.1 ± 10.2[c,e]
AH	179.1 ± 13.7[c,d]	153.6 ± 13.1[e]
BHA	199.2 ± 6.1[d]	147.2 ± 6.8[e]
BAH	183.3 ± 7.7[c,d]	146.6 ± 9.3[e]
BA	199.6 ± 6.9[d]	178.7 ± 7.5[e]
BH	210.7 ± 8.4[d]	145.9 ± 8.9[e]

[a]Total adjusted weight weaned divided by age of dam in years minus one, in kg.

[b]HA=Hereford x Angus, AH=Angus x Hereford, BHA=Brahman-Hereford x Angus, BAH=Brahman-Angus x Hereford, BA=Brahman x Angus and BH=Brahman x Hereford.

[c,d,e]Means not sharing at least one common superscript differ ($P<.05$).

LITERATURE CITED

Bailey, C.M., D.R. Hanks, W.D. Foote and Y.O. Koh. 1988. Maternal characteristics of young dams representing Bos taurus and Bos indicus x Bos taurus breed types. J. Anim. Sci. 66:1144.

Beef Improvement Federation. 1986. Guidelines for Uniform Beef Improvement Programs. Fifth ed.

Belcher, C.G. and R.R. Frahm. 1979. Productivity of two-year-old crossbred cows producing three-breed cross calves. J. Anim. Sci. 49:1195.

Bolton, R.C., R.R. Frahm, J.W. Castree and S.W. Coleman. 1987a. Genotype x environment interactions involving proportion of Brahman breeding and season of birth. I. Calf growth to weaning. J. Anim. Sci. 65:42.

Bolton, R.C. R.R. Frahm, J.W. Castree and S.W. Coleman. 1987b. Genotype x environment interactions involving proportion of Brahman breeding and season of birth. II. Postweaning growth, sexual development and reproductive performance of heifers. J. Anim. Sci. 65:48.

Brown, C.J. 1960. Influence of year and season of birth, sex, sire and age of dam on weights of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19:1062.

Burns, W.C., M. Koger, W.T. Butts, O.F. Pahnish and R.L. Blackwell. 1979. Genotype by environment interactions in Hereford cattle: II. Birth and weaning traits. J. Anim. Sci. 49:403.

Butts, W.J., M. Koger, O.F. Pahnish, W.C. Burns and E.J. Warwick. 1971. Performance of two lines of Hereford cattle in two environments. J. Anim. Sci. 33:923.

Chenette, C.G. and R.R. Frahm. 1981. Yield and compostion of milk from various two-breed cross cows. J. Anim. Sci. 52:483.

Clutter, A.C. and M.K. Nielson. 1987. Effect of level of beef cow milk production on pre- and postweaning calf growth. J. Anim. Sci. 64:1313.

Crockett, J.R., M. Koger and D.E. Franke. 1978a. Rotational crossbreeding of beef cattle: Reproduction by generation. J. Anim. Sci. 46:1163.

Crockett, J.R., M. Koger and D.E. Franke. 1978b. Rotational crossbreeding of beef cattle: Preweaning traits by generation. J. Anim. Sci. 46:1170.

Cundiff, L.V., R.L. Willham and C.A. Pratt. 1966. Effects of certain factors and their two-way interactions on weaning weight in beef cattle. J. Anim. Sci. 25:972.

Cundiff, L.V. 1970. Experimental results on crossbreeding cattle for beef production. J. Anim. Sci. 30:694.

Cundiff, L.V., K.E. Gregory and R.M. Koch. 1984. Cattle germ plasm evaluation program. Progress Rep. No. 11. USDA-ARS. Clay Center, NE.

Daley, D.R., A. McCuskey and C.M. Bailey. 1987. Composition and yield of milk from beef-type Bos taurus and Bos indicus x Bos taurus dams. J. Anim. Sci. 64:373.

Dinkel, C.A. and M.A. Brown. 1978. An evaluation of the ratio of calf weight to cow weight as an indicator of cow efficiency. J. Anim. Sci. 64:614.

Franke, D.E. 1980. Breed and heterosis effects of American Zebu cattle. J. Anim. Sci. 50:1206.

Grass, J.A., P.J. Hansen, J.J. Rutledge and E.R. Hauser. 1982. Genotype x environment interactions on reproductive traits of bovine females. I. Age at puberty as influenced by breed, breed of sire, dietary regimen and season. J. Anim. Sci. 55:1441.

Gregory, K.E. and L.V. Cundiff. 1980. Crossbreeding in beef cattle: Evaluation of systems. J. Anim. Sci. 51:1224.

Harvey, W.R. 1987. User's guide for LSMLMW PC-1 version mixed model least-squares and maximum likelihood computer program.

Hawk, H.W., W.J. Tyler and L.E. Casida. 1954. Some factors affecting age at puberty in Holstein-Friesian heifers. J. Dairy Sci. 37:252.

Holloway, J.W., J.F. Baker, A.D. Chamrod, P.O. Reardon and L.W. Varner. 1988. Breed type x management treatment interactions of cows grazing rangelands. J. Anim. Sci. 66:835.

Koger, M., W.L. Reynolds, W.G. Kirk, F.M. Peacock and A.C. Warnick. 1962. Reproductive performance of crossbred and straightbred cattle on different pasture programs in Florida. J. Anim. Sci. 21:14.

Koger, M., F.M. Peacock, W.G. Kirk and J.R. Crockett. 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. J. Anim. Sci. 40:826.

Koger, M., W.C. Burns, O.F. Pahnish and W.T. Butts. 1979. Genotype by environment interactions in Hereford cattle: I. Reproductive traits. J. Anim. Sci. 49:396.

Koger, M. 1980. Effective crossbreeding systems utilizing Zebu cattle. J. Anim. Sci. 50:1215.

Long, C.R. 1980. Crossbreeding for beef production: Experimental results. J. Anim. Sci. 51:1197.

Marlowe, T.J. and J.A. Gaines. 1958. The influence of age, sex and season of birth of calf and age of dam on preweaning growth rate and type score of beef calves. J. Anim. Sci. 17:706.

McCarter, M.N., D.S. Buchanan and R.R. Frahm. 1989a. Productivity of two-year-old crossbred cows containing various proportions of Brahman breeding in spring or fall calving systems. J. Anim. Sci. (submitted).

McCarter, M.N., D.S. Buchanan and R.R. Frahm. 1989b. Productivity of three-, four- and five-year-old crossbred cows containing various proportions of Brahman breeding in spring or fall calving systems. J. Anim. Sci. (submitted).

McCarter, M.N., D.S. Buchanan and R.R. Frahm. 1989c. Milk production of crossbred cows containing various proportions of Brahman breeding in spring or fall calving systems. J. Anim. Sci. (submitted).

McDonald, R.P. and J. W. Turner. 1972. Estimation of maternal heterosis in preweaning traits of beef cattle. J. Anim. Sci. 35:1146.

Neidhardt, R., D. Plasse, J.H. Weniger, O. Verde, J. Beltran and A. Benavides. 1979. Milk yield of Brahman cows in a tropical beef production system. J. Anim. Sci. 48:1.

Neville, W.E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:320.

Notter, D.R., L.V. Cundiff, G.M. Smith, D.B. Laster and K.E. Gregory. 1978. Characterization of biological types of cattle. VII. Milk production in young cows and transmitted and maternal effects on preweaning growth of progeny. J. Anim. Sci. 46:908.

Peacock, F.M., M. Koger, W.G. Kirk, E.M. Hodges and A.C. Warnick. 1971. Reproduction in Brahman, Shorthorn and crossbred cows on different pasture programs. J. Anim. Sci. 33:458.

Peacock, F.M., M. Koger, J.R. Crockett and A.C. Warnick. 1977. Reproductive performance and crossbreeding Angus, Brahman and Charolais cattle. J. Anim. Sci. 44:729.

Peacock, F.M. and M. Koger. 1980. Reproductive performance of Angus, Brahman, Charolais and crossbred dams. J. Anim. Sci. 50:689.

Peacock, F.M., M. Koger, T.A. Olson and J.R. Crockett. 1981. Additive genetic and heterosis effects in crosses among breeds of British, European and Zebu origin. J. Anim. Sci. 52:1007.

Peters, H.F. and S.B. Slen. 1967. Brahman-British beef cattle crosses in Canada I. Weaned calf production under range conditions. Can. J. Animal Sci. 47:145.

Plasse, D., A.C. Warnick and M. Koger. 1968. Reproductive behavior of Bos indicus females in a subtropical environment. I. Puberty and ovulation frequency in Brahman and Brahman x British heifers. J. Anim. Sci. 27:94.

Reynolds, W.L., T.M. DeRouen and D.C. Meyerhoeffer. 1967. Milk production of Angus, Brahman and Zebu-cross cows. J. Anim. Sci. 26:206 (Abstr.).

Reynolds, W.L., T.M. DeRouen, S. Moin and K.L. Koonce. 1979. Factors affecting pregnancy rate of Angus, Zebu and Zebu-cross cattle. J. Anim. Sci. 48:1312.

Roberson, R.L., J.O. Sanders and T.C. Cartwright. 1986. Direct and maternal genetic effects on preweaning characters of Brahman, Hereford and Brahman-Hereford crossbred cattle. J. Anim. Sci. 63:438.

Rollins, W.C., F.D. Carrol and N.R. Ittner. 1964. Comparison of the performance of 3/4 Hereford-1/4 Brahman calves with Hereford calves in a variable climate. J. Agric. Sci. 62:83.

Sanders, J.O. 1980. History and development of Zebu cattle in the United States. J. Anim. Sci. 50:1188.

Schillo, K.K., P.J. Hansen, L.A. Kanwanja, D.J. Dierschke and E.R. Hauser. 1983. Influence of season on sexual development in heifers: age at puberty as related to growth and serum concentration of gonadotropins, prolactin, thyroxine and progesterone. Biol. of Repro. 28:329.

Sellers, H.I., R.L. Willham and R.C. deBaca. 1970. Effects of certain factors on weaning weight of beef calves. J. Anim. Sci. 31:5.

Todd, J.C., J.K. Riggs and J.C. Smith. 1968. Milk yields and calf weights from Brahman, Hereford and crossbred cows in the Gulf Coast prairie. J. Anim. Sci. 27:286 (Abstr.).

Totusek, R., D.W. Arnett, G.L. Holland and J.V. Whiteman. 1973. Relation of estimation method, sampling interval and milk consumption to milk yield of beef cows and calf gain. J. Anim. Sci. 37:153.

Turner, J.W., B.R. Farthing and G.L. Robertson. 1968. Heterosis in reproductive performance of beef cows. J. Anim. Sci. 27:336.

Turner, J.W. 1969. Preweaning production differences among reciprocal crossbred beef cows. J. Anim. Sci. 29:857.

Turner, J.W. and R.P. McDonald. 1969. Mating type comparisions among crossbred beef cattle for preweaning traits. J. Anim. Sci. 27:336.

US Meat Animal Research Center. 1979. Germ Plasm Evaluation Program. Progress Rep. No. 7. USDA, ARM-NC-6.

Willham, R.L. 1970. Genetic consequences of crossbreeding. J. Anim. Sci. 30:690.

Willham, R.L. 1972. Beef milk production for maximum efficiency. J. Anim. Sci. 34:864.

APPENDIX

TABLE 1. SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR TWO-YEAR-OLD PRODUCTIVITY.

Source	% weaned	Calving Difficulty	Birth weight	Daily gain	Weaning weight	Weaning height	Weaning scores conformation	Weaning scores condition
Cow Group (C)	X	X	X	X	X	X	X	X
Sire(SR)/C	X	X	X	X	X	X	X	X
Season (S)	X		X	X	X	X	X	
Year (Y)				X	X	X		
Sex (SX)		X	X	X	X		X	
CxS	X							
SRxS/C	X							
CxSX		X	X	X	X		X	
SRxSX/C		X	X	X	X		X	
YxS				X	X	X		

[X]Source of variation was included in reduced model.

TABLE 2. SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR THREE-, FOUR- AND FIVE-YEAR-OLD PRODUCTIVITY.

Source	% weaned	Calving Difficulty	Birth weight	Daily gain	Weaning weight	Weaning height	Weaning scores conformation	Weaning scores condition
Cow Group (C)	X	X	X	X	X	X	X	X
Sire(SR)/C	X	X	X	X	X	X	X	X
Season (S)	X		X	X	X	X		X
Year (Y)	X	X	X	X	X	X	X	X
Sex (SX)								
Dam Age (DA)			X	X	X	X	X	
CxS	X			X				
YxS	X			X	X	X		
CxY	X							
YxDA			X	X	X	X	X	
SxDA				X	X	X		

X Source of variation was included in reduced model.

TABLE 3. SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR MONTHLY MEASUREMENTS AND SIX MONTH AVERAGE MILK PRODUCTION

Source	First month	Second month	Third month	Fourth month	Fifth month	Sixth month	Seventh month	Average
Cow Group (C)	X	X	X	X	X	X	X	X
Sire(SR)/C	X	X	X	X	X	X	X	X
Season (S)	X	X	X	X	X	X		X
Year (Y)		X	X	X	X	X		X
Sex (SX)		X		X	X	X		X
Dam Age (DA)			X	X	X	X		X
CxS	X	X	X	X	X	X		X
CxSX								
YxS		X	X	X	X	X		
SxDA			X			X		
YxDA				X				X
DAxSX					X			
SxSX								X

[X]Source of variation was included in reduced model.

TABLE 4. SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR AGE AT FIRST CALF AND LIFETIME PRODUCTIVITY

Source	Age at first calf	Calving Interval	Lifetime % weaned	Average weight weaned	Weight weaned per year
Cow Group (C)	X	X	X	X	X
Sire(SR)/C	X	X	X	X	X
Season (S)	X	X	X	X	X
CxS	X	X	X	X	X
Dam Birth Date	X	X	X	X	X

[X]Source of variation was included in reduced model.

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