GENOTYPE X ENVIRONMENT INTERACTIONS INVOLVING LEVEL OF BRAHMAN AND SEASON OF BIRTH ON CALF GROWTH THROUGH WEANING AND POSTWEANING GROWTH AND REPRODUCTIVE PERFORMANCE OF HEIFERS

By

REBECCA CHRISTINE BOLTON

Bachelor of Science

Colorado State University

Fort Collins, CO

1984

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the degree of
MASTER OF SCIENCE
December, 1986

GENOTYPE X ENVIRONMENT INTERACTIONS
INVOLVING LEVEL OF BRAHMAN AND
SEASON OF BIRTH ON CALF GROWTH
THROUGH WEANING AND
POSTWEANING GROWTH
AND REPRODUCTIVE
PERFORMANCE OF
HEIFERS

Thesis Approved:

Richard R Frahm
Thesis Adviser

Earl Dalgett

Jed McColl III

Norman N. Durham
Dean of Graduate College

ACKNOWLEDGMENTS

For the opportunity to work with this research project as well as for the time spent as my adviser over the past two years, I would like to extend my thanks to Dr. Richard Frahm. The helpful advice and time devoted by advisory committee members Dr. Earl Aalseth and Dr. Ted McCollum are also greatly appreciated.

Special thanks go to Dr. David Buchanan for the many hours of assistance in statistical analysis as well as for his encouragement and support throughout my stay at OSU. The assistance provided by many animal science faculty, staff and graduate students also deserves grateful acknowledgement.

The conscientious herd management of John Castree and his assistants is recognized and appreciated as is work done by Eugene Tinker, Georganne Wilkinson, Sally Patton, Carol Bradley and former graduate students in data collection and recording.

Finally, I would like to thank my parents, Mary Ann and Chris Bolton, my sister, Beth, Jeanne Bolton and the rest of my family for their love and understanding and for the confidence they have always shown in me.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX

LIST OF FIGURES

NOMENCLATURE

adg	average daily gain
cm	centimeters
d	days
g	grams
kg	kilograms

CHAPTER I

INTRODUCTION

In order to increase production efficiency, the use of Brahman and Brahman cross cattle is widely practiced, especially in the southern areas of the United States. In a rotational crossbreeding study conducted in the Florida Everglades, Crockett et al. (1978) used Angus, Brahman and Hereford breeds and found higher heterosis levels for Brahman cross calves than for British cross calves (14.5, 10.5 and 17.5% for birth weight, weaning condition score and actual weaning weight, respectively, for Brahman cross calves versus -3, 3 and 5% for British crosses). Annual production per unit of cow weight of Angus-Hereford rotations exceeded purebreds by 5% while Brahman-Angus and Brahman-Hereford crosses exceeded the parent breeds by 25% over all generations.

While several studies involving Brahman cattle have been conducted in the Gulf Coast area of the United States, few have been conducted in the more temperate environments further north. It seems possible that Brahman and Brahman cross cattle raised in these cooler environments may perform differently relative to other breeds than those in the hot and humid South.

Because many Oklahoma cattle producers have incorporated fall calving programs into their management systems it is also important to evaluate the relative merit of Brahman cross cattle under these alternative calving seasons.

The data presented in this study were collected in the initial phase of a long-term research project at the Oklahoma Agricultural Experiment Station near El Reno, Oklahoma designed to (1) compare productivity of crossbred cows that are 0, 1/4 or 1/2 Brahman, (2) compare spring versus fall calving systems and (3) evaluate the extent of genotype (level of Brahman breeding) by environment (season of calving) interactions. Objectives of this study were to evaluate (1) the performance through puberty of crossbred calves that were 0, 1/4 or 1/2 Brahman, (2) the relative merit of spring versus fall calving systems and (3) the nature and extent of interactions between level of Brahman breeding and season of birth for traits through puberty.

CHAPTER II

REVIEW OF LITERATURE

Effect of Brahman Breeding

Preweaning and weaning traits

Crossbred calves that have some proportion of Brahman breeding have been generally shown to outperform British-cross calves. In Reno, Nevada, Bailey (1981) used Hereford, Red Poll, Angus and Brahman bulls on Charolais-cross, Hereford, Angus and Red Poll dams over four years to obtain crossbred calves from 755 matings. When linear effects of age were held constant, Brahman-sired calves outweighed calves of other sire groups (P<.01) for preweaning (approximately 2 1/2 months of age) and weaning weights. Because of later birth dates of Brahman cross calves, however, actual weights were similar to those of other sire groups.

Two Nebraska studies showed an advantage for Brahman-sired calves over calves from other sire breeds. Notter et al. (1978), using F1 dams of seven breeds to obtain 564 crossbred calves, reported that only calves by Brahman sires (116) grew significantly faster (P<.05) preweaning than calves by Hereford and Angus sires. Partitioning gain into that occurring before 120 days and that occurring between 120 and 200 days, daily gain of Brahman cross calves was greater during the last 80 days. The authors suggested that this could have been due to later maturity of Brahman cattle, more aggressive suckling behavior, better use of forage or greater heat tolerance in late summer relative to cold tolerance in early spring. Cundiff et al. (1984) reported that weaning (200-day) weights of Brahman-sired calves (225 kg) out of Angus and Hereford dams were heavier ($P<.05$) than calves sired by Tarentaise (215 kg), Sahiwal (214 kg), Pinzgauer (211 kg) and Hereford or Angus bulls (209 kg).

In Georgia, Angus and Brahman bulls were mated to Hereford dams to produce three calf crops (McCormick and Southwell 1957). The authors reported that Brahman x Hereford calves were heavier ($P<.01$) at birth than Angus x Hereford calves (33.7 vs. 29.8 kg). Although not significant ($P>.05$), the Brahman-cross calves were 12 kg heavier at weaning than Angus-cross calves (222 vs. 210 kg). Calves in the study were creep-fed, a practice not used in the present study.

Crockett et al. (1979) studied 755 crossbred calves in Florida from Brahman, Brangus, Beefmaster, Limousin, Simmental and Maine-Anjou sires mated to Angus, Brangus and Hereford females. Birth weights of calves from Brahman and Maine-Anjou bulls were similar and were heavier ($P<.01$) than those from other sire breeds (34 kg for Brahman and

Maine Anjou vs. 33 kg for Limousin and Simmental, 31 for Beefmaster and 29 for Brangus crossbred calves). Brangus and Hereford dams (33 kg) produced heavier (P<.01) calves than did Angus dams (31 kg). A sire breed x dam breed interaction existed for 205-day adjusted weaning weight, but Brahman, Maine-Anjou and Simmental sired calves were heavier (P<.01) than other calves. Brangus dams weaned heavier calves than did Hereford or Angus dams. Type (conformation) scores of Brahman-sired calves were lower (P<.01) than scores of calves from Brangus, Maine-Anjou and Simmental sires and similar to those of Limousin sires. Condition scores of Brahman and Brangus sired calves were greater (P<.01) than calves of other sire breeds.

In a study of 804 calves in Florida, Peacock et al. (1960) found that weaning weight and slaughter grade were significantly influenced by proportion of Brahman vs. Shorthorn breeding. 3/4 Brahman-1/4 Shorthorn calves were heaviest (201 kg), followed by 3/4 Shorthorn-1/4 Brahman (198 kg), 1/2 Shorthorn-1/2 Brahman (190 kg), 7/8 Brahman-1/8 Shorthorn (182 kg), 7/8 Shorthorn-1/8 Brahman (172 kg), Brahman (168 kg) and Shorthorn (140 kg). Highest slaughter grades were from 3/4 Shorthorn-1/4 Brahman calves (10.3) followed by 3/4 Brahman-1/4 Shorthorn (10.1). Other crosses, in descending order, were 1/2 Shorthorn-1/2 brahman and 7/8 Brahman-1/8 Shorthorn (9.1), 7/8 Shorthorn-1/8 Brahman (9.0), Brahman (8.5) and Shorthorn (8.2). However, 1/2 Shorthorn-1/2 Brahman calves were out of purebred dams while other crossbred calves were out of crossbred dams, so comparisons between these groups are confounded with the effect of crossbreeding of dam.

Anderson (1968) reported significant differences (P<.001) among weaning weights of 1/4 Brahman, 1/2 Brahman and 3/4 Brahman heifers (154, 200 and 225 kg respectively). However, the 3/4 Brahman calves were progeny of F1 Brahman-Angus cows while the other two groups were progeny of purebred Angus cows, thus confounding proportion of Brahman breeding with maternal heterosis.

Offspring of 28 Angus cows mated to Angus, zebu, Africander and zebu x Angus bulls over several years were analyzed by Rhoad et al. (1945) in Louisiana, with 165 calves analyzed for birth data and 141 for weaning data. Calves from zebu bulls were significantly heavier (P<.05) and calves from Angus bulls significantly lighter (P<.01) than all other breed groups with calves from Africander and zebu x Angus bulls being similar to each other. Weight at 6 months of age of calves by zebu, Africander and zebu x Angus bulls were not statistically different (P>.05), weighing 181, 176 and 172 lb, respectively. The comparison between the former two sire breeds versus the latter crossbred sire group would be similar to the comparison in the present study of calves of 1/2 versus 1/4 Brahman breeding.

One aspect of the present study concerns the adaptability of Brahman and Brahman-cross cattle to environments cooler than those present in sub-tropical climates. In the moderate environment of Clay Center, Nebraska, using Hereford and Angus dams mated to Hereford, Angus, Brahman, Sahiwal, Pinzgauer and Tarentaise sires, Gregory et al. (1979a) found that breed group was a significant source of variation for ADG, relative growth rate (a measure of increase in body weight relative to weight already attained) and 200-day weight. Brahman crosses had more rapid (P<.01) preweaning ADG than all other sire breeds except Tarantaise and had heavier (P<.01) 200-day weights than all other breed of sire groups.

In a study conducted in Alberta, Canada, Peters and Slen (1967) noted that "a question of fundamental interest was whether Brahman crossbred cattle would have enough winterhardiness to perform well on a year-round basis under conditions of the Northern Great Plains region." Brahman bulls were bred to Hereford, Angus and Shorthorn cows to obtain 164 F1 calves over a 4-year period. 1/4 Brahman calves were obtained by breeding F1 females to Hereford sires, but comparing weaning data of 1/4 vs 1/2 Brahman calves in this data set would be biased by the lack of heterosis in dams of 1/2 Brahman calves. The authors reported that Brahman x Angus and Brahman x Shorthorn calves were heavier (P<.05) at weaning (at 188 days) than were Brahman x Hereford calves. The authors noted that relative to purebred Herefords Brahman crossbreds performed well despite the cold northern climate.

Yearling, Puberty and Reproductive Traits

Brahman breeding has been shown to affect several postweaning and puberty traits as well affecting conception rate among heifers.

Heifers of 12 crossbred groups (Angus-Hereford reciprocal crosses and crosses resulting from mating Angus and Hereford cows to Charolais, Jersey, Limousin, Simmental and South Devon sires) were bred to Angus, Brahman, Devon, Hereford and Holstein bulls to produce 267 heifers which were analyzed by Young et al. (1978) in Nebraska to determine postweaning growth, puberty and pregnancy characteristics. Traits analyzed were 200-day weight, feedlot ADG, feedlot RGR (relative growth rate), 400-day weight, pasture ADG, pasture RGR, 550 day weight, percent reaching puberty by 330, 390, 450 and 510 days, age at puberty, puberty weight, and pregnancy rate. Heifers were not creep fed and were weaned in the fall. They were then placed in a feedlot until spring, after which they were turned out on bromegrass pasture at an average age of 400 days. Puberty was defined as the first observed estrus confirmed by a second observed estrus within 46 days.

Sire breed was a significant (P.>01) source of variation for all traits except percent reaching puberty by 330 and 510 days and percent pregnant. Heifers from Brahman sires were heavier (P<.05) at 200 days than Holstein-sired heifers, which were heavier than Hereford- and Angus-sired heifers (185 kg, 173 kg and 162 kg for the respective groups). Devon-sired heifers (168 kg) were intermediate to but not different from Holstein- and Angus/Hereford-sired heifers. Pasture ADG was highest (P<.05) in Brahman-, Angus/Hereford- natural service and Holstein-sired heifers and lowest (P<.05) in Angus/Hereford AI sired heifers and, at 400 and 550 days of age, Brahman- and Holstein-sired heifers were heavier (P<.05) than heifers in other groups. At puberty, heifers from Brahman sires were older and heavier than those of any other sire breed group while heifers from Angus/Hereford natural service matings were the lightest (P<.05) of the breed groups studied. Age and weight at puberty of the breed of sire groups were 383, 388, 426, 370 and 384 days, and 258, 275, 308, 284, and 275 kg for Angus/Hereford natural service, Angus/Hereford AI, Brahman, Holstein and Devon crosses, respectively. Pregnancy rate was not affected (P>.05) by sire breed, but percentages obtained for the breed groups (in the order given above) were 94.7, 84.7, 85.0, 96.6 and 91.2%.

Data on 473 heifers involving Angus, Brahman, Hereford, Holstein and Jersey and their F1 crosses in Texas was reported by Long et al. (1979). Heifers were raised either in individual pens or on pasture with supplementation, with pen-raised heifers receiving a higher level of nutrition. Weights were recorded at 90-day intervals when heifers were 270 to 630 days of age. Ranks changed among crossbred groups depending on the management system. Among the crossbred females, Brahman x Holstein heifers were heavier at all ages than other crossbreds regardless of management system. Angus x Brahman, Brahman x Hereford and Hereford x Holstein crosses were classified as "high" gainers, Angus x Hereford and Angus x Holstein as "intermediate," and Jersey crosses as "low" in their ability to gain on pasture. The rankings were similar for penned heifers except that Angus x Brahman and Brahman x Jersey were classified as "intermediate" and Angus x Hereford as "high" gainers. Brahman x Holstein and Brahman x Jersey were tallest across all ages and management regimens; they were followed by Angus x Brahman, Brahman x Hereford, Hereford x Holstein and Holstein x Jersey which were followed by Angus x Hereford, Angus x Holstein, Angus x Jersey and Hereford x Jersey. The authors concluded that the Brahman cross heifers were either better adapted to the lower plane of nutrition and/or other factors associated with the pasture environment or were more stressed by the pen environment.

Stewart et al. (1980) reported on the puberty characteristics of the heifers in the above study, with puberty defined as the time of first ovulatory estrus as determined through observation followed by palpation. Ninety-one heifers were fed in individual pens while 384 heifers were placed on pasture. Breedtype was a significant ($P<.01$) source of variation in age and weight at puberty among pastured heifers and for weight at puberty in penned heifers, but only approached significance (P<.10) for age at puberty in penned heifers. The average age and weight at puberty among penned heifers was 328 days and 246 kg, respectively, with Angus-Hereford, Angus-Brahman and Hereford-Brahman crosses averaging 312, 378 and 343 days of age and 250, 291 and 276 kg at puberty, respectively. Among pastured heifers, the average of all breed types was 403 days and 237 kg at puberty, with the crossbred groups (as listed) averaging 416, 399 and 425 days of age and 249, 262 and 272 kg at puberty.

Dow et al. (1982) also found a significant influence of breed group on heifer weight and on age at puberty. Their study spanned four years and included 301 fall-born crossbred heifers obtained by mating Hereford, Red Poll, Angus and Brahman bulls to Angus, Hereford, Red Poll and Charolais-cross dams. These heifers were weaned in mid-March at an average age of 6 months, and puberty was monitered beginning in August by visual examination (including use of teaser bulls) and by rectal palpation for ovulatory status. Heifers were about 19.5 months old when they went into the breeding pastures and had gained .4 kg/day from weaning to the beginning of the breeding season. Overall, 44% of the heifers had attained puberty by 11.5 months of age and 62% by 15 months of age. By the end of the 63-day breeding season, 88% of the heifers were pregnant. Brahman crosses gained rapidly during the evaluation period and were above average in weight at 19.5

(P<.01 to P<.05) and 24 (P<.01) months of age; however, Hereford and Brahman crosses had the slowest rate of sexual development, although Brahman crosses had the highest fertility rate of all groups.

Hereford and Friesian cows were inseminated with Brahman, Charolais, Friesian and Hereford semen in a study conducted and reported by Morgan (1981). Calves were born from mid-May through early August and weaned in February at an average age of 8 months. Heifers were then allowed to graze improved pastures without supplementation, and 21 month weight as well as weight and age at puberty were determined for each breed group. Charolais cross and Friesian cross heifers grew faster (P<.05) postweaning and were heavier (P<.05) than Brahman cross and Hereford cross heifers at 21 months. First estrus, as determined by checking 3 times a week for the presence of paint marks from a teaser bull, was also affected (P<.01) by breed group. Brahman x Hereford heifers (568 d) were older at puberty than Hereford (464 d) and Charolais x Hereford (470 d) females which were older at puberty than Friesian x Hereford (347 d), Hereford x Friesian (277 d), Friesian (298 d) and Charolais x Friesian (309 d) heifers (P<.05). Mean weight at puberty was lightest in Friesian-Hereford heifers (263 kg) and heaviest in Charolais-Hereford and Brahman-Hereford (326 and 336 kg) heifers. Morgan also reported that Brahman-sired progeny reached puberty at a later age than progeny of other sire breeds in the study, and concluded that, under the conditions present at Hamilton, Victoria, Australia, "most Brahman x Herefords would not mate at 15 months of age."

McCormick and Southwell (1957) found no difference (P>.05) in postweaning gain of Brahman cross versus British cross heifers. Angus x Hereford females (24) in the feedlot for 140 days gained 117 kg while Brahman x Hereford females (19) gained 107 kg.

The effect of different levels of Brahman breeding has been evaluated in several studies. In a trial comparing postweaning growth of five 1/4 Brahman-3/4 Angus, five 1/2 Brahman-1/2 Angus and five 3/4 Brahman-1/4 Angus heifers, Anderson (1968) found some differences between crossbred groups. At weaning (9 months of age) the three groups weighed 154, 200 and 225 kg (P<.001). The 1/2 Brahman and 3/4 Brahman heifers grew at the same rate postweaning (.41 kg/day) while the 1/4 Brahman heifers gained less (.25 kg/day) (P<.001) over a 544 day period. As with the weaning data previously mentioned, however, maternal heterosis may have influenced the performance of 3/4 Brahman heifers.

Winter gains of cattle with Brahman and Shorthorn breeding in Florida were reported by Peacock et al. (1961). Daily gain over the 137-day trial period was affected (P<.05) by calf breed group, with highest daily gains observed in 1/2 Brahman calves while calves that were more than 1/2 Brahman gained more than calves that were less than 1/2 Brahman. Adjusted daily gain means in the study were as follows: 7/8 to purebred Brahman, .30 kg/day; 5/8-3/4 Brahman, .29 kg/day; 1/2 Brahman, .33 kg/day; 3/8-1/4 Brahman, .26 kg/day; and 1/8 to 0 Brahman, .25 kg/day.

Peacock et al. (1965) reported on summer gains of heifers and steers with various levels of Brahman and Shorthorn breeding. Among yearling steers grazed on improved pasture during the summer over a period of three years, those with 1/2 Brahman breeding had higher weight gains than steers with more or less than 1/2 Brahman. A similar trend was noted among wintering steer and heifer calves. Yearling heifers, however, did not follow this trend; heifers with 1/2 or more Brahman breeding gained at similar rates while heifers with less than 1/2 Brahman breeding gained more slowly. The authors suggested that, since selection had been practiced on these heifers but not on steers, selection may have been more severe for higher-proportion Brahman heifers, thus tending to equalize the performance of these crossbred groups. The gains observed are as follows: 7/8-purebred Brahman, .44 kg/day; 5/8-3/4, .42 kg/day; 1/2, .43 kg/day; 3/8-1/4, .36 kg/day; and 1/8-0, .35 kg/day.

Examining the ability of heifers of various combinations of Angus, Brahman, Charolais and Shorthorn breeds to reach puberty in Florida, Peacock et al. (1976) found that crossbred heifers of predominantly (3/4) Brahman breeding did not reach puberty as early as F1 Brahman cross or heifers with predominantly Bos taurus breeding. Heifers in the study ranged from 0 to 3/4 Brahman breeding. A 100-day breeding season was used, and, in the final analysis, a projected age at conception was calculated to account for differences in proportions of each breed group that were actually bred. These projected ages ranged from 423 days for 1/2 Brahman-1/2 Shorthorn to 528 days for 3/4 Brahman-1/4 Shorthorn females. The authors concluded that F1 Angus x Brahman and Shorthorn x Brahman, followed by 3/4 Shorthorn-1/4 Brahman and Charolais x Brahman heifers, could conceivably be bred as yearlings to calve as 2-year-olds, but that remaining heifers of predominantly Brahman breeding should be held and bred at 2 years of age.

Gregory et al. (1979b) analyzed data from 490 crossbred heifers obtained over a 2 year period by mating Hereford and Angus dams to Hereford, Angus, Brahman, Sahiwal, Pinzgauer and Tarantaise bulls. After weaning in mid-October, heifers were placed on a corn-silage-based diet until mid-April when they were placed on improved cool-season pasture. Puberty attainment was checked visually. The authors reported that Brahman cross heifers were heavier than all other crossbred groups at 200 ($P<.01$ to $P<.05$) and 550 ($P<.01$) days, taller ($P<.01$) at 550 days and had faster ($P<.01$) gain from 400 to 550 days. At 200 days, Sahiwal cross heifers were lighter than Brahman and Pinzgauer crosses but not Tarentaise or Angus/Hereford cross females; at 400 days, Sahiwal cross females weighed less than Brahman, Pinzgauer, Tarentaise and Angus-Hereford crosses; at 550 days, Sahiwal crosses weighed less than Brahman, Pinzgauer and Tarantaise crosses but were not different (P>.05) from Angus-Hereford crosses.

The puberty data from this study showed that Brahman crosses were older and heavier (P<.05) than all other breed groups at puberty, averaging 398 days and 337 kg. Angus-Hereford reciprocal crosses averaged 326 days and 296 kg at puberty. Sahiwal crosses were older than Angus-Hereford, Pinzgauer and Tarentaise crosses at puberty but were similar (P>.05) to Angus-Hereford crosses and Tarentaise crosses in weight at puberty. At 550 days, Sahiwal crosses had the highest percent pregnant (98%) while Angus-Hereford reciprocal crosses were lowest (82% pregnant). The low percentage of pregnancies exhibited by the Angus-Hereford reciprocal crosses was mainly due to 74% of Angus x Hereford crosses being pregnant while 90% of the Hereford x Angus females were pregnant. Since there was a small number (31) of Angus x Hereford crosses observed compared to 70 observations for Hereford x Angus females, the authors concluded that the low pregnancy rate observed was due to chance. This conclusion was also based on a comparison of results to previous studies in the same research program, and mainly those of Laster et al. (1979) who found that heifers out of Hereford dams had a higher (P<.05) pregnancy rate (91.3%) than heifers out of Angus dams (85.4%). Differences in growth rates of Bos indicus and Bos taurus females during summer vs. winter months was concluded to be both climatic and nutritional because dietary regimen was confounded with season in this study. This conclusion was based on previous studies, among them one by Howes et al. (1963) which reported that on low protein diets, Brahman cattle consumed more dry matter and thus digested more protein, and that in the study being reported protein levels on summer pasture were not adequate for developing heifers which would tend to favor Bos indicus cattle; another by Rollins et al. (1964) showing that 3/4 Hereford-1/4 Brahman calves gained faster than Hereford calves in the summer both in pasture and feedlot but grew slower in the winter than Hereford calves; and one by Rankin et al. (1978) where the magnitude of difference between Brangus and Hereford dams in calf weaning weight was greater in a semidesert location than in foothills of New Mexico.

Effect of Season of Birth

Preweaning and Weaning Traits

Season of birth has been shown in many studies to influence preweaning traits of calves of several different breeds. Marlowe and Gaines (1958) analyzed data from Angus, Hereford and Shorthorn herds in Virginia and found an effect of season of birth on growth rate of non-creep-fed calves, with calves born February through May growing about .05 kg per day faster than calves born June through

December. Type scores at weaning of calves born June through September were about one third of a grade lower than calves born in other months. Marlowe et al. (1965) reported that Angus and Hereford calves born in March and April had the fastest preweaning gain while calves born in August and September had the slowest gain among calves born throughout the year in Virginia. Differences in daily gain between these two periods were .11 kg/day for noncreep-fed calves and .08 kg/day for creep-fed calves. Creep feeding was reported to decrease the magnitude of differences in calf gains between months. In Hereford and Angus herds located in Arkansas, Brown (1960) found that fall-born calves were 16 to 18 kg lighter (P<.05) than spring-born calves at 240 days of age when calves were not creep fed.

In Texas, Robertson and Sanders (1983) noted that season of birth was a significant source of variation for birth weight in studies of calves of Brahman, Hereford and F1 dams bred to Brahman, Hereford and F1 sires. Meade et al. (1963) found 205-day weights to be influenced (P<.01) by season of birth among calves of Angus, Brahman, Devon, Brahman-Angus and Brahman-Devon breeding in Florida. Calves born December through June were 8.3 kg heavier than calves born July through October, and November-born calves were 5.4 kg heavier than the latter group.

Alaku (1982) found that birth weight and weight at 3 and 12 months of age were affected (P<.01) by month of birth in Wadara (a zebu breed indigenous to northeastern

Nigeria) cattle. Birth weights were 5.31% higher for calves born June to October than those born from November through April, so that there was a negative relation between birth weight and ambient temperature and a positive relation between birth weight and relative humidity. Body weight at 3 months was highest for calves born during the rainy season (June) and lowest for calves born in the hottest month (April), so that the average daily gain to this age was .44 kg for calves born June through October and .35 kg for calves born November through April. Harricharan et al. (1976) also found that calves born during the wet season of May-November had higher daily gains (.57 kg/day) compared to dry season calves (.30 kg/day) of Brahman and Santa Gertrudis breeds in Guyana. In northern Queensland, however, Donaldson and Larkin (1963) reported an advantage up to weaning for calves born in the dry season.

Cundiff et al. (1966) found that Hereford and Angus calves born in February, March and April in Oklahoma had higher 205-day weaning weight than calves born in any other season, and that calves born in August, September and October had the greatest disadvantage in 205-day weight. Sellers et al. (1970) analyzed data from 157 herds including 19,907 Hereford and Angus calves in Iowa. Based on preliminary analysis, month of birth was combined into four seasons. The authors reported that winter (Dec, Jan., Feb.) and spring (Mar., Apr., May) born calves were heavier at weaning (based on 205-day adjusted weights) and concluded that calves born during these periods received better management because of cold weather and lack of grazing. Season of birth by breed interactions were reported in both of these studies and will be discussed in a later section.

Yearling, Puberty and Reproductive Traits

Several studies have shown an effect of season of growth and/or season of birth on traits measured from weaning age to first conception. Alaku (1982) found that Wadara calves born from June to October were 19.56% heavier at 12 months of age than calves born from November to April. Phillips (1946) noted a seasonal influence on gain in dairy Shorthorn heifers, with low gain during late winter and higher gain in summer, but did not state the ages or season of birth of these heifers. Phillips also reported that autumn-born calves had an advantage over those born at other times, weighing 24.3 kg more at 300 days and 46.0 kg more at 600 days. He attributed this to pre-natal nutrition, the idea that autumn milk is richer in fat and carotene than spring milk, and that autumn-born calves were on grass their first summer while spring calves were kept indoors their first summer.

Hawk et al. (1954) reported that age at puberty in Holstein-Friesian heifers was affected by season of birth. They found that while heifers born in summer, fall and winter did not differ significantly in age at puberty, spring-born heifers reached puberty at a younger age ($P<.01$ to $P<.02$) than heifers born in any other season. Menge et al. (1960) studied Holstein heifers to determine factors affecting age at puberty. These heifers were drylot fed from birth. Season of birth was defined as: winter, December 21-March 20; spring, March 21-June 20; summer, June 21-September 20; and fall, September 21-December 20. Scouring was reported to be significantly correlated ($P<.01$) with age at puberty in fall-born heifers, delaying puberty 136 days.

Evaluating puberty (first estrus observed and confirmed by palpation) characteristics of 62 autumn-born crossbred heifers out of Holstein dams and by Angus, Chianina, Hereford or Simmental bulls, Grass et al. (1982) found that 5 heifers reached puberty in the summer (age 278-339 days) and that few heifers attained puberty in the winter and were thus delayed until the following spring (age 483-613 days). They concluded that fall and winter environments delayed puberty in these crossbred heifers and that there may be "complex interactions between season of birth and puberty attainment with genotype and level of nutrition" and therefore "seasonal variations must be considered in designing experiments."

Schillo et al. (1983) conducted research to determine whether season affected age at puberty and, if so, during which stage of life season exerted its effect. They used

28 Angus x Holstein heifers born in March or September within one day of the vernal or autumnal equinoxes. These heifers were exposed to natural conditions occurring for the first six months following birth for each season. From the ages of 6 to 12 months, animals were maintained in one of two environmental chambers; one chamber simulated conditions (photoperiod, temperature) occurring from spring to fall, while the other simulated conditions that would occur from fall to spring. Therefore, two groups of heifers (September-born, spring-fall chamber and March-born, fall-spring chamber) were exposed to conditions that would naturally be present according to their season of birth while two other groups of heifers would be exposed either to two consecutive spring-fall sequences or two consecutive fall-spring sequences. Body weight during the first six months of age was not influenced by season of birth, but, during the second six months of age, heifers in the fall-spring chambers were heavier ($P<.10$) than heifers in the spring-fall chambers at all ages except 46 weeks. Body weight was negatively correlated ($r=-.48$ to $-.64$) with age at puberty in all but March-born, spring-fall chamber heifers.

Levels of thyroxine were not affected by date of birth or chamber ($P>.10$), but there was a date of birth x chamber interaction ($P<.025$) because March-born heifers had higher thyroxine concentrations upon entering the chambers than did the September-born heifers. March heifers maintained the high thyroxine levels under natural conditions but, under spring-fall conditions, had decreased serum levels of thyroxine. September heifers under natural conditions maintained low thryroxine levels but had increased levels in the fall-spring chamber.

Prolactin concentrations were high during long photoperiods and warm temperatures and paralleled temperature and photoperiod changes ($P<.005$). A date of birth x time interaction ($P<.005$) was also observed, with September-born heifers in natural conditions (spring-fall) reached maximums at 30-33 weeks of age and remained constant thereafter, while March-born heifers under spring-fall conditions had maximum prolactin levels at 38-41 weeks of age, after which the levels declined.

Overall, age at puberty was affected by date of birth (September-born heifers younger than March-born heifers, $P<.06$) and chamber (spring-fall younger than fall-spring, $P<.08$), and weight at puberty was affected by chamber ($P<.01$). Ages at puberty (in days) were 295 for September, spring-fall; 319 for September, fall-spring; 321 for March, spring-fall and 346 for March, fall-spring heifers. The authors concluded from this study that both the first and second six-month periods of life in these heifers affected age at puberty. They reported that growth rate may have been one of the contributing factors during the first six months, as well as other undetermined factors. During the second six-month period, exposure to spring-fall conditions decreased age at puberty regardless of month of birth. They also concluded that, during the second six months, altering growth rate did not seem to be a significant factor affecting age at puberty, but that environmental conditions such as changes in temperature and photoperiod, possibly affecting ovarian size and LH and prolactin secretion, may exert an effect during this period.

Effect of Breed by Season of Birth Interactions

Relatively few studies have dealt with breed or crossbred group by season of birth interactions, and even fewer have involved the Brahman breed as part of the genetic makeup of the cattle studied. In the Oklahoma field data presented by Cundiff (1966), 205-day weights of Angus calves born in May, June or September were heavier compared to their breed average than those born in other months, while Herefords born in October, December or January had an advantage over those born in other months. Month of birth x breed interactions, however, were declared to be small and unimportant.

Pell and Thayne (1978) analyzed data from Hereford and Angus herds in West Virginia, and divided season of birth into two intervals: January through May and June through December. They reported that season of birth had no significant effect in the Hereford calves but that there was a 2 kg advantage ($P<.05$) at weaning for Angus calves born January-May, thus indicating a breed by calving season interaction. A significant season of birth x breed interaction was also reported by Sellers et al. (1970), with spring and summer born Angus calves growing more rapidly than Hereford calves born at the same time and Hereford calves born in the late fall and early winter growing faster than the corresponding Angus calves. The authors hypothesized that this was a reflection of the ability of Herefords to better withstand cold weather and of the Angus better withstanding heat and humidity or better able to produce milk.

Cundiff et al. (1984) measured postweaning growth of steers out of Angus and Hereford dams by Angus, Brahman, Hereford, Pinzgauer, Sahiwal and Tarentaise sires. While Brahman-sired calves were heavier ($P<.05$) at 200 days than calves by other sire breeds, there were few differences observed by 424 days. At this age, calves from all sire groups had gained at similar rates and did not have significantly different weights except for Sahiwal-sired calves which gained at a lower rate and weighed less than all other crossbred groups. The authors concluded that Bos taurus-Bos indicus crosses, when compared to Bos taurus-Bos taurus crosses, gained more during the summer months while on their dams but gained less rapidly during the winter months. They also reported that calves out of Angus dams were heavier at weaning than calves out of Hereford dams but gained less rapidly postweaning than calves from Hereford dams.

In studies involving Hereford and Holstein heifers, Grass et al. (1982) measured age, weight, height, and weight:height ratios at puberty (first estrus confirmed by palpation) as well as ADG, feed intake, TDN intake and feed per gain on sets of twin heifers administered high and low TDN diets. They reported that compared to spring-born heifers (born April through June), winter-born heifers (born January through March) had greater TDN consumption ($P<.001$) (716 kg for winter vs. 586 for spring born) and greater daily feed intake ($P<.025$) (6.6 vs. 6.2 kg/day) from age 210 days to puberty and that they were heavier (303 vs. 278 kg) and fatter at puberty ($P<.01$) than spring-born heifers while reaching puberty at an older age ($P>.10$) (394 vs. 379 days) than spring-born heifers. They found a breed by season of birth interaction for TDN intake and feed per gain but concluded that it may be more likely due to a season x diet interaction because rate of gain decreases and feed intake increases as animals get older and, since the traits were measured to puberty, data would be affected by the animal's age at puberty. They also based their conclusion on the fact that diet changes, photoperiods and temperatures were also affected by age at puberty.

Studying Brahman and Brahman x Shorthorn crossbred heifers, Plasse et al. (1968) determined age at puberty by monthly palpation and detection of the first corpus luteum. Heifers were grown on pastures and supplemented as necessary. Brahman heifers (83) reached puberty at an average age of 19.4 months (range 14-24 mo.) while Brahman-Shorthorn heifers (17) averaged 17 months of age at puberty (range 15-20 mo.). Season of birth was reported to have no effect on age at puberty, but correlations of -.46 (P<.01) and -.41 (P<.05) were reported between 205-day weight and age at puberty for Brahman and Brahman-cross females, respectively. Frequency of corpora lutea was depressed during the winter in Brahman cattle, but the authors reported no such seasonal variation in the Brahman-Shorthorn heifers. Dale et al. (1959) had previously demonstrated this type of anestrous during winter. Plasse et al. (unpub data; according to Plasse et al. (1968)) reported that low temperatures decreased exhibited estrus but not ovulation in 3-year-old Brahman heifers.

Gregory et al. (1979b) analyzed postweaning growth and puberty traits of crossbred heifers (refer to review of influence of breed on postweaning growth). The authors noted differences in ADG between crosses involving Bos indicus vs. Bos taurus cattle and concluded that the differences may have been due to differences in climatic adaptability and/or adaptability to feed environments. Bos indicus crosses gained faster than Bos taurus crosses from age 400 to 550 days (during summer months), and among the Bos indicus crosses the Brahman outgained Sahiwal. From age 200 to 400 days (during the winter) Angus-Hereford, Pinzgauer and Tarentaise crosses gained faster ($P<.05$ to $P<.01$) than Brahman and Sahiwal crosses.

Summary

Although the effects of Brahman breeding on beef production are well documented (especially in areas of the southern United States), studies involving Brahman cattle in genotype x environment interactions are limited. Brahman breeding has been generally shown to increase weaning weight and condition score, and Brahman-cross heifers have been determined to be older and heavier at puberty than British-cross heifers. Spring-born calves have been reported to have an advantage over fall-born calves for preweaning gain and weaning weight, and spring-born heifers generally reach puberty at a younger age compared to their fall-born counterparts.

The performance of cattle with Brahman breeding in more temperate environments is less thoroughly documented, but authors have reported performance of Brahman cross cattle to be at least equal if not superior to British cross cattle (Peters and Slen, 1967 and Gregory et al., 1979a).

Very little research has been published concerning the interaction of genotype with season of birth, and Brahman breeding x season of birth interactions is even less well documented. While the interactions have been shown to exist (Sellers et al. 1970, Pell and Thayne 1978, Grass et al. 1982), few studies published have dealt with the effect of interactions among Brahman-cross cattle. It appears, however, that the performance of cattle with Brahman breeding tends to be reduced during winter months (Gregory et al. 1979b, Cundiff et al. 1984).

Although genotype by season of birth interactions generally have not been evaluated in the past, the studies that have been published indicate that the interactions do exist. It appears that this genotype x environment interaction should be carefully evaluated in the design of future experiments and that further research on the interaction would be useful for determining optimum beef production systems.

Literature Cited

Alaku, O. 1982. The influence of season on birth weight, body weight at 3 and 12 months in Wadara calves in the Sahel region of north east Nigeria. Wld. Rev. of Anim. Prod. 18:23.

Anderson, J. L. 1968. Growth of cattle in Papua and New Guinea. 1. Brahman-British crossbreds. Aust. J. Exp. Agric. Anim. Husb. 8:121.

Bailey, C. M. 1981. Calf survival and preweaning growth in divergent beef breeds and crosses. J. Anim. Sci. 52:1244.

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.

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

Crockett, J. R., F. S. Baker, Jr., J. W. Carpenter and M. Koger.1979.Preweaning, feedlot and carcass characteristics of calves sired by continental, Brahman and Brahman-derivative sires in subtropical Florida. J. Anim. Sci. 49:900.

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., R. M. Koch and K. E. Gregory. 1984. Characterization of biological types of cattle (Cycle III) IV. Postweaning growth and feed efficiency. J. Anim. Sci. 58:312.

Dale, H.E., A.C. Ragsdale and C.S. Cheng. 1959. Effect of constant environmental temperatures, 50 and 80 F., on appearance of puberty in beef calves. J. Anim. Sci. 18:1363.

Donaldson, L.E. and R.M. Larkin. 1963. Observations on time of calving and growth to weaning of beef calves in coastal northern Queensland. Qd. J. Agric. Sci. 20:199.

Dow, J. S. Jr., J. D. Moore, C. M. Bailey and W. D. Foote. 1982. Onset of puberty in heifers of diverse beef breeds and crosses. J. Anim. Sci. 55:1041.

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., G. M. Smith, L. V. Cundiff, R. M. Koch and D. B. Laster. 1979a. Characterization of biological types of cattle--Cycle III: I. Birth and weaning traits. J. Anim. Sci. 48:271.

Gregory, K. E., D. B. Laster, L. V. Cundiff, G. M. Smith and R. M. Koch. 1979b. Characterization of biological types of cattle--Cycle III: II. Growth rate and puberty in females. J. Anim. Sci. 49:461.

Harricharan, H., P. Mahadevan and B.G.F. Springer. 1976. The performance of Santa Gertrudis, Sahiwal, Brahman and crossbred animals in the intermediate savannahs of Guyana: 2. Birth weight and preweaning performance. J. Agric. Sci., Camb. 87:269.

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.

Howes, J.R., J.F. Hentges, Jr. and G.K. Davis. 1963. Comparative digestive powers of Hereford and Brahman cattle. J. Anim. Sci. 22:22.

Laster, D.B., G.M. Smith, L.V. Cundiff and K.E. Gregory. 1979. Characterization of biological types of cattle (Cycle II): II. Postweaning growth and puberty of heifers. J. Anim. Sci. 48:500.

Long, C. R., T. S. Stewart, T. C. Cartwright and J. F. Baker. 1979. Characterization of cattle of a five breed diallel: II. Measures of size, condition and growth in heifers. J. Anim. Sci. 49:432.

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.

Marlowe, T.J., C.C. Mast and R.R. Schalles. 1965. Some nongenetic influences on calf performance. J. Anim. Sci. 24:494.

McCormick, W. C. and B. L. Southwell. 1957. A comparison of Brahman crossbred with British crossbred cattle. J. Anim. Sci. 16:207.

Meade, J. H. Jr. et al. 1963. Environmental factors affecting weaning weights of beef cattle in the Everglades. Tech. Bull. Fla. Agric. Exp. Sta. No. 663.

Menge, A. C., S. E. Mares, W. J. Tyler and L. E. Casida. 1960. Some factors affecting age at puberty and the first 90 days of lactation in Holstein heifers. J. Dairy Sci. 43:1099.

Morgan, J. H. L. 1981. A comparison of breeds and their crosses for beef production. II. Growth and puberty of heifers. Aust. J. of Agric. Research 32:839.

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. et al. 1960. Genetic and environmental influences on weaning weight and slaughter grade of Brahman, Shorthorn and Brahman x Shorthorn crossbred calves. Bull. Fla. Agric. Exp. Sta. No 624.

Peacock, F. M., J. E. McCaleb, E. M. Hodges and W. G. Kirk. 1961. Factors influencing winter gains of beef calves. Bull. Fla. Agric. Exp. Sta. No. 635.

Peacock, F. M., W. G. Kirk and M. Koger. 1965. Effect of Brahman breeding on performance of calves from weaning to feedlot. Bull. Fla. Agric. Exp. Sta. No. 705.

Peacock, F. M., E. M. Hodges, W. G. Kirk, M. Koger and A. C. Warnick. 1976. Reproductive behavior of crossbred heifers bred as yearlings. Circular, Agric. Exp. Sta., Fla. Univ. No. S-236.

Pell, E. W. and W. V. Thayne. 1978. Factors influencing weaning weight and grade of West Virginia beef calves. J. Anim. Sci. 46:596.

Peters, H. F. and S. B. Slen. 1967. Brahman-British beef cattle crosses in Canada. 1. Weaned calf production under range conditions. Can. J. Anim. Sci. 47:145.

Phillips, R. 1946. Seasonal variation in the rate of growth of young cattle. Nature 158:202.

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.

Rankin, B.J., S.M. Shaffer, S.P. Neville and L.A. Holland. 1978. Crossbreeding Hereford and Brangus cattle in varied southwestern environments. New Mexico State Univ. Agric. Exp. Sta. Bull. No. 661.

Rhoad, A. O., R. W. Phillips and W. M Dawson. 1945. Evaluation of species crosses of cattle by pollyallel crossing. A study of zebu and Africander x Aberdeen-Angus cattle under subtropical conditions. J. Hered. 36:367.

Robertson, R. L. and J. O. Sanders. 1983. Genetic effects on birth weight in Brahman and Hereford cattle and their crosses. In Beef Cattle Research in Texas. Texas Agric. Exp. Sta. p. 16.

Rollins, W.C., F.D Carroll 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.

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. Effect of certain factors on weaning weight of beef calves. J. Anim. Sci. 31:5.

Stewart, T.S., C.R. Long and T.C. Cartwright. 1980. Characterization of cattle of a five-breed diallel. III. Puberty in bulls and heifers. J. Anim. Sci. 50:808.

Young, L. D., D. B. Laster, L. V. Cundiff, G. M. Smith and K. E. Gregory. 1978. Characterization of biological types of cattle. IX. Postweaning growth and puberty of three-breed cross heifers. J. Anim. Sci. 47:843.

CHAPTER III

GENOTYPE X ENVIRONMENT INTERACTIONS INVOLVING LEVEL OF BRAHMAN AND SEASON OF BIRTH.

I. CALF GROWTH TO WEANING

Summary

Performance to weaning was evaluated on 489 spring-born and 416 fall-born crossbred calves of three levels of Brahman (B) breeding (0, 1/4 and 1/2 B) over a three year period. The calves were produced by appropriate matings of Angus (A), Hereford (H), Brahman (B), B:A and B:H bulls to A and H cows. Averaged over crossbred groups the 205-day weaning weight of spring-born calves was 20 kg heavier than the 240-day weaning weight of fall-born calves.

Interactions between percent Brahman and season of birth were significant (P<.01) for all traits except birth weight. In the spring calving group, 1/4 and 1/2 B calves were 21 and 28 kg heavier at weaning than 0 B calves (195 kg), respectively, while in the fall calving group the three levels of Brahman breeding had similar weaning weights. Hip height increased as the percent Brahman increased in both seasons. Averaged over both spring and fall, 1/4 and 1/2 B calves were 1.8 and 5.3 cm taller, respectively, than 0 B calves.

For growth traits through weaning, these data indicated a general advantage as proportion of Brahman breeding increased with the advantage being of greater magnitude for spring-born calves. Within each crossbred group spring-born calves exhibited more rapid growth than fall-born calves.

(Key Words: Genotype-Environment Interaction, Brahman, Crossbreeding, Calving Season).

Introduction

Different genetic types of cattle have been used as a means of increasing production efficiency. In a rotational crossbreeding study conducted in the Florida Everglades, Crockett et al. (1978) found higher heterosis levels for Brahman cross calves than for British cross calves and increased annual production per unit of cow weight among Brahman cross compared to British cross cows.

Genotype by environment interactions, however, have been shown to exist. 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 in the location from which they originated. A season of birth by breed interaction was reported by Sellers et al. (1970), who found that spring- and summer-born Angus calves grew more rapidly to weaning than Hereford calves born in these seasons while fall- and winter-born Hereford calves grew faster preweaning than the corresponding Angus calves.

Because optimum performance of different types of cattle may occur in different environments, a long-term study was initiated to evaluate the productivity of crossbred cows with different proportions of Brahman breeding managed under spring or fall calving systems. In the present study, the performance of the crossbred calves produced in the initial phase of this long-term study was used to evaluate the effects of proportion of Brahman breeding, season of birth, and proportion of Brahman breeding by season of birth interactions on growth of crossbred calves to weaning.

Materials and Methods

All crossbred calf groups were produced using Angus (A) or Hereford (H) dams. Cows were randomly assigned within age and breed subclasses to spring or fall calving groups and mated to A, H, Brahman (B), B:A and B:H bulls to produce crossbred calves that were 0 B (H:A and A:H), 1/4 B (1/4 B:1/4 H:1/2 A and 1/4 B:1/4 A:1/2 H) and 1/2 B (B:A and B:H). The same set of three bulls of each sire breed were used for spring and fall calving groups in the same year with a different set of bulls used each year. During the three-year period (1981-1983) there were 489 and 416 produced in the spring and fall calving periods, respectively, and 162, 379 and 364 0, 1/4 and 1/2 B calves, respectively (Table I). Cows ranged in age from 2 to 12 years for the first year's calf crop and 4 to 13 years for the third year of the study. All cows were bred by natural service in single-sire breeding pastures except that the three B bulls used for the 1981 calf crop were by artificial insemination.

The cattle involved in the foundation crosses were largely from well-established herds of known genetic background and generally represented cattle that were above average in productivity and performance traits for the respective breeds or crossbred groups. The H and A cows and bulls were primarily from the selection lines at the Oklahoma Agricultural Experiment Station at El Reno, Oklahoma that had been intensely selected for increased weaning or yearling weight since the early 1960's (Frahm et al. 1985a,b; Aaron et al. 1986a,b). The B:A and B:H crossbred bulls were selected as the larger, growthier bulls at weaning time from two different large ranches in Texas that specialize in producing F1 B:A and B:H heifers, respectively. Three B bulls used by artificial insemination for the 1981 calf crop were bulls being used by Texas A & M University in the crossbreeding research project being conducted at the experiment station located at McGregor, Texas. These bulls were described by the project leader as being "typical and representative of the Brahman breed." The balance of the bulls were obtained from prominent Brahman breeders in Oklahoma.

Cows were maintained on native tallgrass pastures at the Oklahoma Agricultural Experiment Station near El Reno, OK. Predominant forage species were big bluestem (Andropogon gerardii), little bluestem (Andropogon scoparius), buffalograss (Buchloe dactyloides), side oats (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon). Because these are warm-season grasses which are dormant in the winter, cows were supplemented during winter months with alfalfa and cottonseed meal to meet protein requirements.

Average summer (April-September) minimum and maximum temperatures for 1981-1983 were 16 and 28^{o}C and rainfall for these six months totaled 69 cm (Table II). Minimum and maximum average temperatures and total rainfall were 1^{o}C, 13^{o}C and 46 cm, respectively, for winter (October-March) periods (1981-82 through 1983-84) of calf growth.

Spring calves were born from February through April and fall calves were born from September through November. Birth weights were recorded within 24 hours of birth. Calves remained with their dams on pasture and were not creep-fed.

Spring- and fall-born calves were weaned at an average age of 205 and 240 days, respectively. Average weaning dates for the three years were September 25 and May 20 for spring and fall calves, respectively. At weaning, calf weights and hip heights were recorded. Calf condition scores (1=very thin to 9=very fat with 5=average) and conformation scores (an indicator of muscling with 13=average choice) were determined by averaging scores assigned by three evaluators. Calf weaning weights and heights were adjusted to 205 and 240 days of age for calves born in the spring and fall, respectively. Twin calves were deleted from the data set prior to analysis.

Data were analyzed using least squares procedures. The full model included effects for dam breed, sire breed group, calf sex, dam age, year, season of birth, all two-way interactions and all 3-way interactions involving either season of birth or proportion B. Least squares means were based on reduced models that contained appropriate significant interaction effects ($P<.20$). Comparisons among means were based on protected least significant differences for sources of variation that were significant ($P<.05$). A preliminary analysis showed that it was appropriate to combine dam age into 5 age groups: 2, 3, 4, 5, and greater than 5 years old. The sire breed group x dam breed interactions were determined to be nonsignificant ($P>.10$); therefore it was appropriate to combine calves into groups of either 0, 1/4 or 1/2 B breeding.

Results and Discussion

Significance levels of proportion B, season of birth and the proportion B x season of birth interaction for all traits are presented in Table III. The genotype by environment interaction was significant (P<.01) for all traits analyzed except birth weight.

Birth weight means are presented in Table IV. Birth weight increased (P<.01) with level of B breeding both in spring and fall calving systems, with 1/4 and 1/2 B calves weighing 1.4 and 3.8 kg more than 0 B calves (33.9 kg) when averaged over both seasons. Crockett et al. (1979) found that birth weights of Brahman-sired calves (34 kg) were one to five kg heavier than those of Brangus, Beefmaster, Limousin and Simmental sires. Brahman:Hereford calves were reported to be four kg heavier at birth then Angus:Hereford calves (30 kg) (McCormick and Southwell, 1957). The results obtained in the present study are in very close agreement with those obtained in both of these previous studies and indicate that Brahman breeding tends to increase calf birth weight.

Preweaning daily gain and weaning weight were both affected (P<.01) by the genotype x environment interaction, with differences of magnitude within a crossbred group occurring between the two seasons (Figures 1 and 2, respectively). Crossbred group means for both traits are presented by season in Table IV. Preweaning daily gain and weaning weight did not differ (P>.10) among fall-born calves. Among spring-born calves, however, daily gain and weaning weight increased (P<.01) with each increasing level of B breeding. Calves with 1/4 and 1/2 B breeding gained 36 and 69 g more per day, respectively, than 0 B calves

(787 g/day) and weighed 9 and 18 kg more at weaning (0 B=195 kg). Anderson (1968) reported weaning (nine month) weights of 1/2 Brahman heifers to be 46 kg heavier than those of 1/4 Brahman heifers (154 and 200 kg, respectively). Even when taking the younger weaning age of calves in the present study into consideration, the difference between weaning weights of 1/4 and 1/2 Brahman calves reported by Anderson (1968) is much larger than that observed in the present study. It seems probable that the severe tropical climate in Papua allowed greater expression of adaptability of the higher-proportion Brahman calves; the more temperate environment of central Oklahoma likely did not permit variation among different levels of Brahman breeding to be so large. Weaning (200-day) weights of 1/2 Brahman calves (225 kg) were 16 kg heavier than 0 Brahman (Angus:Hereford and Hereford:Angus) calves (Cundiff et al. 1984) at Clay Center, Nebraska, a difference very similar to that observed in the current study.

Spring calves outgained ($P<.001$) and outweighed ($P<.01$) fall calves of the same proportion B, with spring-born 0, 1/4 and 1/2 B calves gaining 157, 210 and 245 g/day more preweaning and weighing 11, 21 and 28 kg more at weaning than fall-born calves of the same crossbred group despite being 35 days younger at weaning. Brown (1963) and Cundiff et al. (1966) reported 12 to 18 kg advantages in weaning weight for spring-born Angus and Hereford calves, and Marlowe et al. (1965) reported an 114 g/day advantage in gain for spring over fall non-creep-fed Angus and Hereford calves. Differences observed among spring and fall calving systems in these studies are comparable to those found for 0 B calves in the present study. Weaning weights of Brahman and Brahman-cross calves were also reported to be influenced by season (Robertson and Sanders, 1983).

Weaning hip height was affected by the proportion B x calving season interaction, with a slight change in rank between spring- and fall-born 0 and 1/4 B calves and a significant ($P<.05$) difference between height of spring and fall 1/2 B calves (Figure 3). In the spring calving group height increased with increasing level of B; 1/4 B calves were 2.6 cm taller than 0 B calves and 1/2 B calves were 4 cm taller than 1/4 B calves (Table V). Among fall-born calves, 0 and 1/4 B calves were of similar height ($P>.10$) while 1/2 B calves were 3.7 and 2.8 cm taller than 0 and 1/4 B calves, respectively. Hip heights within crossbred groups were generally similar across both seasons, with height tending to increase with increasing levels of B breeding. This would indicate that structural growth was generally not limited even in the fall calving group; thus, differences in weaning weights among crossbred groups between the two seasons could be attributed more to limited energy availabilty in winter months causing an inability of fall calves to put on lean and fat tissues.

The genotype x environment interaction for condition and conformation score was caused by changes in rank of crossbred groups born in different seasons (Figures 4 and 5). Least squares means for both traits are presented in Table V. Condition scores of spring calves were similar between levels of B breeding, but condition score decreased as level of B increased ($P<.05$) in calves born in the fall: each 25% increase in B breeding decreased condition score by .3 units (average score=5.6, 5.3 and 5.0 for 0, 1/4 and 1/2 B calves, respectively). Likewise, no differences were observed between conformation grades of crossbred groups born in the spring, while conformation grade decreased by .3 points with each level of increase of B (0, 1/4 and 1/2 B calves averaged 13.1, 12.8 and 12.5, respectively). This would tend to reinforce the idea that the lower weaning weight of fall-born calves was due to lack of lean and fat tissue development rather than lack of structural growth.

In summary, these data indicated that traits through weaning were generally improved as level of B breeding increased. The improvement made by using B crossbred calves was more evident in spring than in fall calving systems. Calves of all crossbred groups performed better when born in the spring than when born in the fall, weighing an average of 20 kg more at weaning.

Because the performance of even 0 B calves was depressed in the fall calving system, and given that calves were sired by the same bulls in any two seasons of a single year, environmental factors seem to have been negating the genetic growth potential of fall-born calves. Structural growth, as measured by hip height, increased with increasing level of B in both spring and fall systems, while weaning weight and conformation and condition scores decreased as level of B breeding increased in fall-born calves. This would indicate that environmental factors present (limited energy availability for milk production of dams and/or cold stress, for example) were generally not limiting enough to depress structural growth but did limit the ability of calves to put on muscle and fat.

While this study suggested that fall calving would be unadvisable under the given management conditions, it also showed that interactions between season of birth and level of Brahman breeding do exist. Therefore, the use of different crossbred types of cattle should be carefully evaluated for the type of management system to be used. Furthermore, the existence of genotype x environment interactions should be carefully considered in the design of future experiments.

TABLE I

NUMBER OF CALVES IN EACH SEASON AND CROSSBRED GROUP

Proportion Brahman	Spring	Fall	TOTAL
0	94	68	162
1/4	214	165	379
1/2	181	183	364
TOTAL	489	416	905

TABLE II

RAINFALL AND AVERAGE MONTHLY TEMPERATURES IN EL RENO, OKLAHOMA

	1981			1982			1983			1984		
	Temp.[a]		Rain-fall[b]	Temp.		Rain-fall	Temp.		Rain-fall	Temp.		Rain-fall
Month	Min	Max		Min	Max		Min	Max		Min	Max	
Jan.	- 3	11	0.4	- 6	7	7.9	- 2	7	4.3	- 6	7	4.6
Feb.	- 1	13	0.9	- 3	7	2.9	0	9	1.7	- 2	13	6.9
Mar.	3	18	6.6	- 1	16	5.5	3	13	6.1	1	13	18.4
Apr.	12	25	3.8	7	19	4.8	6	17	8.8	6	19	9.7
May	12	23	11.9	14	24	45.0	11	24	18.2	14	26	3.9
June	20	27	19.6	17	27	11.3	17	28	13.3	19	32	25.1
July	23	34	7.4	21	32	10.7	21	34	0	20	35	0.8
Aug.	19	31	15.0	22	36	0	21	36	15.6	20	34	7.4
Sept.	17	29	11.1	16	28	5.5	16	30	4.1	14	27	0.8
Oct.	11	19	28.2	9	23	0.6	12	23	26.2	9	21	4.2
Nov.	4	15	5.4	4	14	5.1	5	15	4.1	2	14	4.2
Dec.	- 1	9	1.7	0	12	2.6	- 5	6	4.5	- 1	9	14.6
Avg. or Total	10	21	112	8	21	102	9	20	107	8	21	101

[a]Average minimum or maximum temperature for the month in ^{o}C

[b]Rainfall given in centimeters/month

TABLE III

SIGNIFICANCE LEVELS OF FACTORS IN ANALYSIS OF VARIANCE

Source	Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Ht.	Weaning Conf.	Weaning Cond.
Proportion Brahman (B)	**	*	**	**	**	**
Calving Season (S)	NS	**	**	NS	NS	NS
B x S	NS	**	**	**	**	**

* P<.05
** P<.01
NS Not significant (P>.05)

TABLE IV

LEAST SQUARES MEANS AND STANDARD ERRORS FOR BIRTH WEIGHT, PREWEANING DAILY GAIN AND WEANING WEIGHT[a]

		Season of Birth			
		Spring		Fall	
Proportion Brahman	Birth Wt. (kg)	Preweaning ADG (g/d)	Weaning Wt. (kg)	Preweaning ADG (g/d)	Weaning Wt. (kg)
0	33.9±.45^{b}	787±12^{b}	195±3^{b}	630±14^{b}	184±3^{b}
1/4	35.3±.35^{c}	823± 9^{c}	204±2^{c}	612±10^{b}	183±2^{b}
1/2	37.7±.34^{d}	856±10^{d}	213±2^{d}	612±10^{b}	185±2^{b}
Average	35.6±.22	822± 7	204±2	618± 8	184±2

[a]Weaning weights adjusted to 205 and 240 days of age for spring and fall calving groups, respectively

[bcd]Means in the same column not sharing at least one common superscript differ (P<.05)

TABLE V

LEAST SQUARES MEANS AND STANDARD ERRORS FOR WEANING HEIGHT,[a] CONDITION AND CONFORMATION SCORE

Proportion Brahman	Season of Birth					
	Spring			Fall		
	Ht. (cm)	Cond.[b]	Conf.[c]	Ht. (cm)	Cond.	Conf.
0	102.2 ± .7[d]	5.4 ± .11[d]	12.8 ± .09[d]	103.2 ± .9[d]	5.6 ± .13[f]	13.1 ± .11[f]
1/4	104.8 ± .4[e]	5.3 ± .06[d]	12.8 ± .06[d]	104.1 ± .4[d]	5.3 ± .06[e]	12.8 ± .07[e]
1/2	108.8 ± .4[f]	5.2 ± .06[d]	12.9 ± .07[d]	106.9 ± .4[e]	5.0 ± .06[d]	12.5 ± .07[d]
Average	105.3 ± .3	5.3 ± .05	12.8 ± .05	104.7 ± .4	5.3 ± .06	12.8 ± .06

[a]Weaning height adjusted to 205 and 240 days of age for spring and fall calving groups, respectively
[b]Condition: 1=thin to 9=fat with 5=average
[c]Conformation: 12=low choice, 13=average choice
[def]Means in the same column not sharing at least one common superscript differ (P<.05)

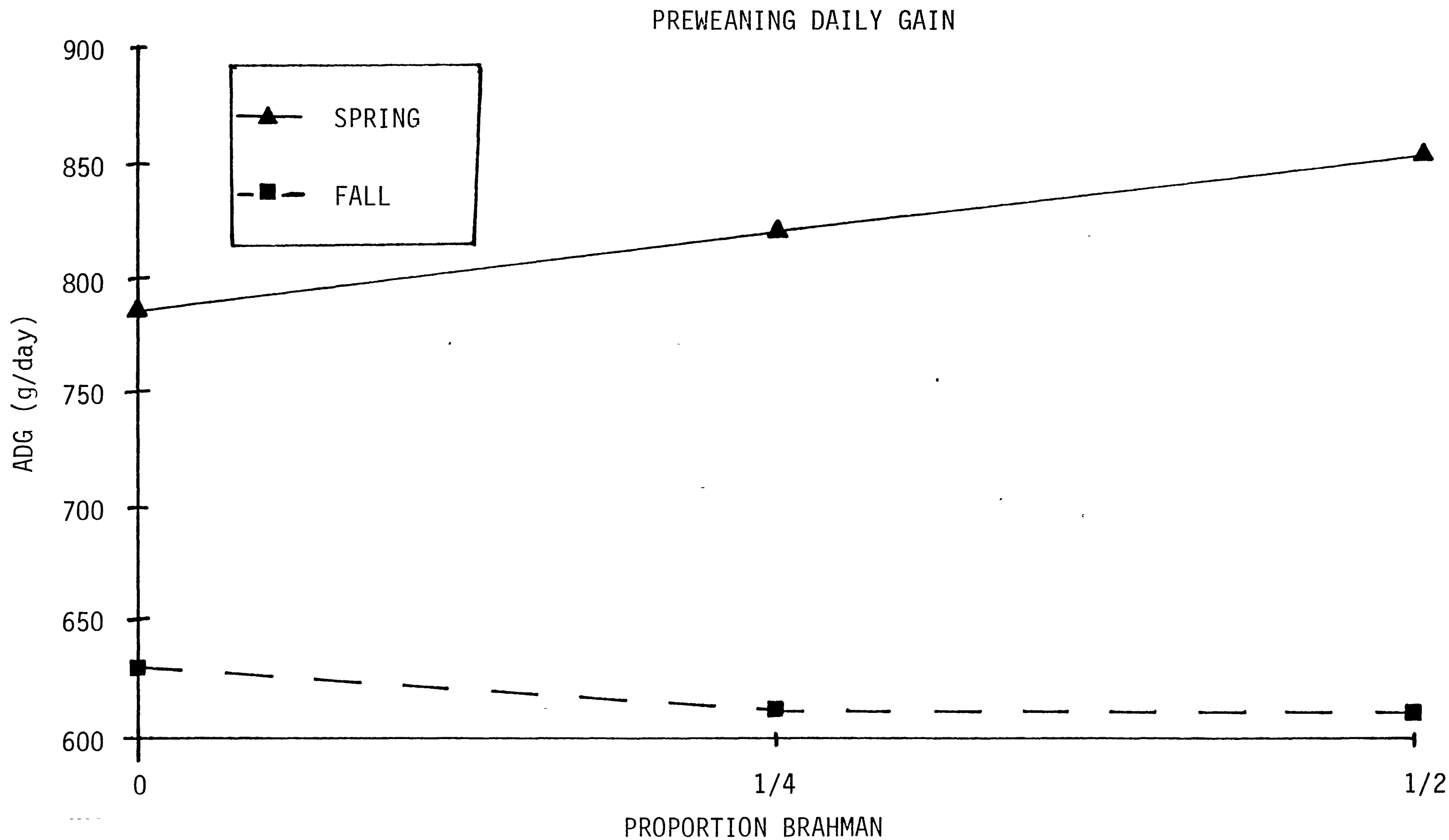

Figure 1. Preweaning Daily Gain of Calves With Different Levels of Brahman Breeding Born in Spring and Fall

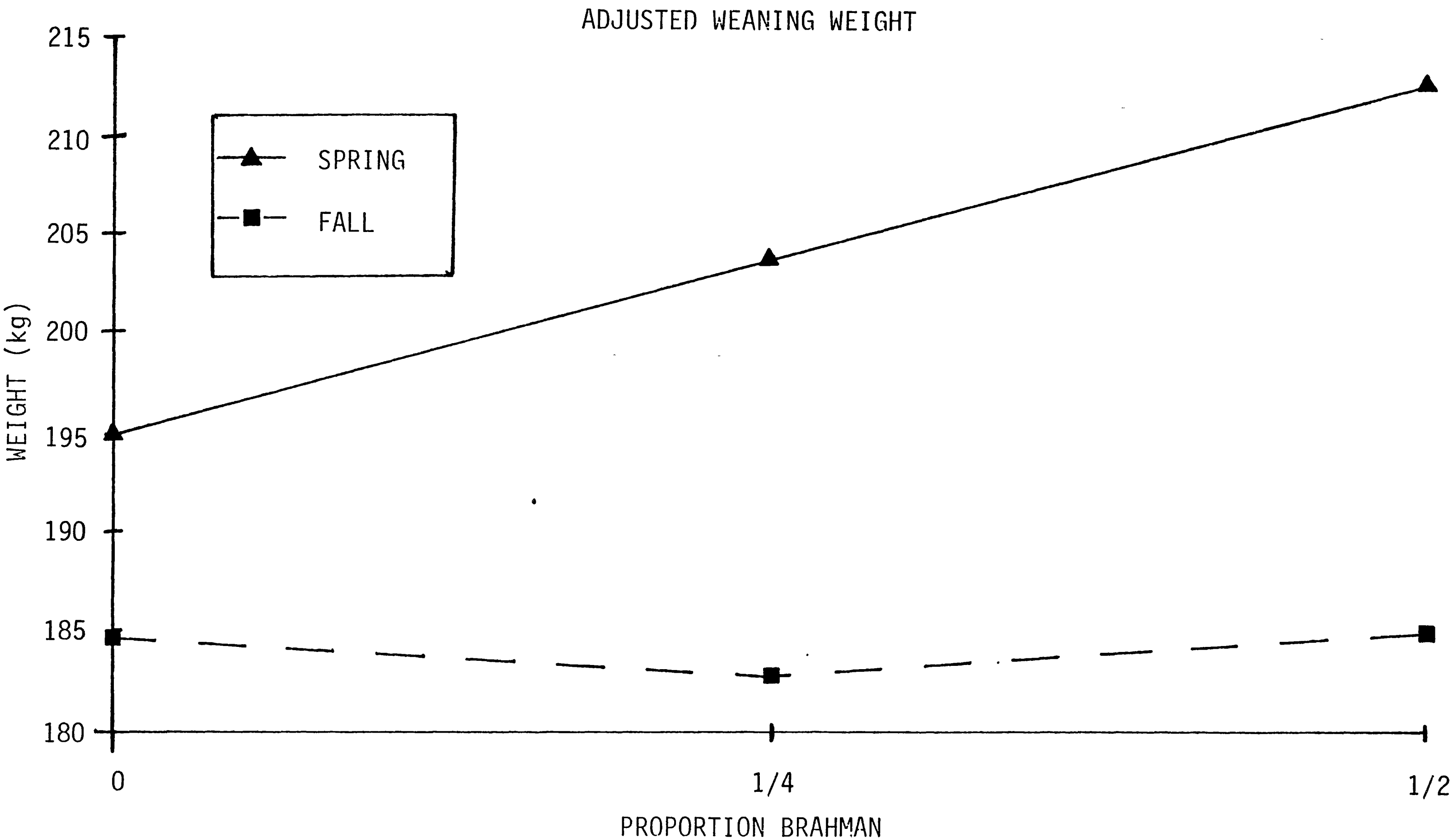

Figure 2. Adjusted Weaning Weight of calves With Different Levels of Brahman Breeding Born in Spring and Fall

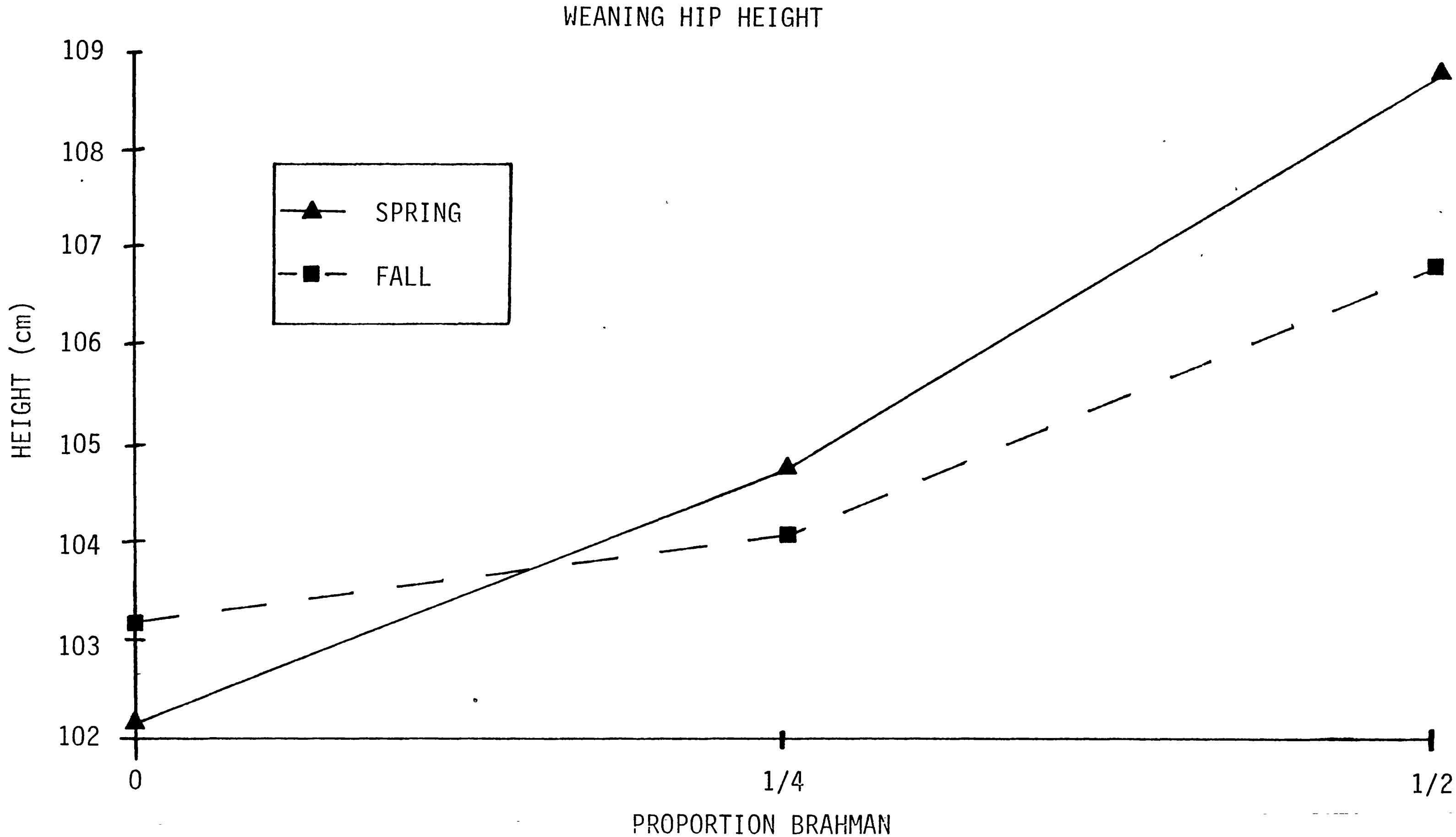

Figure 3. Adjusted Weaning Height of Calves With Different Levels of Brahman Breeding Born in Spring and Fall

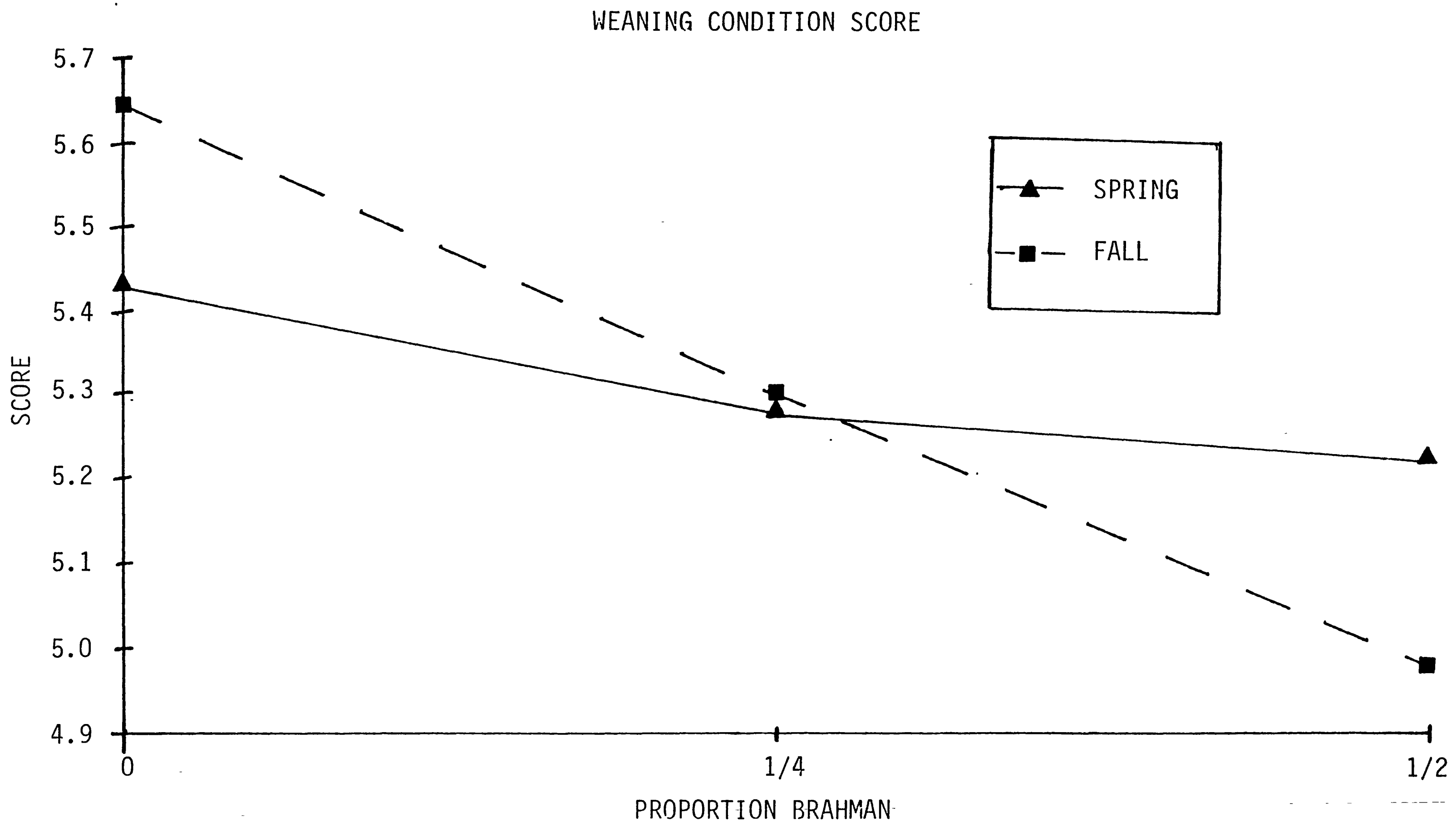

Figure 4. Weaning Condition Score of Calves With Different Levels of Brahman Breeding Born in Spring and Fall

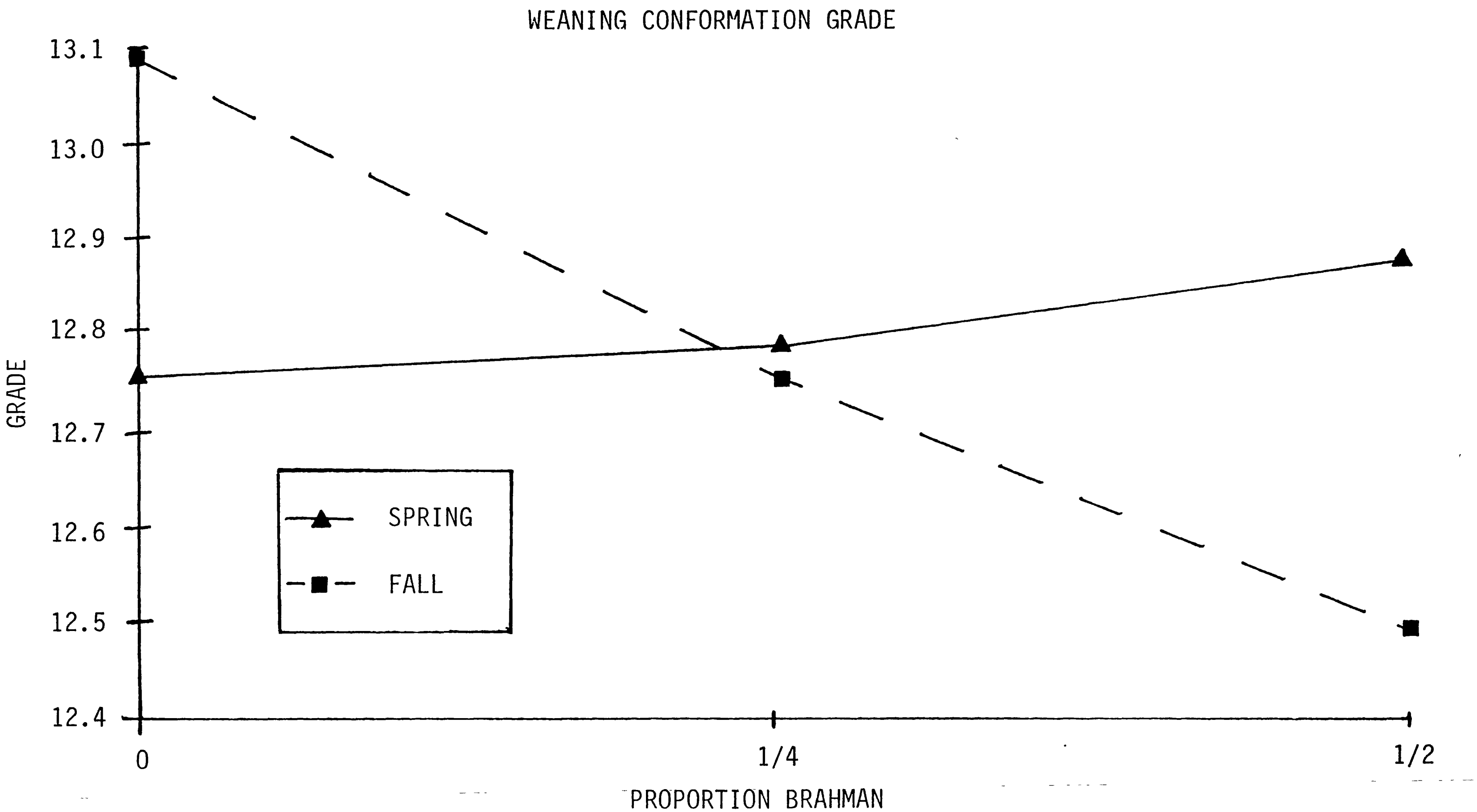

Figure 5. Weaning Conformation Grade of Calves With Different Levels of Brahman Breeding Born in Spring and Fall

Literature Cited

Aaron, D.K., R.R. Frahm and D.S. Buchanan. 1986a. Direct and correlated responses to selection for increased weaning or yearling weight in Angus cattle. I. Measurement of selection applied. J. Anim. Sci. 62:54.

Aaron, D.K., R.R. Frahm and D.S. Buchanan. 1986b. Direct and correlated responses to selection for increased weaning or yearling weight in Angus cattle. II. Evaluation of Response. J. Anim. Sci. 62:66.

Anderson, J.L. 1968. Growth of cattle in Papua and New Guinea. 1. Brahman-British crossbreds. Aust. J. Exp. Agric. Anim. Husb. 8:121.

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.

Butts, W.T., 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.

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

Crockett, J.R., F.S. Baker, Jr., J.W. Carpenter and M. Koger. 1979. Preweaning, feedlot and carcass characteristics of calves sired by continental, Brahman and Brahman-derivative sires in subtropical Florida. J. Anim. Sci. 49:900.

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., R.M. Koch and K.E. Gregory. 1984. Characterization of biological types of cattle (Cycle III) IV. Postweaning growth and feed efficiency. J. Anim. Sci. 58:312.

Frahm, R.R., C.G. Nichols and D.S. Buchanan. 1985a. Selection for increased weaning or yearling weight in Hereford cattle. I. Measurement of selection applied. J. Anim. Sci. 60:1373.

Frahm, R.R., C.G. Nichols and D.S. Buchanan. 1985b. Selection for increased weaning or yearling weight in Hereford cattle. II. Direct and correlated responses. J. Anim. Sci. 60:1385.

Marlowe, T.J., C.C. Mast and R.R. Schalles. 1965. Some nongenetic influences on calf performance. J. Anim. Sci. 24:494.

McCormick and Southwell. 1957. A comparison of Brahman crossbred with British crossbred cattle. J. Anim. Sci. 16:207.

Robertson, R.L. and J.O. Sanders. 1983. Genetic effects on birth weight in Brahman and Hereford cattle and their crosses. In Beef Cattle Research in Texas. Texas Agric. Exp. Sta. p. 16.

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

CHAPTER IV

GENOTYPE X ENVIRONMENT INTERACTIONS INVOLVING LEVEL OF BRAHMAN AND SEASON OF BIRTH. II. YEARLING, PUBERTY AND REPRODUCTIVE PERFORMANCE OF HEIFERS

Summary

Yearling, puberty and pregnancy traits for 201 spring-born and 180 fall-born crossbred heifers that were 0, 1/4 or 1/2 Brahman (B) breeding collected over a three-year period were evaluated. The heifers were produced by appropriate matings of Angus (A), Hereford (H), B, B:A and B:H bulls to A and H cows.

Postweaning gain to 365 days increased as level of B breeding increased, with gains of fall-born heifers (over summer months) being 168 g/d greater than spring-born heifers (over winter months). At 365 days of age, spring-born heifers were an average of 16 kg heavier and 2 cm taller than fall-born heifers.

Heifers born in the spring were 66 kg heavier at the beginning of the breeding season as yearlings and had a 52% higher pregnancy rate averaged over all crossbred groups

compared to fall-born heifers. The proportion Brahman x season of birth interaction was highly significant for pregnancy rate, with heifers in the spring calving group having similar pregnancy rates while heifers in the fall group showed a decreasing pregnancy rate with increasing level of B breeding.

The data indicated that heifers born in the spring were heavier and taller as yearlings and were better able to attain puberty and to conceive in order to calve as two-year-olds compared to fall-born heifers. Pregnancy rates were similar among crossbred heifer groups in the spring calving system. However, pregnancy rate declined with increased level of B breeding in the fall calving system.

(Key Words: Genotype-Environment Interaction, Brahman, Crossbreeding, Calving Season)

Introduction

Genotype by environment interactions are generally known to exist. Butts et al. (1971) reported significant genotype by environment interactions for birth, weaning and yearling traits among Hereford cattle in Florida and Montana, with the cattle performing best at each location being those than originated from that location.

While Brahman cross cattle have been shown to perform better than British cross cattle in the Florida Everglades (Crockett et al. 1978), few reports have been published concerning performance of Brahman cross cattle in more temperate environments. Gregory et al. (1979) noted differences in summer versus winter postweaning daily gains between crosses involving Bos indicus and Bos taurus cattle. They suggested that species differences for climatic adaptability and/or adaptabilty to different feed environments may have caused the differences in gain.

As part of a long-term research project designed to evaluate genotype by environment interactions among cows with different levels of Brahman breeding managed under spring or fall calving systems, this study evaluates the performance of crossbred heifers from weaning through first pregnancy as yearlings. The previous chapter dealt with calf performance to weaning. The ability of heifers to attain puberty and conceive as yearlings in order to calve as two-year-olds affects the lifetime production efficiency of the cow herd. Therefore, the objectives of this study were to evaluate the effects of proportion of Brahman breeding, season of birth, and proportion of Brahman breeding by season of birth interactions on growth of heifers to yearling age and on the ability of heifers to calve at two years of age.

Materials and Methods

Postweaning and puberty traits were evaluated for heifers born over the three-year period 1981-1983. Heifers were produced by mating Angus (A) and Hereford (H) dams to A, H, Brahman (B), B:A or B:H sires to produce calves that were 0 B (A:H and H:A), 1/4 B (1/4 B:1/4 H:1/2 A and 1/4 B:1/4 A:1/2 H) and 1/2 B (B:A and B:H). The same set of three bulls of each sire breed were used for spring and fall calving groups in the same year with a different set of bulls used each year. Cows ranged in age from 2 to 12 years for the first calf crop in 1981 and 4 to 13 years for the third calf crop in 1983 and were bred by natural service in single-sire breeding pastures except that the three Brahman bulls used for the 1981 calf crop were by artificial insemination.

The cattle involved in the foundation crosses were largely from well-established herds of known genetic background and generally represented cattle that were above average in productivity and performance traits for the respective breeds or crossbred groups. The H and A cows and bulls were primarily from the selection lines at the Oklahoma Agricultural Experiment Station at El Reno, Oklahoma that had been intensely selected for increased weaning or yearling weight since the early 1960's (Frahm et al. 1985a,b, Aaron et al. 1986a,b). The B:A and B:H crossbred bulls were selected as the larger, growthier bulls at weaning time from two different large ranches in Texas that specialize in producing F1 B:A and B:H heifers, respectively. Three B bulls used by artificial insemination for the 1981 calf crop were bulls being used by Texas A & M University in the crossbreeding research project being conducted at the experiment station located at McGregor, Texas. These bulls were described by the project leader as being "typical and representative of the Brahman breed." The balance of the bulls were obtained from prominent B breeders in Oklahoma.

Cattle were maintained throughout the study at the Southwest Livestock and Forage Research Station near El Reno, OK on native tallgrass pastures. Forage species were predominantly warm-season grasses that were dormant during the winter and included big bluestem (Andropogon gerardii), little bluestem (Andropogon scoparius), buffalograss (Buchloe dactyloides), side oats (Bouteloua curtipendula), silver bluestem (Bothriochloa saccharoides) and bermudagrass (Cynodon dactylon).

Spring calves were born from February through April and weaned in September at an average age of 205 days, while fall calves were born from September through November and weaned in May at an average age of 240 days. Calves were reared with their dams on pasture and were not creep fed. Dams were supplemented during the winter to meet protein requirements.

After weaning, all heifers were retained and managed to be bred as yearlings. Target prebreeding weights for 0, 1/4 and 1/2 B heifers were 295, 318 and 340 kg, respectively. Heifers were maintained on native tallgrass pastures and supplemented with oat-alfalfa silage, corn, milo and cottonseed meal to meet protein requirements and to provide additional energy in an attempt to allow them to attain the target prebreeding weights.

Rainfall and temperatures by month were presented in the previous chapter. Summer (April-September) average minimum and maximum temperatures were 16 and 28°C for 1982-1984 and rainfall for these months averaged 62 cm. Winter (October-March) minimum and maximum temperatures averaged 1 and 13°C, respectively, and average rainfall was 48 cm for the winters of 1982-83 through 1984-85.

At an average age of 365 days, heifer yearling weights and hip heights were recorded and condition scores (1=very thin to 9=very fat with 5=average) and conformation scores (used as indicators of muscling with 13=average choice) were determined by averaging scores assigned by three evaluators. Yearling weight and height were adjusted to 365-day measurements. Over the three years of the study there were 201 spring-born and 180 fall-born heifers and 68, 138 and 125 0, 1/4 and 1/2 B heifers, respectively, and data from all heifers were included in the analysis of yearling traits (Table I).

Puberty was detected visually with the aid of teaser bulls wearing chin markers. Heat detection was started when heifers were approximately 325 d of age and ended at approximately 410 d of age when heifers were placed in breeding pastures, and puberty weight was recorded within two weeks of first estrus. Adjusted puberty weights were calculated by determining average daily gain from yearling to prebreeding and adjusting actual puberty weight forward or back to the date of observed estrus. Data for heifers born in the spring of 1982 were incomplete and therefore not included in the analysis, leaving 123 spring-born and 180 fall-born heifers (61, 127 and 115 0, 1/4 and 1/2 B heifers, respectively) that were analyzed for percent heat detection (Table II). Of these heifers, 152 were detected in heat by the beginning of the breeding season; weight and age at puberty were analyzed for these 152 heifers (Table II).

At the beginning of the 60-day breeding season, prebreeding weights and condition scores for all heifers were determined. Prebreeding data for heifers born in the spring of 1983 were missing, leaving 151 and 180 spring- and fall-born heifers, respectivly, to be included in the analysis of prebreeding traits (Table II). Pregnancy rate was analyzed by palpation for pregnancy at approximately 80 days from the end of the breeding season, and data from all heifers (Table I) were analyzed.

Traits were analyzed using least squares procedures. The full model included effects for dam breed, sire breed group, dam age, year, season of birth, all two-way interactions, and all 3-way interactions involving either season of birth or sire breed group. Least squares means were based on reduced models that contained appropriate significant interaction effects (P<.20). Comparisons among means were based on protected least significant differences for sources of variation that were significant (P<.05). A preliminary analysis showed that it was appropriate to combine dam age into 5 age groups: 2, 3, 4, 5, and greater than 5 years old. The sire breed group x dam breed interactions were determined to be nonsignificant (P>.10); therefore it was appropriate to combine heifers into groups of either 0, 1/4 or 1/2 B breeding.

Results and Discussion

Significance levels of proportion B, season of birth and the proportion B x season of birth interaction for yearling traits are presented in Table III. The genotype by environment interaction was significant (P<.10) for only two of the six traits analyzed (postweaning daily gain and yearling condition score). Least squares means for yearling traits affected by the genotype x environment interaction (postweaning daily gain and yearling condition score) are presented in Table IV, while means for traits not affected by the interaction (ADG birth to yearling, 365-d weight, 365-d height, and yearling conformation score) are in Table V.

The proportion B x season of birth interaction for ADG from weaning to 365 d approached significance (P=.054) and was caused by differences of magnitude between different calving seasons (Figure 1). In the spring calving group, 1/4 and 1/2 B heifers gained 50 and 77 g/d more than 0 B heifers (Table IV). Among fall-born heifers, postweaning gain increased with each increase in level of B breeding, with 1/4 and 1/2 B heifers gaining 41 and 104 g/d more than 0 B heifers. Anderson (1968) reported a 156 g/d advantage for 1/2 compared to 1/4 Brahman calves during the postweaning period, a difference much greater than the 27 to 63 g/d difference observed in the present study. This may be due to the fact that severe tropical conditions exist in Papua compared to the temperate environment of Oklahoma, and genetic differences between cattle with different proportions of Brahman breeding are likely more easily expressed in the extremely hot and humid environment.

Fall heifers of each crossbred group gained at a faster rate postweaning than their spring counterparts. It seems likely that compensatory growth occurred among these fall-born heifers, as their 240-d weaning weights were lower than the 205-d weaning weights of the spring-born calves (refer to previous chapter). This idea is supported by the data reported by Cundiff et al. (1984) who indicated that although spring-born Brahman cross calves were heavier than Angus or Hereford cross calves, few differences were observed between crossbred groups by 424 d of age.

Average daily gain from birth to yearling was affected by season of birth and by proportion of Brahman (Table V). Spring-born heifers gained 49 g more per day from birth to yearling than did fall-born heifers, and 1/2 B heifers gained 30 and 24 g/d more than 0 and 1/4 B heifers, respectively. Although preweaning daily gain (refer to previous chapter) and postweaning daily gain were affected by genotype x environment interactions, the ADG from birth to yearling was not affected by the interaction. This may be explained by the fact that the preweaning gain of spring calves (over a 205 d period) was 204 g/d higher than fall-born calves (over a 240 d period), with gain increasing as level of B increased among spring calves and decreasing slightly among fall calves. Postweaning daily gain of spring heifers (over a 160 d period), however, was 165 g/d less than that of fall calves (over a 125 d period), with rate of gain among fall-born calves increasing with increased B breeding. By combining the interaction effects for preweaning and postweaning daily gain, the overall daily gain from birth to yearling would tend to be similar between crossbred groups born in different seasons.

The proportion B x season of birth interaction was not significant for 365-day weight or hip height. Spring-born heifers were 16 kg heavier and 2.2 cm taller than fall-born heifers at yearling age (Table V). Yearling weights of 1/2 B heifers were 13 and 10 kg more ($P<.05$) than those of 0 and 1/4 B heifers, respectively. Hip height increased with each increasing level of B, with 1/4 and 1/2 B heifers averaging 1.9 and 5.7 cm taller than 0 B heifers. Long et al. (1979) found that Brahman:Angus and Brahman:Hereford heifers averaged 23 kg heavier and 9 cm taller at 360 d than Angus:Hereford heifers at McGregor, Texas. These differences are slightly larger than those observed in the present study and may be attributable to the different climate and/or different forage conditions present at McGregor.

Yearling conformation score, a measure of muscling, was not affected by the genotype x environment interaction. However, condition score, a measure of fatness, was highly affected by the interaction with a reversal in rank of 1/4 and 1/2 B heifers between the two calving seasons (Figure 2). Conformation scores of heifers born in the fall were .2 units higher than those of spring-born heifers, and 0 B heifers averaged .2 units higher than 1/4 and 1/2 B heifers (Table V). Condition scores of heifers in the spring calving group decreased as level of B breeding increased, with 0 B heifers averaging .3 and .7 units higher than 1/4 and 1/2 B heifers (Table IV). In the fall group, condition scores of 0 and 1/2 B heifers were similar while 1/4 B heifers scored .3 and .2 units lower, respectively. The 0 B heifers apparently came out of winter in better condition than Brahman cross heifers, but there were fewer differences between crossbred groups coming out of summer months. Since all heifers were supplemented to meet energy and protein requirements as needed, this may indicate a disadvantage for B cross heifers in colder weather.

For puberty and breeding data, significance levels of proportion B, season of birth, and the genotype x environment interaction are presented in Table VI. The proportion B x season of birth interaction at least approached significance (P<.10) for 3 of the 6 traits studied (percent detected in heat by 410 d, prebreeding condition score and pregnancy rate). The least squares means for these three traits are presented in Table VII, while means for traits not affected by the interaction (age at puberty, weight at puberty and prebreeding weight) are presented in Table VIII.

Of those heifers detected in heat by 410 days of age, the genotype x environment interaction approached significance (P=.054), with the nature of the interaction being one of magnitude between spring- and fall-born 1/4 and 1/2 B heifers (Figure 3). The percent of 1/4 B heifers detected in heat was intermediate to that of 0 and 1/2 B heifers in the spring, and 19% fewer 1/2 B heifers were detected in heat compared to 0 B heifers (Table VII). In the fall group, the percent of heifers reaching puberty by 410 d decreased with each increasing level of B breeding, with 1/4 and 1/2 B heifers showing 47 and 61% lower heat detection rates. Young et al. (1978) found that the percent of heifers attaining puberty by 390 d was 43% greater for Angus:Hereford crosses than for B crosses among spring-born heifers. This difference is much larger than that observed among spring-born heifers in the present study, especially since the present study included observation for estrus up to approximately 410 days. Study differences may be attributable to genotype x location interactions as Young's (1978) study was conducted further north in Clay Center, Nebraska.

Spring-born heifers that reached puberty by 410 d were 14 d younger but 40 kg heavier at puberty compared to fall-born heifers (Table VIII). Menge et al. (1960) reported that fall-born Holstein heifers were 136 d older at puberty than spring-born heifers, a difference which they attributed mainly to increased scouring among fall-born calves. Grass et al. (1982) also reported that fall and winter calving delayed puberty. Proportion of B breeding was not significant for either age or weight at puberty, although puberty weight showed a nonsignificant increase with increased level of Brahman breeding (1/2 and 1/4 B heifers were 6 and 10 kg heavier at puberty than 0 B heifers). Several authors have reported that Brahman cross heifers are older and heavier at puberty (Gregory et al. (1979b), Stewart et al. (1980) and Morgan (1981)). It is not surprising that heifers of different crossbred groups were of similar age at puberty because the data were tightly grouped into an 85-day observation period. If the heifers had been observed until all had reached puberty, data would have been present for an extended period of time and differences in age and weight at puberty for different crossbred groups likely would have been more readily apparent.

Season was a significant source of variation for prebreeding weight, with spring heifers averaging 66 kg heavier than fall heifers at the beginning of the breeding season (Table VIII). While 0 B heifers exceeded their set target breeding weight by 15 kg, 1/4 and 1/2 B heifers weighed 15 and 31 kg less than their desired target weights at the beginning of the breeding season. Prebreeding score was affected (P<.10) by the proportion B x season of birth interaction, with a difference of magnitude occurring between spring- and fall-born 1/2 B heifers (Figure 4). Differences between crossbred group scores among the spring-born heifers was relatively large, with 0 B heifers scoring .5 and 1.0 units higher than 1/4 and 1/2 B heifers, respectively (Table VII). In the fall calving group, condition scores of 1/4 B heifers were intermediate to those of 0 and 1/2 B heifers while scores of 1/2 B heifers averaged .5 units lower than those of 0 B heifers. Young et al. (1979) found 450-day weight of Angus:Hereford heifers to be 21 kg lower and condition score .15 units higher than those of Brahman:Angus and Brahman:Hereford heifers.

The genotype x environment interaction for pregnancy rate is shown in Figure 5, with differences of magnitude between spring- and fall- born heifers increasing as level of Brahman breeding increased. There were no statistical differences in pregnancy rate between crossbred groups born in the spring, although 1/4 B heifers showed a 10% advantage over 0 and 1/2 B heifers (Table VII). This is in agreement with Young et al. (1978), who found that sire breed of heifer (Angus or Hereford versus Brahman) was not a significant source of variation for pregnancy rate. They reported pregnancy rates of natural service Angus- and Hereford-sired heifers that were 9.7% greater than those of Brahman-sired heifers and pregnancy rates of heifers from artificial insemination of Angus and Hereford sires that were .3% lower than Brahman-sired heifers. In the fall-calving group, pregnancy rate decreased as level of B breeding increased: 0 B heifers showed 47 and 61% advantages over 1/4 and 1/2 B heifers, respectively.

In general, these data indicated that postweaning traits were not affected by proportion B x season of birth interactions to the extent that weaning traits were affected (refer to previous chapter). Average daily gain postweaning was higher for fall-born calves of all crossbred groups. Because the postweaning period for fall-born calves was during the summer months when native forages were more plentiful, and since fall calves had gained at lower rates preweaning and were lighter at weaning, the increased forage availability likely allowed compensatory growth of these heifers.

It was shown in the previous chapter that a significant genotype by environment interaction for preweaning daily gain existed, with ADG of spring-born calves increasing with increased levels of B breeding and decreasing slightly for B calves born in the fall. The genotype x environment interaction for for postweaning gain showed increasing ADG for fall-born heifers as level of B breeding increased and an advantage for 1/2 B heifers over 0 and 1/4 B heifers born in the spring. When both effects are considered together, the result is a nonsignificant proportion B x season of birth interaction effect for the overall ADG from birth to yearling as well as for yearling weight.

Yearling weight, as well as yearling height, was slightly different between crossbred groups. More significant differences existed between spring and fall calving systems with spring-born calves being 16 kg heavier and 2.2 cm taller at 365 days of age.

For puberty and pregnancy traits, spring-born heifers had a definite advantage since they were heavier at the beginning of the breeding season and thus more likely to reach puberty and conceive as a yearling. The proportion B x season of birth interaction was an important source of variation for percent reaching puberty by 410 d and pregnancy rate, with increased level of B breeding being very detrimental to the reproduction of fall-born heifers. While pregnancy rates of spring-born heifers of all crossbred groups were similar and acceptable, extremely poor pregnancy rates were noted among Brahman-cross heifers and higher but unacceptable pregnancy rates were observed for 0 B heifers.

In conclusion, fall calving systems under this production environment would not be advisable. Not only was yearling performance reduced, but the economically important reproductive traits of even 0 B heifers were seriously impaired by the fall calving system. The effect of the proportion of B x season of birth interaction on pregnancy rate indicates that fall-born heifers, especially if they have Brahman breeding, will not be able to calve as two-year-olds unless alternative management schemes that will counteract the negative environmental influence of fall calving are practiced.

TABLE I

NUMBER OF HEIFERS IN EACH SEASON AND CROSSBRED GROUP FOR YEARLING TRAITS AND PREGNANCY RATE

Proportion Brahman	Spring	Fall	TOTAL
0	38	37	68
1/4	87	70	138
1/2	76	73	125
TOTAL	201	180	381

TABLE II

NUMBER OF HEIFERS IN EACH SEASON AND CROSSBRED GROUP FOR PUBERTY AND REPRODUCTIVE TRAITS

Proportion	HEAT DETECTION			AGE & WT AT PUBERTY			PRE-BREEDING TRAITS		
Brahman	Sprg	Fall	TOTAL	Sprg	Fall	TOTAL	Sprg	Fall	TOTAL
0	24	37	61	19	30	49	31	37	68
1/4	57	70	127	38	25	63	68	70	138
1/2	42	73	115	23	17	40	52	73	125
TOTAL	123	180	303	80	72	152	151	180	331

TABLE III

SIGNIFICANCE LEVELS OF FACTORS IN ANALYSIS OF VARIANCE FOR YEARLING TRAITS

Source	ADG Birth-Yrlg	ADG Wng-Yrlg	Yearling Wt.	Yearling Ht.	Yearling Conf.	Yearling Cond.
Proportion Brahman (B)	**	**	**	**	*	**
Calving Season (S)	**	**	**	**	**	NS
B x S	NS	+	NS	NS	NS	**

* P<.05
** P<.01
\+ P<.10
NS Not significant (P>.10)

TABLE IV

LEAST SQUARES MEANS AND STANDARD ERRORS FOR YEARLING TRAITS AFFECTED (P<.10) BY THE GENOTYPE X ENVIRONMENT INTERACTION

	Season of Birth			
	Spring		Fall	
Proportion Brahman	ADG Wng-Yrlg (g/d)	Yearling Cond.[a]	ADG Wng-Yrlg (g/d)	Yearling Cond.
0	331 ± 19[b]	5.7 ± .11[d]	490 ± 19[b]	5.5 ± .10[c]
1/4	381 ± 13[c]	5.4 ± .07[c]	531 ± 15[c]	5.2 ± .09[b]
1/2	408 ± 14[c]	5.0 ± .08[b]	594 ± 15[d]	5.4 ± .09[c]
Average	373 ± 11	5.4 ± .06	538 ± 12	5.4 ± .06

[a]Condition score: 1=thin to 9=fat with 5=average
[bcd]Means in the same column not sharing at least one common superscript differ (P<.05)

TABLE V

LEAST SQUARES MEANS AND STANDARD ERRORS FOR YEARLING TRAITS NOT AFFECTED (P>.10) BY THE GENOTYPE X ENVIRONMENT INTERACTION

Source	ADG Birth-Yrlg (g/d)	365-d Weight (kg)	365-d Height (cm)	Yearling Conf.[a]
Season				
Spring	628 ± 6[c]	263 ± 2.5[c]	113.1 ± .4[c]	13.0 ± .07[b]
Fall	579 ± 7[b]	247 ± 2.8[b]	110.9 ± .4[b]	13.2 ± .12[c]
Proportion Brahman				
0	591 ± 9[b]	250 ± 3.4[b]	109.5 ± .6[b]	13.2 ± .10[c]
1/4	597 ± 7[b]	253 ± 2.7[b]	111.4 ± .4[c]	13.0 ± .08[b]
1/2	621 ± 7[c]	263 ± 2.7[c]	115.2 ± .4[c]	13.0 ± .08[b]
Average	603 ± 3	255 ± 1.2	112.0 ± .2	13.1 ± .02

[a]Conformation score: 13=average choice and 14=high choice
[bc]Means within each source in the same column not sharing at least one common superscript differ (P<.05)

TABLE VI

SIGNIFICANCE LEVELS OF FACTORS IN ANALYSIS OF VARIANCE FOR PUBERTY AND REPRODUCTIVE TRAITS

Source	% Heat Detection	Puberty Age	Puberty Weight	% Conception	Prebreeding Wt.	Prebreeding Cond.
Proportion Brahman (B)	**	NS	NS	**	+	**
Calving Season (S)	**	**	**	**	**	NS
B x S	+	NS	NS	**	NS	+

* P<.05
** P<.01
\+ P<.10
NS Not significant (P>.10)

TABLE VII

LEAST SQUARES MEANS AND STANDARD ERRORS FOR PUBERTY AND REPRODUCTIVE TRAITS AFFECTED (P<.10) BY THE GENOTYPE X ENVIRONMENT INTERACTION

Proportion Brahman[a]	Season of Birth					
	Spring			Fall		
	% Heat Detection	Prebreeding Cond.[b]	% Pregnant	% Heat Detection	Prebreeding Cond.	% Pregnant
0	69.2 ± 10.8[d]	6.15 ± .19[e]	86.4 ± 7[c]	78.8 ± 9.5[e]	6.03 ± .16[d]	62.9 ± 7[e]
1/4	63.9 ± 7.0[d]	5.63 ± .12[d]	97.2 ± 5[c]	31.5 ± 6.9[d]	5.64 ± .11[c,d]	37.7 ± 6[d]
1/2	50.2 ± 7.6[c]	5.20 ± .14[c]	86.8 ± 6[c]	17.8 ± 6.8[c]	5.58 ± .12[c]	13.5 ± 6[c]
Average	61.1 ± 5.8	5.66 ± .10	90.1 ± 5	42.7 ± 5.7	5.75 ± .09	38.0 ± 5

[a]Number of heifers analyzed for each trait given in Table II
[b]Condition score: 1=thin to 9=fat with 5=average
[cde]Means in the same column not sharing at least one common superscript differ (P<.05)

TABLE VIII

LEAST SQUARES MEANS AND STANDARD ERRORS FOR PUBERTY AND REPRODUCTIVE TRAITS NOT AFFECTED (P>.10) BY THE GENOTYPE X ENVIRONMENT INTERACTION

Source	Puberty[a] Age (d)	Puberty[a] Weight (kg)	Prebreeding Weight (kg)[b]
Season			
Spring	367 ± 5[c]	296 ± 5[d]	340 ± 4[d]
Fall	381 ± 5[d]	256 ± 6[c]	274 ± 4[c]
Proportion Brahman			
0	380 ± 5[c]	270 ± 6[c]	310 ± 5[c]
1/4	373 ± 4[c]	277 ± 6[c]	303 ± 4[c]
1/2	378 ± 5[c]	281 ± 5[c]	309 ± 4[c]
Average	375 ± 1	276 ± 2	307 ± 4

[a]Means based only on those heifers having attained puberty by 410 d of age (Table II)

[b]Means based on number of heifers shown in Table II

[cd]Means within each source in the same column not sharing at least one common superscript differ (P<.05)

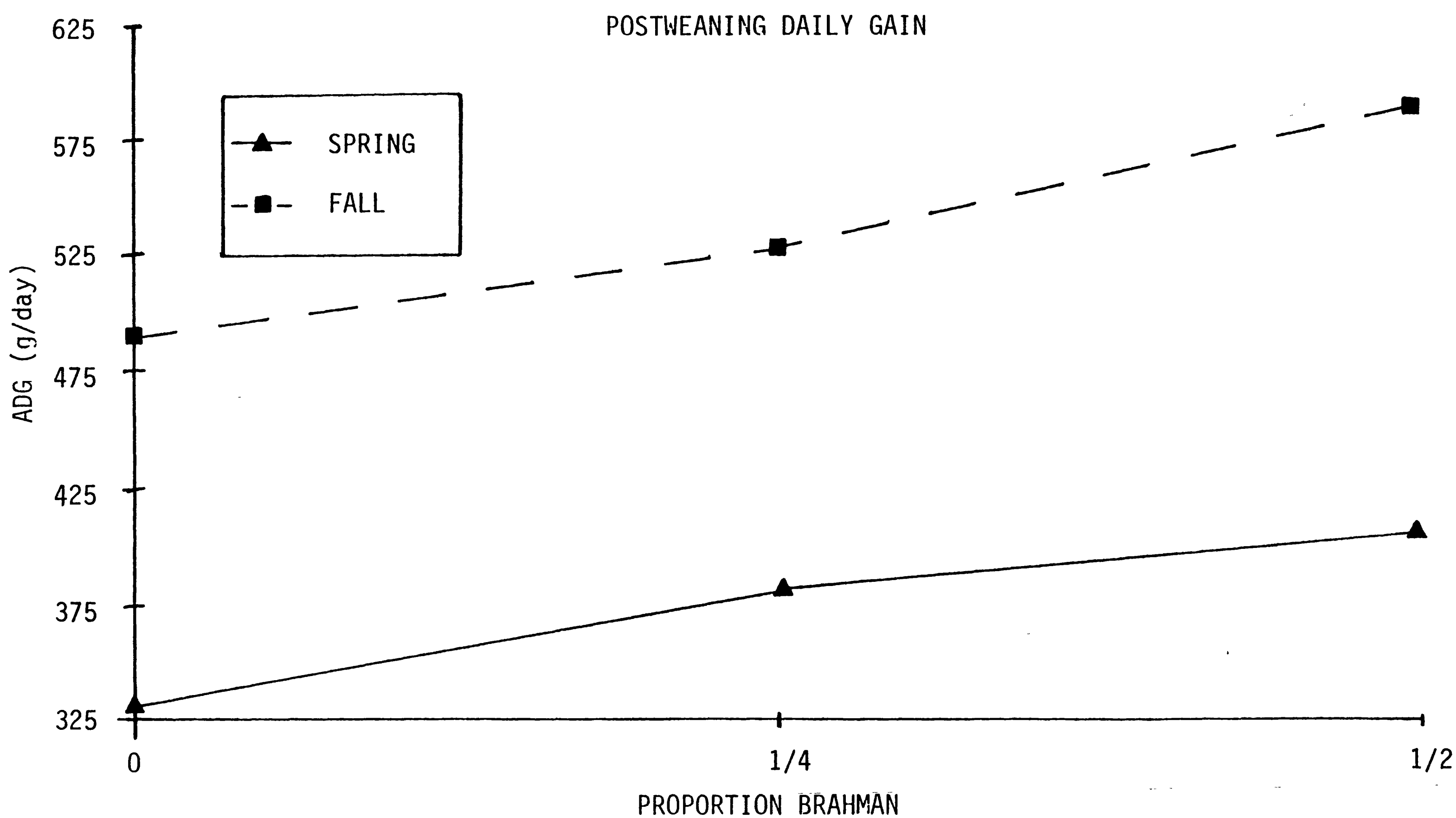

Figure 1. Postweaing Daily Gain of Heifers With Different Levels of Brahman Breeding Born in Spring and Fall

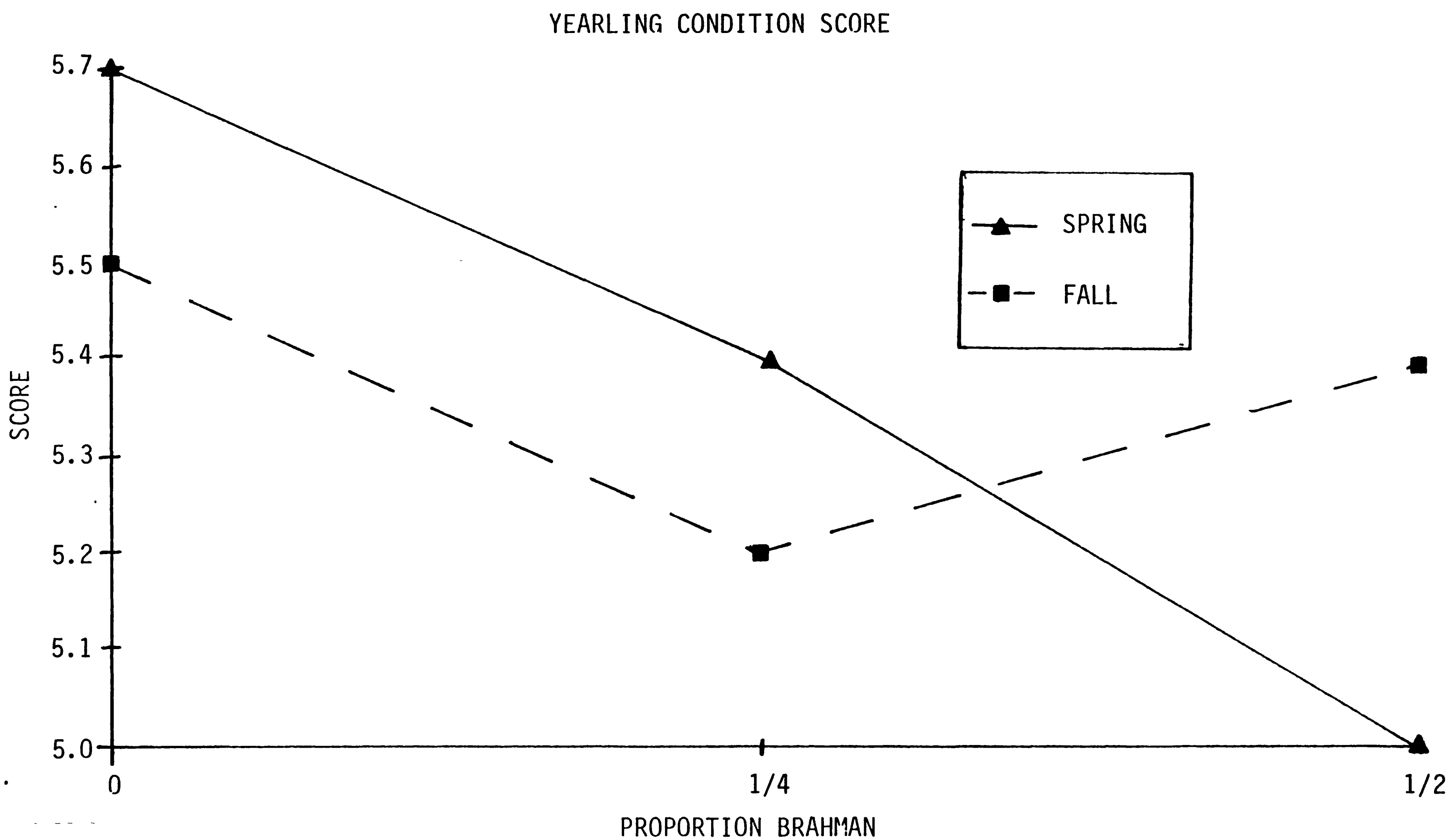

Figure 2. Yearling Condition Score of Heifers With Different Levels of Brahman Breeding Born in Spring and Fall

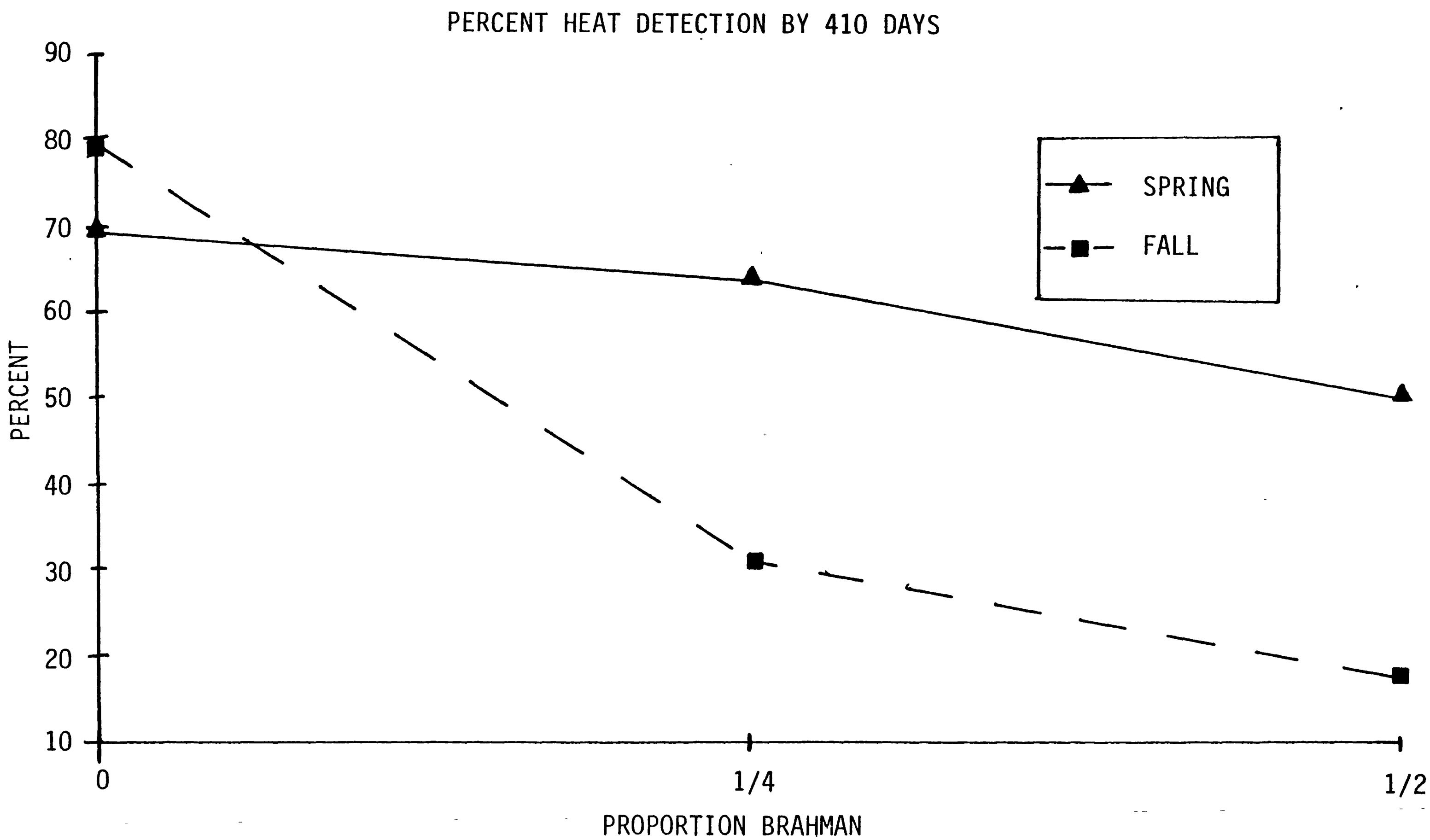

Figure 3. Percent of Heifers With Different Levels of Brahman Breeding Born in Spring and Fall Attaining Puberty by 410 Days

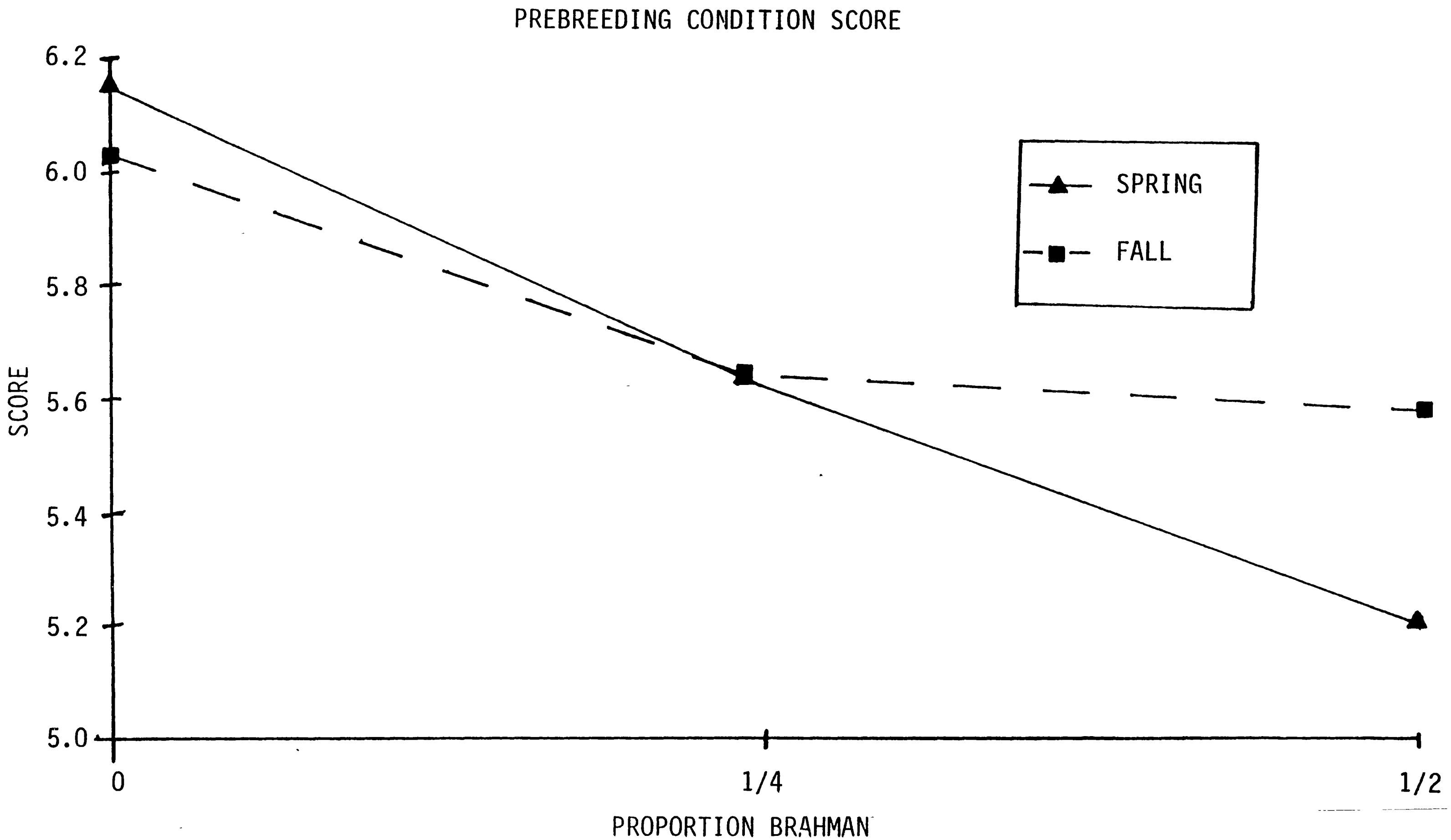

Figure 4. Prebreeding Condition Score of Heifers With Different Levels of Brahman Breeding Born in Spring and Fall

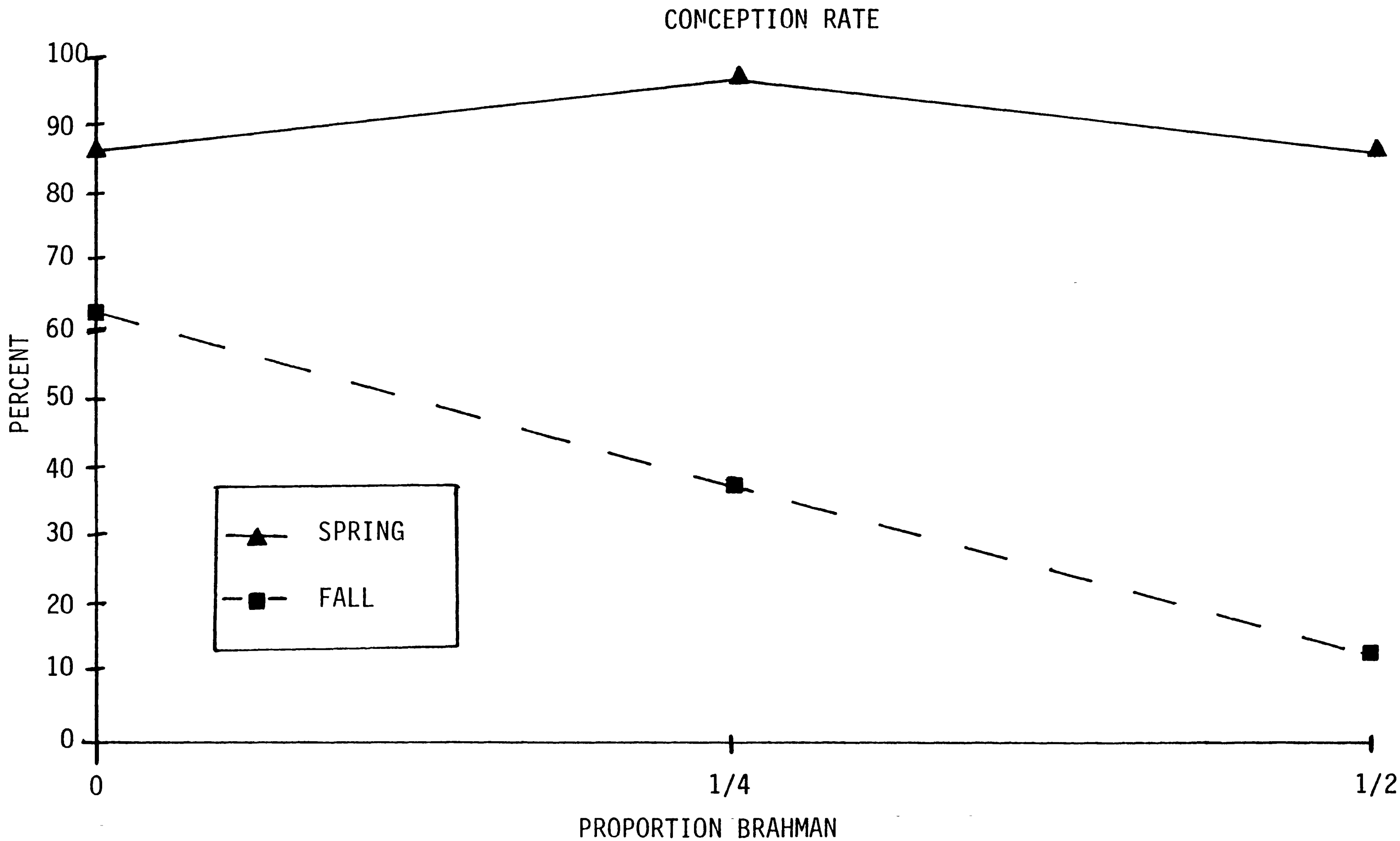

Figure 5. Conception Rate of Heifers With Different Levels of Brahman Breeding Born in Spring and Fall

Literature Cited

Aaron, D.K., R.R. Frahm and D.S. Buchanan. 1986a. Direct and correlated responses to selection for increased weaning or yearling weight in Angus cattle. I. Measure of selection applied. J. Anim Sci. 62:54.

Aaron, D.K., R.R. Frahm and D.S. Buchanan. 1986b. Direct and correlated responses to selection for increased weaning or yearling weight in Angus cattle. II. Evaluation of response. J. Anim Sci. 62:66.

Anderson, J.L. 1968. Growth of cattle in Papua and New Guinea. 1. Brahman-British crossbreds. Aust. J. Exp. Agric. Anim. Husb. 8:121.

Butts, W.T., 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.

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

Cundiff, L.V., R.M. Koch and K.E. Gregory. 1984. Characterization of biological types of cattle (Cycle III) IV. Postweaning growth and feed efficiency. J. Anim. Sci. 58:312.

Frahm, R.R., C.G. Nichols and D.S. Buchanan. 1985a. Selection for increased weaning or yearling weight in Hereford cattle. I. Measurement of selection applied. J. Anim. Sci. 60:1373.

Frahm, R.R., C.G. Nichols and D.S. Buchanan. 1985b. Selection for increased weaning or yearling weight in Hereford cattle. II. Direct and Correlated Responses. J. Anim. Sci. 60:1385.

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., D.B. Laster, L.V. Cundiff, G.M. Smith and R.M. Koch. 1979. Characterization of biological types of cattle--Cycle III: II. Growth rate and puberty in females. J. Anim. Sci. 49:461.

Long, C.R., T.S. Stewart, T.C. Cartwright and J.F. Baker. 1979. Characterization of cattle of a five breed diallel: II. Measures of size, condition and growth in heifers. J. Anim. Sci. 49:432.

Menge, A.C., S.E. Mares, W.J. Tyler and L.E. Casida. 1960. Some factors affecting age at puberty and the first 90 days of lactation in Holstein heifers. J. Dairy Sci. 43:1099.

Morgan, J.H.L. 1981. A comparison of breeds and their crosses for beef production. II. Growth and puberty of heifers. Aust. J. of Agric. Research 32:839.

Stewart, T.S., C.R. Long and T.C. Cartwright. 1980. Characterization of cattle of a five-breed diallel. III. Puberty in bulls and heifers. J. Anim. Sci. 50:808.

Young, L.D., D.B. Laster, L.V. Cundiff, G.M. Smith and K.E. Gregory. 1978. Characterization of biological types of cattle. IX. Postweaning growth and puberty of three-breed cross heifers. J. Anim. Sci. 47:843.

APPENDIX

TABLE I

SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR WEANING TRAITS

	TRAIT					
	Birth	Preweaning	Weaning			
Source	Wt.	ADG	Wt.	Ht.	Conf.	Cond.
Proportion Brahman (B)	X	X	X	X	X	X
Calving Season (S)	X	X	X	X	X	X
Year (Y)	X	X	X	X	X	X
Dam Breed (D)	X	X	X	X	X	X
Dam Age (A)	X	X	X	X	X	X
Calf Sex (X)	X	X	X	X	X	X
B x S	X	X	X	X	X	X
B x Y		X		X		X
B x D	X	X	X	X	X	X
B x X	X		X	X	X	
S x Y			X	X	X	X
S x D	X	X	X	X	X	X
S x X			X		X	
Y x D				X		X
D x X	X		X	X	X	
B x D x Y				X		X
B x D x X			X	X	X	
S x B x D	X	X	X	X	X	X
S x D x X	X					

XSouce of variation was included in reduced model

TABLE II

SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR YEARLING TRAITS

	TRAIT					
	ADG Birth-	ADG Wng-	Yearling			
Source	Yrlg	Yrlg	Wt.	Ht.	Conf.	Cond.
Proportion Brahman (B)	X	X	X	X	X	X
Calving Season (S)	X	X	X	X	X	X
Year (Y)	X	X	X	X	X	X
Dam Breed (D)	X	X	X	X	X	X
Dam Age (A)	X	X	X	X	X	X
B x S		X		X	X	X
B x Y		X		X	X	
B x D					X	
B x A		X		X	X	
S x Y	X	X	X	X	X	
S x D		X			X	
S x A				X	X	
Y x D					X	X
Y x A		X			X	
D x A					X	
B x S x Y					X	
B x S x A				X	X	
B x Y x D					X	
B x Y x A		X			X	
S x Y x A					X	
S x D x A					X	

[X] Source of variation was included in reduced model

TABLE III

SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR PUBERTY AND REPRODUCTIVE TRAITS

	TRAIT					
	% Heat	Puberty	Puberty	% Con-	Prebreeding	
Source	Detection	Age	Weight	ception	Wt.	Cond.
Proportion Brahman (B)	X	X	X	X	X	X
Calving Season (S)	X	X	X	X	X	X
Year (Y)	X	X	X	X	X	X
Dam Breed (D)	X	X	X	X	X	X
Dam Age (A)	X	X	X	X	X	X
B x S	X			X		X
B x Y						X
B x D						X
B x A						X
S x Y	X	X	X		X	X
Y x D						X
D x A				X		
B x S x Y						X
B x S x A						X
S x Y x A						X

[X]Source of variation was included in reduced model

VITA

Rebecca Christine Bolton

Candidate for the Degree of

Master of Science

Thesis: GENOTYPE X ENVIRONMENT INTERACTIONS INVOLVING LEVEL OF BRAHMAN AND SEASON OF BIRTH ON CALF GROWTH THROUGH WEANING AND POSTWEANING GROWTH AND REPRODUCTIVE PERFORMANCE OF HEIFERS

Major Field: Animal Science

Biographical:

Personal Data: Born in Tahlequah, Oklahoma, October 12, 1962, the daughter of Chris and Mary Ann Bolton.

Education: Graduated from Platte Canyon High School, Bailey, Colorado, in May, 1980; received Bachelor of Science degree from Colorado State University in 1984; completed requirements for the Master of Science degree at Oklahoma State University in December, 1986.

Professional Experience: Graduate Assistant, Oklahoma State University, Animal Science Department, 1984-86.

Professional Societies: American Society of Animal Science; Gamma Sigma Delta.