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To the Graduate Council:

I am submitting herewith a dissertation written by David C. Meyerhoeffer, entitled "A Study of Crossbreeding and Inter Se Mating of Bos taurus and Bos indicus Cattle." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Robert R. Shrode
Major Professor

We have read this dissertation
and recommend its acceptance:

Karl M. Barth

L. M. Josephson

Don O. Richardson

Will T. Butts Jr.

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

A STUDY OF CROSSBREEDING AND *INTER SE* MATING OF *BOS TAURUS* AND *BOS INDICUS* CATTLE

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

---

by

David C. Meyerhoeffer

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ABSTRACT

Records accumulated from Brahman, Angus, Africander and their crosses during the period 1934 through 1962 at the Iberia Livestock Experiment Station, Jeanerette, Louisiana, were studied to estimate heterosis, compare birth weights, weaning weights and weaning type scores of straightbred and crossbred calves and to estimate retained heterosis in inter se matings of initial crosses.

Significant differences ($P < .01$) were found between calves of Angus dams and Brangus and Brahman dams in birth weight (65.5 vs. 61.1 lbs) and weaning weight (417 vs. 449 lbs.) but not in weaning type (11.10 vs. 10.89). Also, calves of Brangus dams were significantly different ($P < .01$) from Brahman dams in birth weight (64.9 vs. 57.3), but no differences were found in weaning weight (458 vs. 440) or type at weaning (10.88 vs. 10.90) of calves from these two kinds of dams.

Angus-sired calves were significantly ($P < .01$) different in birth weight (60.6 vs. 63.8) and weaning type (11.70 vs. 10.59) from Brangus and Brahman-sired calves. They were lower in birth weight (61 vs. 64 pounds) than Brangus-sired calves and higher (61 vs. 58 pounds) than Brahman-sired calves. No significant difference was found among these three kinds of sires with respect to weaning weight of their calves.

There were no apparent differences between the birth weights of the straightbred calves and those of crossbred calves; however, the crossbreds were significantly ($P < .01$) heavier at weaning (453 vs.

409 pounds). The crosses graded lower ($P < .05$) than the straightbreds, although the average difference was small (10.91 vs. 11.04 where 1 equals 1/3 of a grade).

Heterosis was significantly ($P < .01$) greater in the first cross Angus x Brahman (including the reciprocal) than in the first cross Angus x Brangus (including the reciprocal) for both birth weight and weaning weight. It should be noted that calves out of Brahman cows and sired by Angus bulls were lighter at birth by 14 pounds but heavier by 8 pounds at weaning than calves from the reciprocal of this mating. The same effect was evident in the Angus-sired calves from Brangus cows.

Inter se mated Brangus progeny averaged 64 pounds in birth weight, 448 pounds in weaning weight or 59 pounds above the average of the parental straightbreds and 6 pounds below the average of first crosses. These figures indicate a retention of about 90 percent of the heterotic effect after approximately two complete generations of inter se mating, when measured as the ratio of the deviation of these means above contemporaries of the breeds which formed the hybrid to the corresponding deviations of the first cross of the parental breeds. Inter se mated Africander-Angus progeny weighed 63 pounds at birth and 404 pounds at weaning and graded slightly lower at weaning than the average of all calves. These calves were similar in weight at weaning to Angus calves but graded somewhat lower. Progeny from Africander-Angus cows mated to Angus bulls were heaviest of the crosses including Africander or Africander-Angus at both birth and weaning (74 and 449 pounds) but graded lower by approximately one-third of a grade.

When simple averages were used, the crosses to Angus and Brahman sires showed heterotic responses also.

Africander-Angus females mated to Brahman sires had progeny which weighed 63 pounds at birth and 417 pounds at weaning and graded 11+ at weaning.

A small group of Brahman cows bred to Africander males had calves weighing 66 pounds when born and 414 pounds at weaning, about the same as progeny from Africander-Angus cows mated to Brahman sires.

These data indicate that crossbreeding and the increased weights at weaning time are advantageous to the producer. This is especially true for the producer of calves to be slaughtered at light weights in the Gulf Coast area for local consumption.

The analyses showed significant heterosis in most crosses with the most pronounced effect in first crosses and a retention of an appreciable amount of heterosis by the second generation produced from inter se matings of crossbreds.

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CHAPTER I

INTRODUCTION

The commercial beef industry in the Gulf Coast area of the United States consists primarily of cow-calf operations. These herds are in many instances an enterprise secondary to sugarcane, rice, soybeans or some other cash crop. Herds may be found in Louisiana to be composed of purebreds, purebreds and crossbreds, all crossbreds and graded-up native cows. Most of the crossbreds contain some percentage of Brahman and one or more of the British breeds. Generally, calves are weaned and sold from these herds as feeders and for stockers. The economic value of these calves is usually determined by their weight and quality at weaning time when they are marketed. A large number of calves are slaughtered in the Louisiana Gulf Coast area at weights varying from 450 to 550 pounds for local consumption.

Practical methods or systems to allow maximum utilization of crossbreeding and to implement its advantages are needed. The two basic reasons for crossing are: (1) to obtain hybrid vigor or heterosis, and (2) to combine the strong points of the different breeds.

One objective of beef cattle research is to devise methods and systems of breeding and selection which can be used effectively to increase efficiency and economy of production in various environmental situations. Low reproductive rates and long generation interval make for slow progress in making genetic changes by selection.

Early work at the Iberia Livestock Experiment Station consisted of crossing the purebred heat-resistant Brahman and Africander cattle with Angus which is one of the so-called standard beef breeds. The Angus, as a rule, are not well adapted to the coastal area and usually do not attain satisfactory size, while the Brahman and Africander do not, as a rule, finish as early or have as desirable beef carcasses.

The Brahman and Africander cattle are of the species Bos indicus and generally exhibit conformation showing long, narrow heads, a hump at the withers (varying degrees), high shoulders, straight, long ribs and narrow hips. The skin has more pigmentation and is looser than that of the Angus cattle. The hair is short, smooth and may be of various colors.

A great deal of interest has been shown in recent years in beef cattle crossing, both between similar breeds and between very unlike breeds.

The purposes of the present study were the following: (1) to estimate heterosis from crosses among Angus, Brahman and Africander breeds with respect to birth weight, weaning weight and weaning conformation score; (2) to compare the performance to weaning of two kinds of Bos indicus in a similar cross when managed alike and grown in the same environment; (3) to estimate the amount of retained heterosis in inter se matings of initial crosses.

CHAPTER II

REVIEW OF LITERATURE

A number of studies have been conducted with beef cattle in recent years to estimate the economic consequences of crossbreeding. Several studies have been conducted using crosses between the British breeds (i. e., Angus, Hereford, Shorthorn). Others have utilized the Brahman and one or more of the British breeds. An early report, Rhoad and Black (1943), indicates that Brahman cattle were used extensively in Texas and Louisiana to cross with range cattle to obtain a hardy fast-growing type of animal that would fatten on pasture and be adapted to the adverse conditions of the Gulf coast.

Gaines et al. (1966) in Phase I of a two-phase study of British vs. British crossbreds showed a distinct advantage in livability of the crossbred calf. Calves were born to 85 percent of the cows mated to bulls of their own breed compared to 93 percent for those in two-breed crosses, 89 percent in three-breed crosses and 93 percent in backcross matings. They reported also that calf losses at or within 36 hours of birth were higher for straightbreds (7 vs. 4 percent). They found 76, 88, 84 and 87 percent weaned, respectively, for straightbred, two-breed, three-breed and backcross matings, or an advantage of 10 more calves weaned per 100 cows bred in favor of the crossbreds. They concluded that fertility and livability are heterotic traits in cattle of the British beef breeds and that percent calf crop may be the most important advantage of crossbreeding.

Donald, Russell and Taylor (1962) found highly significant maternal influences but no heterosis in birth weights of reciprocal crosses among the Ayrshire, British Friesian and Jersey breeds and are therefore somewhat at variance with work reported by Gaines et al. (1966).

In a Louisiana study where 24 different crossbred types of cattle were produced over a five-year period, Damon, McCraine and Crown (1957) found that calves raised by Brahman-Angus and Brahman cows were considerably heavier than those raised by Angus and Hereford cows.

Chapman, Clyburn and McCormick (1970) found crossbred calves to be significantly superior to straightbred calves in weaning weight, average daily gain and slaughter score in two consecutive generations. They showed estimates of heterosis (superiority over the mid-parent) ranging from 3.25 to 7.37 percent for weaning weight and slaughter score.

It has been reported by Gregory et al. (1965) that crosses were generally superior in birth weight, weaning weight, average daily gain and weaning conformation score and that these traits exhibited significant heterotic effects as well.

Kincaid (1962) reported that calves from Hereford and from British-Brahman crossbred cows were similar in birth weight and were consistently heavier at weaning than calves from Brahman cows and sired by Brahman bulls. A number of others, including Cartwright, Butler and Cover (1958), Baker and Black (1950) and Kidder and Chapman (1952), have reported some degree of heterosis for birth weight.

Ellis, Cartwright and Kruse (1965) found 10.8 percent heterosis for birth weight in firstcross Brahman x Hereford calves, 5.5 percent for backcross calves from firstcross cows, 8.2 percent for backcross calves by firstcross bulls mated to purebred cows and 2 percent for calves from F_1 cows mated to F_1 bulls.

Ohio workers Gerlaugh, Kunkle and Rife (1951) found crosses between Angus bulls and Hereford cows to result in short gestation periods, lighter birth weights, less calving trouble, heavier weaning weights and more rapid gains in the feed lot as compared to straight-bred Angus or Hereford or Hereford bulls bred to Angus cows.

Black (1935) reported that the popular breeds of cattle--Angus, Hereford and Shorthorn--do not fully meet the requirements of the extreme South, particularly the Gulf Coast area, owing primarily to their low tolerance to the climate. He stated that experimental data showed part-Brahman calves to be 91 pounds heavier at weaning time than highly bred calves of British breeds under the same conditions.

Cundiff (1970) concluded that the major benefit from crossing British breeds would be the cumulative effects of heterosis on fertility, maternal ability and growth rate. He concluded also that the Brahman and British breeds complement each other for a number of production traits and express heterosis to a higher degree than has been observed in crosses between any other breeds.

Lush et al. (1930) reported the results of 9 years of cross-breeding work under Texas range conditions. They found that Brahman-Hereford cows raised considerably heavier calves than did Brahman or Hereford cows when all three types of cows were bred to Hereford bulls.

Baker and Black (1950) reported that Brahman x Angus calves averaged 57 pounds heavier at weaning than purebred Angus calves, and that Africander x Angus calves also were superior to the purebred Angus calves in this trait.

In Florida work, Kidder and Chapman (1952) found that calves from Brahman x Angus and Brahman x Devon and from the reciprocals of these crosses were heavier in birth weight and higher in weight gains than purebred calves of these breeds.

In most cattle research, heterosis has been measured as a deviation from the average of the straightbreds. Crosses have averaged 8 to 12 percent more calves per cow bred. They have been 5 to 9 percent heavier at weaning time and have shown 3 to 4 percent advantage over the straightbred average for growth. Heifers have generally reached first heat at younger ages.

In experimental herds the breeding season is limited, and age difference at weaning usually varies from 75 to 120 days. Reynolds et al. (1963) indicated that the differences due to age of calves born in the same season was small. In most experimental work, rate of gain from birth to weaning has been essentially linear in herds where breeding season and, consequently, calving season have been limited to 75 to 120 days as reported by Koch, Schleicher and Anthaud (1955); Marlowe and Gaines (1958); Swiger et al. (1962) and Brinks et al. (1961).

South Carolina researchers (Godbey et al., 1959) reported that Brahman x Angus calves were heaviest (86.6 pounds) and Angus calves lightest (68.9 pounds) at birth among crosses and breeds they studied.

They found no significant difference in birth weight among Hereford x Angus (76.5 pounds), Hereford (78.0 pounds), Angus x Hereford (77.2 pounds) and Brahman x Hereford (78.3 pounds). Crosses were found to be significantly heavier than purebreds in each case with the 210-day weight of Brahman x Angus calves being 567.79 pounds and that of Hereford x Angus calves, 561.53 pounds, respectively.

Turner and McDonald (1969) reported a study of various straightbreds, single crosses, backcrosses and three-breed crosses, and found year, breed of sire and mating type of calf to be significant sources of variation. Also, the three-breed cross calves were generally found to be superior for all traits while the effect of breed of sire varied with each trait. Gaines et al. (1966) reported genetic advantages of backcrosses and three-breed crosses independent of any maternal effects of crossbred dams by using crossbred bulls, thus indicating heterosis in the cow to be independent of heterosis in the calf.

Bray (1933) in a Louisiana study found half-Brahman calves to weigh considerably more at weaning than Angus or Hereford calves when treated as nearly alike as possible in the University herd.

White, Eisen and Legates (1970), working with mice, found no significant heterosis in crosses and reciprocal crosses in preweaning traits. They did find significant heterosis for postweaning gain and weight. This is contrary to the findings of Kidwell and Nash (1964) and Carmon (1963) who showed significant heterosis for preweaning traits in crosses of inbred lines of mice. However, Kidwell et al. (1960) found heterosis for weight in rats to be significant at 70 days

but not at 28 days. Chambers and Whatley (1951), in a swine study, found heterosis for growth to increase subsequent to weaning.

Wiltbank (1971) used two methods of comparison to study reproductive performance: (1) comparison of crossbred females with straightbred females of each breed going into the cross and (2) comparison of crossbred females with the average of the two breeds making up the cross. His data indicated a heterotic effect on reproductive performance when European breeds of cattle are crossed. Crossbred heifers reached puberty at an earlier age than straightbred heifers when both were wintered at low levels (to gain one-half pound per day). There was a greater percent survival of crossbred calves from birth to weaning, and cows carrying crossbred calves usually completed a successful pregnancy. A larger percentage of crossbred cows conceived at first service, gave birth to a calf and weaned a calf than did straightbred cows. It was shown also that a larger percentage of straightbred cows carrying crossbred calves weaned a calf than of cows carrying straightbred calves. This was the result of a greater survival of the crossbred calf from birth to weaning and of more cows carrying crossbred calves completing a successful pregnancy.

Rotational crossbreeding in a Montana experiment, Knapp, Baker and Clark (1949), using three breeds--Angus, Hereford and Shorthorn--was compared with purebreeding of Herefords. Shorthorn bulls were bred to Hereford cows; the resulting crossbred heifers were bred to Angus bulls; and the three-breed-cross heifers were bred back to Hereford bulls. First, second and third generation crossbred steer calves were 20, 50 and 79 pounds heavier at weaning than the respective

purebreds. First, second and third generation crossbred heifers were 5, 39 and 71 pounds heavier than the comparable purebreds at weaning. These results indicate a considerable advantage for crossbreds over purebreds, especially in the second and third generations. These results are in agreement with Virginia work (Gaines et al., 1966) in which two- and three-breed crosses as well as backcrosses were superior in weaning weight to the purebreds or straightbreds.

Brinks et al. (1967) reported heterosis in preweaning traits, with greater heterosis in gain and weaning weight than in birth weight or weaning score. They also showed more heterosis for heifer calves than for bull calves in these traits.

Tables I, II, III and IV, adapted from Warwick (1952), contain a summary of results concerning various preweaning traits that exhibit heterosis.

Table I (Warwick, 1952) shows a summary of results before 1945 and after 1945 with respect to weanling traits of calves from British type dams when bred straight and when crossed to Brahman bulls. Prior to 1945, the crosses exhibited two pounds more birth weight and were 27 pounds heavier than contemporary straightbreds at weaning. After 1945, the crosses averaged 11 pounds more at birth and were 29 pounds heavier at weaning.

Table II gives the performance of crossbred cows vs. straightbred British type cows and shows a four-pound advantage for the British cow in birth weight of calf with the crossbreds being weaned seven days older and 83 pounds heavier.

TABLE I

AVERAGE CALF PERFORMANCE TO WEANING - ALL COWS OUT OF BRITISH TYPE DAMS (WARWICK, 1952)

	Brahman x British		British x British		Difference
	No. of Calves	Avg.	No. of Calves	Avg.	Brah.-Brit.
Before 1945:					
Birth Weight (lbs.)	276	73	172	71	+ 2
Weaning Age (days)	329	199	253	201	- 2
Weaning Weight (lbs.)	329	399	253	372	+27
Since 1945:					
Birth Weight (lbs.)	386	79	278	68	+11
Average Birth Date	323	Mar. 25	159	Mar. 16	- 9 days
Weaning Age (days)	480	217	372	222	- 5
Weaning Weight (lbs.)	480	446	372	417	+29

TABLE II

CALF RAISING PERFORMANCE OF BRAHMAN X BRITISH AND BRITISH COWS (WARWICK, 1952)

	Brahman x British		British		Difference
	No.	Avg.	No.	Avg.	Brah.-Brit.
Birth Weight (lbs.)	253	64	255	68	- 4
Weaning Age (days)	289	207	309	200	+ 7
Weaning Weight (lbs.)	289	456	309	373	+83

TABLE III

WEIGHTS (LBS.) OF 1/4 BRAHMAN CALVES PRODUCED BY RECIPROCAL CROSSES (WARWICK, 1952)

	No. of Animals		
	British Bull x 1/2 Brah. Cows	1/2 Brah. Bull x Brit. Cows	Advantage-Calves from Crossbred Cows
Birth	54	42	-1.2
Weaning	75	75	67.4

TABLE IV

AVERAGE WEIGHTS (LBS.) OF DEVON AND BRAHMAN CATTLE AND OF CROSSES BETWEEN THEM (WARWICK, 1952)

Age	Devon		Brahman		F_1	
	No.	Avg. Wt.	No.	Avg. Wt.	No.	Avg. Wt.
Birth	66	62	22	54	85	73
6 Months	62	338	20	350	77	398
12 Months	49	481	19	520	67	597

	Advantages of F_1 Over:	
	Avg. of Parental Breeds	Best Parental Breed
Birth	15	11
6 Months	54	48
12 Months	98	77

Table III shows that one-quarter Brahman calves produced by reciprocal crosses were lighter at birth by 1.2 pounds and 67.4 pounds heavier at weaning time. These results are similar to those found throughout the literature by researchers in more recent experiments.

Warwick (1952) reported also on Devon, Brahman and the F_1 crosses between them. Table IV gives these results and shows the F_1 to be superior in weight to either parent at birth, at six months and at a year of age.

A summary by Warwick (1968) indicates that Brahmans are lower in calf crop weaned than British cows (Table V), and that crossbred dams are superior to either Brahman or British cows when bred to sires of either type. Cartwright et al. (1964) reported this same phenomenon and attributed it to lower calving rate and lower survival from birth to weaning in pure Brahmans.

Calving rate as reported in six independent studies and summarized by Warwick (1968), was 1.3 percent higher in crosses. Survival of crossbred calves was higher in all six experiments reported and the average advantage was 3 percent. In five of the six experiments, calf crops weaned were greater for the crossbred. Weaning weight of crossbred calves was superior to that of straightbreds in 12 of 13 experiments summarized by Warwick (1968) with a weighted average advantage of 4.9 percent.

Only a few experiments have been reported using breeds recently introduced or recently developed. Damon et al. (1959a,b; 1960) reported that calves sired by Brangus (based on cross of Brahman and Angus) bulls were lighter at weaning than those sired by Charolais and Hereford bulls

TABLE V

BRAHMAN-BRITISH CROSSBREEDING - CALF CROP WEANED EXPRESSED AS DEVIATIONS FROM BRITISH AVERAGES (WARWICK, 1968)

	Dams		
Sires	British	Brahman British	Brahman
British	0	+7.6%	-12.3%
Brahman	-2.9%	+3.9%	-17.3%

and slightly lighter than those sired by Shorthorn and Brahman. However, Brangus cows weaned heavier calves than Angus, Hereford or Brahman cows when bred to bulls of the same six breeds. They reported heterosis for weaning weight of first cross Angus-Brangus and Brahman-Brangus calves of 3.6 and 3.8 percent, respectively, and less than that of 9.7 percent in Angus-Brahman crosses.

In general, the amount of heterosis exhibited by various traits is inversely proportional to the heritability of the traits, the heterozygosity of crosses permitting expression of any non-additive effects of which the genes involved may be capable. Thus, as would be expected, heterosis is generally greater in Brahman-British crosses than in crosses of the British breeds as a result of the greater heterozygosis of the Brahman-British crosses.

CHAPTER III

MATERIALS AND METHODS

I. SOURCE OF DATA

Data used in this study were taken from the birth-to-weaning records of 2,708 calves born at the Iberia Livestock Experiment Station between 1934 and 1962. Breeding investigations have been conducted using Angus, Brahman and Africander since 1932 with the objective of developing strains of cattle that "breed true" for good beef conformation, have high fertility and utilize feed efficiently. The early phases of this work were reported by Baker and Black in 1950. A later segment of the research was reported by Vernon, Harvey and Warwick (1964). The Angus in this study were obtained primarily from Louisiana breeders and formed the foundation herd for the crossing scheme (Fig. 1). Additional Angus females were purchased in 1952 and 1953. The Brahman bulls were purchased from Texas breeders and were considered to be of excellent breed type. The Africander bulls also were purchased from a Texas breeder.

II. DESCRIPTION OF DATA

Most of the foundation cows were Angus, but a few purebred Brahman foundation cows were used. All herd sires were of pure Angus, American Brahman and Africander breeding.

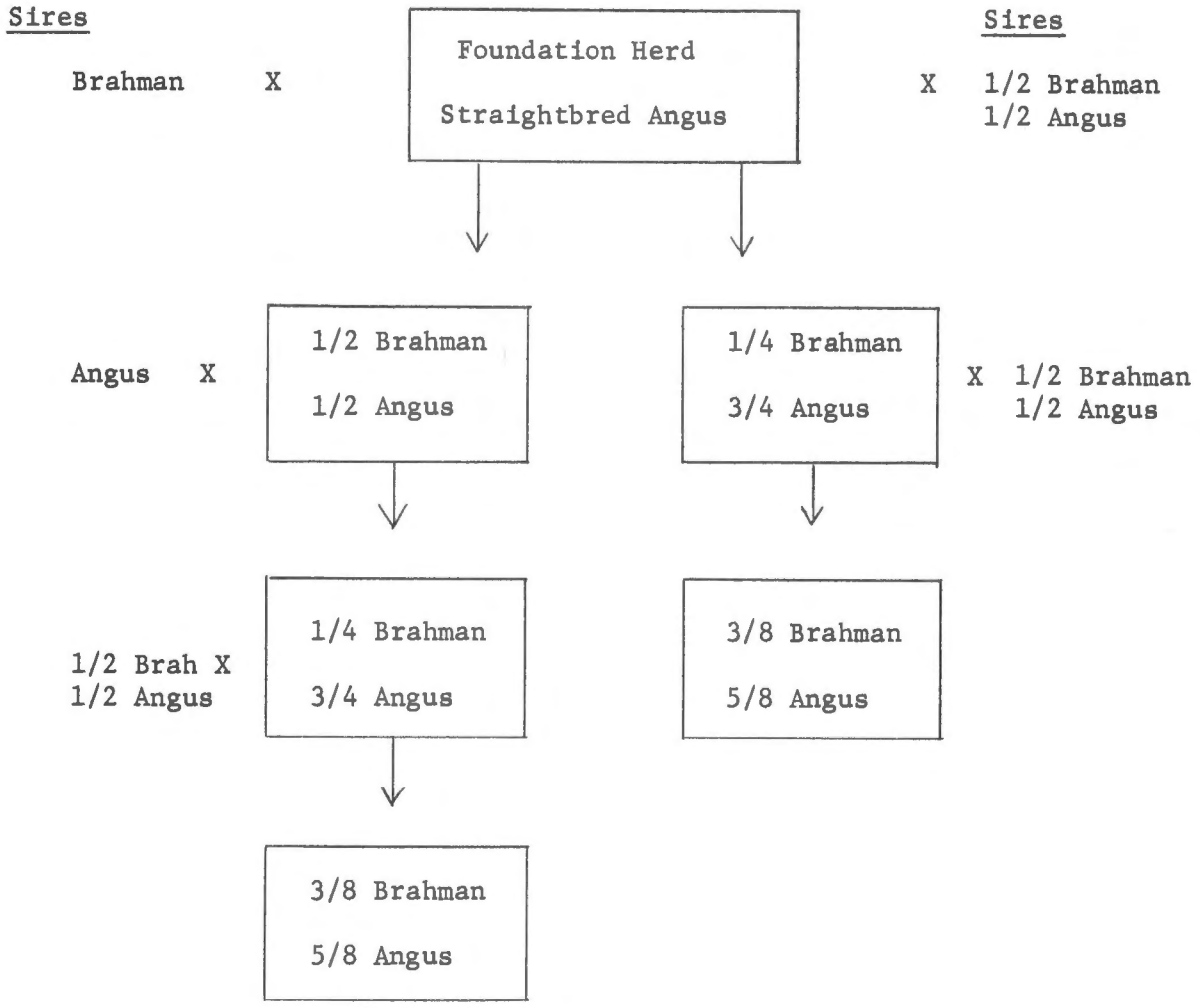


Figure 1. Breeding scheme adapted from Baker and Black (1950).

This scheme shows how early breeding at the Iberia Livestock Experiment Station was used in developing the cattle used in this study. Some of these cattle are registered with the Brangus Association and others are known as Brangus at the station.

Breeding seasons varied from 75 to 120 days in length during the period covered by this study. From 1949 through 1962, the breeding season varied from 75 to 90 days in length. In most years, the calving season began in late December and concluded in early April. Calf weights were recorded at 14-day intervals, beginning the week the oldest calf was 180 days old and continuing until the youngest calf reached that age, at which time all calves were weaned.

From 1934 through 1952, all bull calves were subjectively scored for conformation or type at 140 days of age, where the grading system used was 17-15 fancy; 14-12 choice; 11-9 good; 8-6 medium; and 5-3 cull. Those calves not selected as prospective sires were castrated. After 1952 all bull calves were left intact until weaning. Heifers generally were placed in the breeding herds when two years of age. However, a few well-developed heifers that weighed 600 pounds as yearlings were bred as yearlings. A few extremely light and unthrifty heifers were marketed in some years, but generally, all others were kept as replacements.

Management of the herds and research objectives were changed in the early 1960's, and, therefore, the present study was based on records obtained through 1962. Variables subjected to analysis were birth weight, weaning weight and weaning type score.

III. METHOD OF ANALYSIS

Separate preliminary least-squares analyses were run for the nine breed and breed-cross groups to estimate the effects of year, age of dam and sex, independent of breed.

Upon inspection of these analyses, most of the independent variables were found to be important sources of variation. Year constants on the average were less with respect to birth weight and considerably more with respect to weaning weight. The constants for age of dam were small for birth weight except for calves of two-year olds which weighed more than 10 pounds less than the average. Age-of-dam constants showed age of dam also to be an important source of variation in weaning weight.

It was decided that rather than try to pool these results, it would be desirable to combine the data into two major analyses where year group, breed group, age of dam, year within year group, sex within year group, breeding within breed group and the regression of weaning weight on calf age and on the square and cube of calf age could be estimated.

The two models chosen for analysis of the combined data are as follows:

MODEL 1 - BIRTH WEIGHT

$$Y_{ijklmno} = \mu + T_i + S_j + G_k + A_l + M_m + C_{kn} + e_{ijklmno}$$

μ = the general mean

T_i = year effect (i = 34-62)

S_j = effect of sex (j = 1,2; 1 = male, 2 = female)

G_k = effect of breed group (k = 1,2; 1 = A,B,BA; 2 = A,B,AF,AFA)

A_l = effect of age of dam (l = 1,2,3,4,5 years)

M_m = effect of month of birth (m = 1,2,3)

C_{kn} = effect of breed (n within k; individual breed in breed group)

$e_{ijklmno}$ = random error

MODEL 2 - WEANING WEIGHT AND WEANING TYPE

$$Y_{ijklmnop} = \mu + G_i + B_j + A_k + T_l + S_{im} + C_{jo} + b_1 (X-\bar{X}) + b_2 (X^2-\bar{X}^2) + b_3 (X^3-\bar{X}^3) + e_{ijklmnop}$$

Where: μ = general mean

G_i = effect of year group (i = 1,2; 1934-1952, 1953-1962)

B_j = effect of breed group (j = 1,2; 1 = A,B,BA; 2 = A,B,AF, AFA)

A_k = effect of age of dam (k = 1,2,3,4,5 years)

T_l = effect of year within year group (l = 1,2; an individual year)

S_{im} = effect of sex within year group (m = 1,2,3,4,5; bull, heifer, steer, bull, heifer)

C_{jo} = effect of breeding within breed group (o = 1,2,3,4,5)

b_1 = regression on calf age

b_2 = regression on squared calf age

b_3 = regression on cubed calf age

$e_{ijklmnop}$ = random error

The two models are different due to the sex of calves present at the different ages. In the analysis of birth weights, all calves in all years and breed groups were either bulls or heifers and were treated as such in the analysis using Model 1. In this analysis, month of birth was fitted as an independent variable.

Model 2 included male calves which were castrated prior to weaning in years before 1952. No steers were represented in the data after 1952, and, therefore, sex was fitted differently in the two year groupings.

This type of analysis provided a measure of the effect of castration on steers as compared to bulls and heifers in the earlier years. It gave also a measure of the male vs. female differences in the years 1953 through 1962 when all calves were either bulls or heifers.

The effect of age of calf in Model 2 is confounded with month of birth effects. A cubic regression was fitted in an attempt to statistically remove the effect of calf age at weaning from the weanling traits.

It was desirable to partition the eight degrees of freedom for Breed Group I so that this treatment sum of squares could be used as a measure of breed differences. This was accomplished by setting up the orthogonal comparisons shown in Table VI where each breed or crossbreed is represented by a number which indicates the weight given each mean in the additive calculation of a particular orthogonal difference. These numbers total to zero by row with the sign considered.

TABLE VI

TRANSFORMATION MATRIX OF ORTHOGONAL COEFFICIENTS

Orthogonal Comparison	Breed or Crossbreed*								
	11	12	13	21	22	23	31	32	33
Angus Dams vs. Brangus and Brahman Dams	-1	-1	-1	+2	+2	+2	-1	-1	-1
Brangus Dams vs. Brahman Dams	+1	+1	+1	0	0	0	-1	-1	-1
Angus Sires vs. Brangus and Brahman Sires	-1	+2	-1	-1	+2	-1	-1	+2	-1
Brangus Sires vs. Brahman Sires	+1	0	-1	+1	0	-1	+1	0	-1
Straightbreds vs. Crossbreds	+2	-1	-1	-1	+2	-1	-1	-1	+2
Heterosis in Angus x Brangus vs. Heterosis in Angus x Brahman	-1	+1	0	+1	0	-1	0	-1	+1
Other	+1	+1	-2	+1	-2	+1	-2	+1	+1
Other	0	+1	+1	+1	0	-1	-1	-1	0

*1 = Brahman, 2 = Angus, 3 = Brangus, 11 = straight Brahman, 12 = Brahman x Angus, 13 = Brahman x Brangus, etc., the first number indicating breed of dam.

These coded figures are then used to arrive at the respective matrices from the overall analysis of variance which includes the constants of interest. Then by matrix multiplication, the sums of squares required to perform tests of significance for orthogonal contrasts were obtained by Harvey's (1960) method of transforming that segment of the inverse matrix corresponding to the set of constants in question. If T is the transformed segment of the inverse, K is the transformation matrix and Z is the square segment of the variance-covariance inverse, then it can be shown that $T = KZK'$ when the additional row and column are added. After these constants are obtained, the sums of squares for the single-degree-of-freedom orthogonal contrasts are obtained from $B'Z^{-1}B$ in the usual manner. It should be noted that the sums of squares do not add to the total sum of squares from the original analysis of variance.

The orthogonal contrasts of major interest are shown in Table VI.

CHAPTER IV

RESULTS AND DISCUSSION

I. THE EFFECTS OF VARIOUS INDEPENDENT VARIABLES ON BIRTH WEIGHT, WEANING WEIGHT AND WEANING TYPE

The overall analysis of variance (Table VII) for the independent variables shows all except breed group to be highly significant sources of variation in birth weight. Tables VIII and IX show all independent variables to be significant sources of variation in weaning weight and all but breed group to significantly influence type.

Many studies have shown the significant effect on preweaning traits that maternal and natural environment exhibit (Turner et al. 1969, Marlowe et al. 1958 and others).

Birth weight averaged 64 pounds and ranged from 58 to 70 pounds over the entire period studied. Vernon et al. (1964) in earlier work found a mean birth weight of 63.4 pounds which is in close agreement with the present study.

Average weaning weight was 429 pounds which is somewhat higher than that shown by Vernon et al. (1964) where they used 180-day weights as weaning weights. Also, they separated the Brahman-Angus and Africander-Angus groups for analysis purposes, whereas, these groups were all included in one analysis in the present study. All fitted variables were significant ($P < .01$) sources of variation in weaning weight.

TABLE VII

ANALYSIS OF VARIANCE OF BIRTH WEIGHT

Source of Variation	Degrees of Freedom	Mean Squares	F
Year	28	775.88	8.21**
Sex	1	13883.64	146.90**
Breed Group	1	344.87	3.65
Age Dam	4	4332.42	45.84**
Mo. Birth	2	4784.48	50.62**
Breed 1	8	1802.30	19.07**
Breed 2	4	648.96	6.87**
Remainder	2659	94.51	

**P < .01.

TABLE VIII

ANALYSIS OF VARIANCE OF WEANING WEIGHT

Source of Variation	Degrees of Freedom	Mean Squares	F
Year Group	1	84906.96	36.22**
Breed Group	1	23846.80	10.17**
Age of Dam	4	172610.86	73.64**
Year, within Year Group 1	18	45123.63	19.25**
Year, within Year Group 2	9	59595.48	25.43**
Sex, Year Group 1	2	321558.87	137.19**
Sex, Year Group 2	1	4890606.01	208.89**
Breed, within Breed Group 1	8	110735.41	47.25**
Breed, within Breed Group 2	4	10456.73	4.46**
Regression, Weaning Weight on Age Linear	1	1313435.63	560.38**
Regression, Weaning Weight on Age Quadratic	1	141270.81	60.27**
Regression, Weaning Weight on Age Cubic	1	52864.53	22.56**
Remainder	2656	2343.84	

**P < .01.

TABLE IX

ANALYSIS OF VARIANCE OF WEANING TYPE

Source of Variation	Degrees of Freedom	Mean Squares	F
Year Group	1	741.95	352.03**
Breed Group	1	7.33	3.48
Age of Dam	4	45.38	21.53**
Year, within Year Group 1	18	36.60	17.37
Year, within Year Group 2	9	382.10	181.29**
Sex, Year Group 1	2	120.86	57.35**
Sex, Year Group 2	1	14.95	7.09**
Breed, within Breed Group 1	8	41.06	19.48**
Breed, within Breed Group 2	4	17.89	8.49**
Regression, Weaning Type on Age of Calf Linear	1	248.45	117.88**
Regression, Weaning Type on Age of Calf Quadratic	1	14.97	7.10**
Regression, Weaning Type on Age of Calf Cubic	1	29.64	14.06**
Remainder	2656	2.11	

**P < .01.

Differences due to age of calf can be partially controlled where breeding and, consequently, calving season are limited to a shorter period. Many factors can and do contribute to the variation in weight at different ages. When this variation is not properly removed through one or a combination of the independent variables in the model, the error term is expanded accordingly. The genetic worth among animals is difficult to measure with large variation in weaning age. Age of calf is usually confounded with month of birth within a given herd. Swiger et al. (1962) reported a linear association between age and gain to 130 days of age, but a significant ($P < .05$) curvilinear relationship from 130 to 200 days.

The plotted curve of the cubic regression of weaning weight on calf age in days is shown in Figure 2 and indicates several effects of calf age on calf performance to weaning.

The most pronounced indication from the significant cubic polynomial is that both the youngest and the oldest calves grew less rapidly than those intermediate in age. Those calves weaned from 190 to 270 days of age grew almost linearly but outside this range, the curve becomes curvilinear.

It may be pointed out that month of birth was treated as an independent variable in the work of Vernon et al. (1964) but was confounded with age in this study. Their terminal weight taken at 180 days is considerably below the average weaning age of 230 days as found in this study. When these points are considered, the two studies corroborate each other with respect to calf gain at a given age.

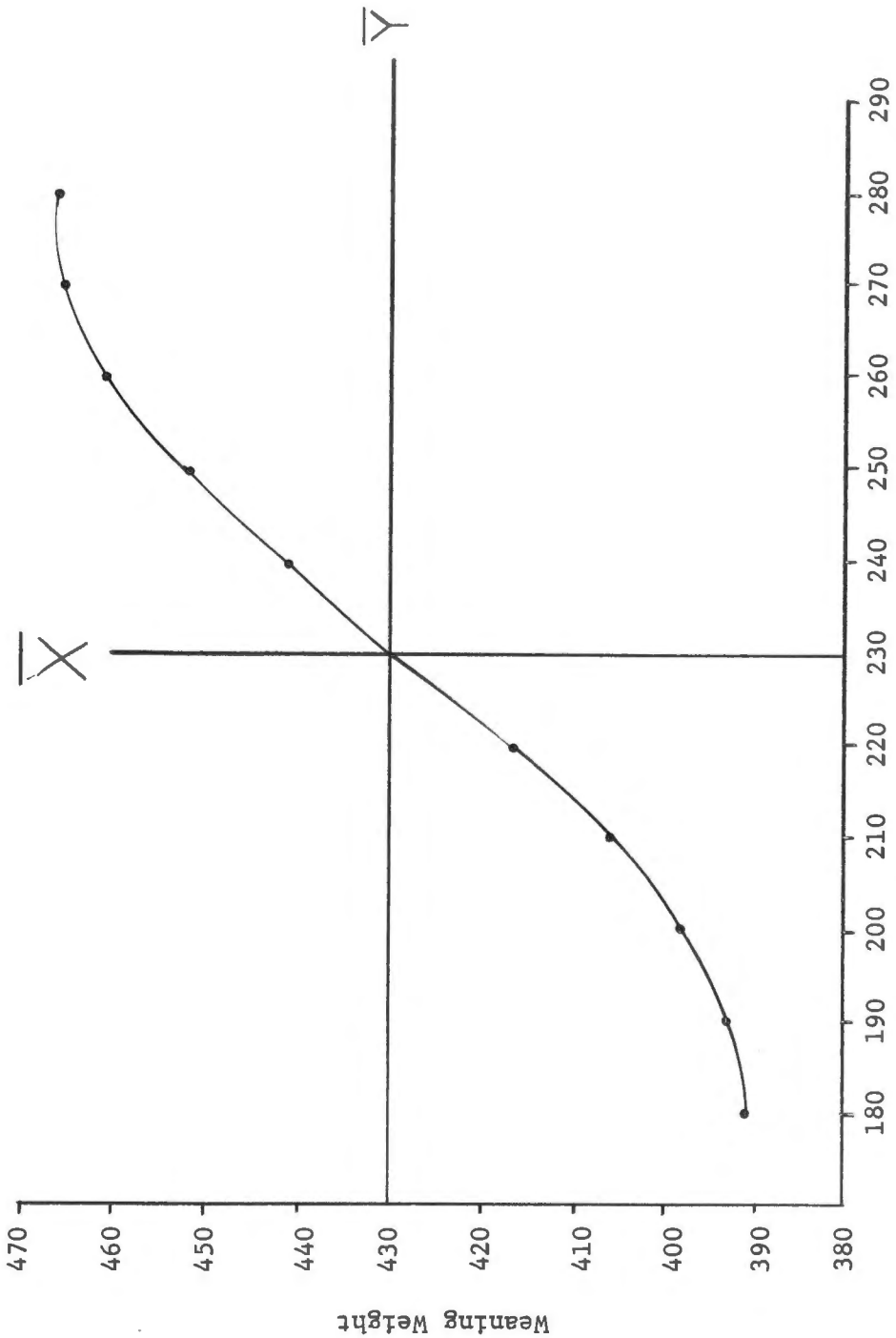


Figure 2. Growth response curve

Weaning type, on the average, was found to be 10.87 in this study which is in close agreement with the previous study where type averaged 11.0 for Brahman-Angus and 10.6 for Africander-Angus. Breed group was not a significant source of variation in weaning type, but all other effects were significant at the .01 level of probability.

Table X gives the least-squares constants, means and standard errors for straightbreds and crossbreds in this analysis. Straightbreds averaged three pounds less than crossbreds in birth weight, 33 pounds less in weaning weight and graded about the same, 10.81 vs. 10.85 at weaning time.

These results indicate that Brahman calves were lighter than Angus at birth by about 2 pounds, weighed 10 pounds more and graded two-thirds of a grade lower at weaning, on the average. These results are in agreement with previous work (Vernon et al., 1964 and Turner et al. 1969).

Brahman cows bred to Angus bulls gave birth to calves that were lighter at birth by 14 pounds, heavier at weaning by 8 pounds and which graded slightly higher than did calves from the reciprocal of this cross.

Calves from Brahman cows bred to Brangus bull were lightest at birth and heaviest at weaning of any cross in breed group one and graded one-third of a grade higher than calves from the reciprocal of this cross.

Straightbred Angus calves were lightest at weaning (384 pounds) and graded higher (12.05) than any other breed or cross.

TABLE X

BREED OR CROSSBREED LEAST-SQUARES MEANS, CONSTANTS AND STANDARD ERRORS FOR DEPENDENT VARIABLES

Breed*		Birth Weight		Weaning Weight		Weaning Type	
Female	Male	Const. ± Std. Err.	Mean	Const. ± Std. Err.	Mean	Const. ± Std. Err.	Mean
Group 1 Mean			62.9		429		10.96
B	B	-4.57 ± .88	58.4	-44.17 ± 4.28	394	- .65 ± .13	10.31
B	A	-4.35 ± 1.45	58.6	19.20 ± 7.16	458	.31 ± .21	11.28
B	BA	-8.04 ± 4.95	54.9	28.88 ± 24.86	467	.14 ± .75	11.10
A	B	9.93 ± 1.18	72.9	11.73 ± 5.87	450	- .12 ± .18	10.84
A	A	-2.31 ± .91	60.6	-54.11 ± 4.49	384	1.08 ± .13	12.05
A	BA	3.10 ± 1.33	66.0	-19.24 ± 6.68	419	- .56 ± .20	10.40
BA	B	5.31 ± 1.98	68.0	26.51 ± 9.79	465	- .85 ± .29	10.11
BA	A	- .12 ± 1.02	62.8	22.03 ± 5.16	461	.83 ± .15	11.78
BA	BA	1.03 ± .40	64.0	9.16 ± 1.81	448	- .19 ± .05	10.76
Group 2 Mean			65.3		419		10.67
B	AFA	-5.26 ± 4.22	60.0	- 9.71 ± 21.12	409	.25 ± .63	10.87
B	AF	.65 ± 1.49	65.9	- 5.27 ± 7.53	414	.02 ± .22	10.64
AFA	A	8.81 ± 2.15	74.1	30.33 ± 10.68	449	- .66 ± .32	9.95
AFA	B	-2.32 ± 1.64	63.0	- 1.43 ± 8.08	417	.88 ± .24	11.49
AFA	AFA	-1.87 ± .56	63.4	13.90 ± 2.56	404	- .49 ± .08	10.12
General Mean			64.1		429		10.78

*B = Brahman; A = Angus; BA = Brangus; AF = Africander; AFA = Africander Angus.

Generally, calves having a higher percent of Angus graded higher and had less weight for age than did other calves. These findings agree quite well with those of Vernon et al. (1964) and others.

Straight Brangus calves were intermediate in birth weight (64 pounds) and type score (10.7) but somewhat heavier at weaning (448 pounds) than either Angus (384 pounds) or Brahman (394 pounds).

Africander-Angus calves averaged 63.4 pounds at birth, 404 pounds at weaning and graded 10.12 at weaning. Breed Group 2, which consisted of crosses with Africander-Angus and Africander as well as with Brahman and Angus were small in number, and results could be misleading. No orthogonal contrasts were made in this grouping due to small numbers and empty cells in a two-way classification.

II. COMPARISON OF BREEDS AND BREED COMBINATIONS

The eight degrees of freedom associated with Breed Group 1 in the analysis pertain to Angus, Brahman, Brangus and crosses among them. These eight degrees of freedom were partitioned into single-degree-of freedom orthogonal contrasts as outlined by Harvey (1960). Differences and significance levels resulting from this treatment of the data are presented in Tables XI, XII and XIII.

Calves from Angus cows were different ($P < .01$) in their effect on birth weight and weaning weight from the progeny of either Brahman or Brangus cows but were not significantly different in weaning type. Straight Angus calves weighed 61 pounds at birth, 384 pounds at weaning and graded 12.1 or low choice in type at weaning time. Angus cows bred to Brahman bulls gave birth to calves that weighed 73 pounds at

TABLE XI

ORTHOGONAL COMPARISONS (BIRTH WEIGHT)

Comparison	Difference (lbs.)
Angus Dams vs. Brangus and Brahman Dams	(66.5-61.1)**
Brangus Dams vs. Brahman Dams	(64.9-57.3)**
Angus Sires vs. Brangus and Brahman Sires	(60.6-63.8)**
Brangus Sires vs. Brahman Sires	(61.6-66.4)**
Straightbreds vs. Crossbreds	(61.0-63.8)
Heterosis in Angus x Brangus vs. Heterosis in Angus x Brahman	(3.2%-10.1%)**

**P < .01.

TABLE XII

ORTHOGONAL COMPARISONS (WEANING WEIGHT)

Comparison	Difference (lbs.)
Angus Dams vs. Brangus and Brahman Dams	(417-449)*
Brangus Dams vs. Brahman Dams	(458-440)
Angus Sires vs. Brangus and Brahman Sires	(434-441)
Brangus Sires vs. Brahman Sires	(445-436)
Straightbreds vs. Crossbreds	(409-453)**
Heterosis in Angus x Brangus vs. Heterosis in Angus x Brahman	(5.8%-16.7%)**

*P < .05.

**P < .01.

TABLE XIII

ORTHOGONAL COMPARISONS (WEANING TYPE)

Comparison	Difference (grade)
Angus Dams vs. Brangus and Brahman Dams	(11.10-10.89)
Brangus Dams vs. Brahman Dams	(10.88-10.90)
Angus Sires vs. Brangus and Brahman Sires	(11.70-10.59)**
Brangus Sires vs. Brahman Sires	(10.75-10.42)**
Straightbreds vs. Crossbreds	(11.04-10.91)*
Heterosis in Angus x Brangus vs. Heterosis in Angus x Brahman	(2.70%-1.07%)

*P < .05.

**P < .01.

birth, 450 pounds at weaning and had a type score of 11.3 or high good. When Angus cows were bred to Brangus bulls, their progeny weighed 66 pounds at birth, 419 pounds at weaning and had a type score of 10 or middle good. These findings are in agreement with Cartwright et al. (1964) and others.

Calves from Brangus cows were found to exhibit significantly higher ($P < .01$) birth weight than calves from Brahman cows, but there was no significant difference in weaning weight or in type at weaning. Straight Brangus calves averaged 64 pounds at birth, 448 pounds at weaning and graded 10.8 in type at weaning. Calves from Brangus cows and sired by Angus bulls were born weighing 63 pounds, had attained 460 pounds at weaning and typed at 11.8 at weaning. When bred to Brahman bulls, Brangus cows had calves weighing 68 pounds at birth, 465 pounds at weaning and with a type score of 10 or average good.

Straight Brahman cows weaned calves which were 10 pounds heavier than those from straight Angus cows, and calves from Angus cows were 2 pounds heavier at birth and graded 12.0 or approximately two-thirds of a grade higher at weaning time than those from straight Brahman cows. When Brahman females were mated to Angus bulls, their calves weighed almost the same as straight Brahman calves (58.4 vs. 58.6) at birth but were much heavier (394 vs. 458) at weaning and graded one-third of a score higher. Calves out of Brahman dams and sired by Brangus bulls were lighter at birth (55 pounds vs. 59 pounds) but weighed more at weaning (467 pounds vs. 458 pounds) than did the Angus-sired calves.

There were significant differences ($P < .01$) in birth weight and type at weaning between Angus-sired calves and Brahman- or Brangus-sired calves. The Angus-sired calves were intermediate in weight at birth, only slightly different in weaning weight but graded higher in type.

Brahman-sired calves out of Angus dams were heaviest at birth ($P < .01$) of all crosses (73 pounds) in the Breed Group 1 comparisons. These calves weighed 450 pounds at weaning but were not significantly different from Angus-sired calves in weaning weight. They were significantly lower in type score at weaning than the Angus-sired calves.

When comparing straightbreds to crossbreds, no significant difference was found in weight at birth; however, the crosses were different ($P < .01$) in weight at weaning and in type score ($P < .05$). The crossbreds were heavier (409 vs. 453 pounds) at weaning and graded lower (11.04 vs. 10.91) than the straightbreds. Since 1 equals 1/3 of a type score, this difference is relatively small and, since grade is a subjective score, probably means very little.

Heterosis was found to be significantly ($P < .01$) greater in the first cross Angus x Brahman (including the reciprocal) than in the first-cross Angus x Brangus (including the reciprocal) for both birth weight and weaning weight. When calculated as the deviation above the average of the parental breeds, these figures were 9.5 percent vs. 3.3 percent for birth weight and 14.3 percent vs. 5.5 percent for weaning weight. No heterosis was shown in these crosses for type score at weaning time. Calves out of Brahman dams and sired by Angus

bulls were lighter at birth by 14 pounds but heavier by 8 pounds at weaning than the reciprocal of this cross.

The averages for straightbreds vs. crossbreds are shown in Table XIV.

TABLE XIV

COMPARISON OF STRAIGHTBREDS VS. CROSSBREDS

	Birth Weight (lbs.)	Weaning Weight (lbs.)	Weaning Type
Straightbreds	62	408	10.8
Crossbreds	65	441	10.9
Difference	+ 3	+ 33	+ .1

These figures indicate a 7.5-percent increase in weaning weight for crossbreds over straightbreds and 4.7-percent increase in birth weight with practically no difference in weaning type. It is of interest to compare these figures to the findings of other workers. Cartwright et al. (1964) observed 3 to 5 percent heterosis for weaning weight in British crosses when Brahman sires were mated to British-breed dams. Gregory et al. (1965) found heterotic effects in British crosses for birth weight, average daily gain, weaning weight and weaning conformation score. Ellis et al. (1965) found 10.8 percent heterosis for firstcross calves, 5.5 percent for backcross calves from firstcross

cows, 8.2 percent for backcross calves from purebred cows and 2.0 percent for F_2 calves. Warwick (1968) reported an 11-percent advantage in weaning weight of calves from crossbred British-Brahman dams. Most authors have reported heterosis in weaning weight of firstcross calves and calves from crossbred cows. The findings of this study are in general agreement as indicated in Table XIV.

Brangus progeny from inter se matings in this study averaged 64 pounds for birth weight and 448 pounds for weaning weight. They were 59 pounds heavier than the average of the straightbred averages and 6 pounds lighter in weaning weight than the average of the first crosses. There were 1,416 of these calves with complete records that could be used to estimate differences in weights.

These figures indicate that after at least two generations of inter se mating, approximately 90 percent of the heterotic effect for weight still prevails. This estimate was obtained as the ratio of the difference between the Brangus and the average of the parental breeds to the difference between the first cross and the average of the parental breeds. The Brangus average was 13.2 percent above the average of the parental breeds and 1.1 percent below that of the first cross.

Breed Group 2 in this analysis consisted of Africander-Angus, straight Africander and crosses of these. No straightbred Angus or Brahman dams were in this group, and numbers of Angus and Brahman crossbred-sired calves were small. Africander-Angus mated inter se had the largest number of calves in this group with 514 calves having complete records. Due to the small numbers and empty cells, no

further statistical analysis was attempted on these data; however, some worthwhile observations can be made on the basis of the overall analysis.

Straight Africander-Angus when mated *inter se* produced calves averaging 63 pounds at birth, 417 pounds at weaning and with a type score of 11.5. Progeny from mating Africander-Angus dams to Angus sires were heavier at birth (74 pounds) and weaning (449 pounds) but graded slightly lower in type.

Calves by Africander-Angus sires and out of Brahman dams had an average birth weight of 60 pounds, an average weaning weight of 409 pounds and an average type score of 10.87 or nearly a high good grade.

Calves from Brahman cows and sired by straightbred Africander bulls averaged 66 pounds, 414 pounds and 10.64 for birth weight, weaning weight and type score, respectively. Since there probably are no longer any straight Africander cattle in this country, the above comparisons may be only of academic interest.

Africander-Angus cows when bred to Angus sires had calves which were heavier at birth (74 vs. 63 pounds) than when bred to Brahman sires. Also, the Africander-Angus x Angus calves averaged heavier at weaning time by 32 pounds than calves sired by Brahman bulls and from the same kind of cows.

The investigations of others are substantiated by the findings of this study relative to gain of calves from birth to weaning from various crosses between *Bos taurus* and *Bos indicus* cattle. Heterosis is evident in birth weight, but much more pronounced in weaning weight.

A relatively large amount of heterosis or hybrid vigor is retained through several generations and theoretically should remain for relatively long periods of inter se mating.

From 1953 through 1957, the average price of calves sold through Louisiana markets for slaughter, grading good and choice, averaged $18.52 or $3.00 per hundred weight above the average of all calves sold. From 1959 through 1963, the average price for these kinds of calves was $25.25 and $2.00 per hundred weight more than prices paid on the average for all calves excluding stockers.

These figures indicate that heavier calves which graded the same, as they did in this study, would bring more return when marketed for slaughter.

For example, a calf weighing 33 pounds more at weaning (see Table XIV, page 39) if sold on the slaughter market would have returned $1.00 per hundred weight more on the 1953 through 1957 market and about $0.60 more on the 1959 through 1963 market. This would make a 500-pound calf be worth $3.00 to $5.00 more per head.

These figures are based on actual market prices received in Louisiana. No cost figures are available on the production of various kinds of calves in Louisiana; however, the information would be valuable. Therefore, in the reasoning verbalized above, the assumption has been made that these production costs are comparable which may or may not be true. Of course, crossbreeding in a well planned program can augment herd income considerably simply as a result of yielding more marketable calves because of the generally well established improvement in

reproduction and livability which can be realized from crossbreeding. This is in addition to the increased average return from individual calves discussed above.

CHAPTER V

SUMMARY

Records accumulated from Brahman, Angus, Africander and their crosses during the period 1934 through 1962 at the Iberia Livestock Experiment Statsion, Jeanerette, Louisiana, were studied to estimate heterosis, compare birth weights, weaning weights and weaning type scores of straightbred and crossbred calves and to estimate retained heterosis in inter se mating of initial crosses.

Significant differences ($P < .01$) were found between calves of Angus dams and Brangus and Brahman dams in birth weight (65.5 vs. 61.1 lbs.) and weaning weight (417 vs. 449) but not in weaning type (11.10 vs. 10.89). Also calves of Brangus dams were significantly different ($P < .01$) from Brahman dams in birth weight (64.9 vs. 57.3) but no differences were found in weaning weight (458 vs. 440) or type at weaning (10.88 vs. 10.90) of calves from these two kinds of dams.

Angus-sired calves were significantly ($P < .01$) different in birth weight (60.6 vs. 63.8) and weaning type (11.70 vs. 10.59) from Brangus and Brahman-sired calves. They were lower in birth weight (61 vs. 64 pounds) than Brangus-sired calves and higher (61 vs. 58 pounds) than Brahman-sired calves. No significant differences were found among these three kinds of sires with respect to weaning weight of their calves.

There were no apparent differences between the birth weights of the straightbred calves and those of crossbred calves; however, the crossbreds were significantly ($P < .01$) heavier at weaning

453 vs. 409 pounds). The crosses graded lower ($P < .05$) than the straightbreds, although the average difference was small (11.04 vs. 10.91 where 1 equals 1/3 of a grade).

Heterosis was significantly ($P < .01$) greater in the first cross Angus x Brahman (including the reciprocal) than in the first cross Angus x Brangus (including the reciprocal) for both birth weight and weaning weight. It should be noted that calves out of Brahman cows and sired by Angus bulls were lighter at birth by 14 pounds but heavier by 8 pounds at weaning than calves from the reciprocal of this mating. The same effect was evident in the Angus-sired calves from Brangus cows.

Inter se mated Brangus progeny averaged 64 pounds in birth weight, 448 pounds in weaning weight or 59 pounds above the average of the parental straightbreds and 6 pounds below the average of first crosses. These figures indicate a retention of about 90 percent of the heterotic effect; after approximately two complete generations of inter se mating when measured as the ratio of the deviation of these means above contemporaries of the breeds which formed the hybrid to the corresponding deviation of the first cross of the parental breeds. Inter se mated Africander-Angus progeny weighed 63 pounds at birth and 404 pounds at weaning and graded slightly lower at weaning than the average of all calves. These calves were similar in weight at weaning to Angus calves but graded somewhat lower. Progeny from Africander-Angus cows mated to Angus bulls were heaviest of the crosses including Africander or Africander-Angus at both birth and weaning (74 and 449 pounds) but graded lower by approximately one-third

of a grade. When simple averages were used, the crosses to Angus and Brahman sires showed heterotic responses also.

Africander-Angus females mated to Brahman sires had progeny which weighed 63 pounds at birth and 417 pounds at weaning and graded 11+ at weaning.

A small group of Brahman cows bred to Africander males had calves weighing 66 pounds when born and 414 pounds at weaning, about the same as progeny from Africander-Angus cows mated to Brahman sires.

These data indicate that crossbreeding and the increased weights at weaning time are advantageous to the producer. This is especially true for the producer of calves to be slaughtered at light weights in the Gulf Coast area for local consumption.

The analyses showed significant heterosis in most crosses with the most pronounced effect in first crosses and a retention of an appreciable amount of heterosis by the second generation produced from inter se matings of crossbreds.

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LITERATURE CITED

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APPENDIX

TABLE XV

CONSTANTS, MEANS AND STANDARD ERRORS (BIRTH WEIGHT)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
Mean	2708	64.12	64.12	0.66
YEAR 34	34	-0.62	63.50	1.92
YEAR 35	37	-2.62	61.50	1.83
YEAR 36	32	-1.43	62.69	1.89
YEAR 37	37	-2.88	61.24	1.84
YEAR 38	32	-3.85	60.27	1.89
YEAR 39	42	3.68	67.80	1.66
YEAR 40	62	1.50	65.62	1.40
YEAR 41	60	0.50	64.62	1.42
YEAR 42	45	-2.73	61.38	1.60
YEAR 43	71	-1.23	62.89	1.35
YEAR 44	66	-0.91	63.20	1.40
YEAR 45	86	4.58	68.69	1.25
YEAR 46	101	-5.92	58.20	1.22
YEAR 47	102	-4.87	59.24	1.22
YEAR 48	84	-2.45	61.67	1.30
YEAR 49	99	0.75	64.87	1.24
YEAR 50	116	0.83	64.95	1.18
YEAR 51	112	-1.65	62.47	1.17
YEAR 52	102	-0.34	63.77	1.22
YEAR 53	98	-1.15	62.97	1.23
YEAR 54	126	6.02	70.14	1.15
YEAR 55	106	4.42	68.54	1.20
YEAR 56	139	2.26	66.38	1.11
YEAR 57	155	1.85	65.97	1.07
YEAR 58	145	-2.59	61.53	1.09
YEAR 59	138	4.27	68.39	1.09
YEAR 60	155	1.86	65.98	1.00
YEAR 61	152	1.11	65.23	1.01
YEAR 62	174	1.60	65.71	0.97
SEX 1	1403	2.29	66.41	0.68
SEX 2	1305	-2.29	61.83	0.69
BRD GRP 1	2071	-1.18	62.94	0.69
BRD GRP 2	637	1.18	65.30	1.07
AGE DAM 1	575	-4.19	59.93	0.74
AGE DAM 2	417	-1.52	62.60	0.79
AGE DAM 3	712	1.75	65.86	0.72
AGE DAM 5	103	1.66	65.78	1.14
AGE DAM 4	901	2.30	66.42	0.69

TABLE XV (continued)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
MO BIR 1	926	-3.18	60.93	0.71
MO BIR 3	352	2.94	67.06	0.82
MO BIR 2	1430	0.24	64.36	0.67
BREED 1	150	-4.57	58.27	0.88
BREED 1	50	-4.35	58.59	1.45
BREED 1	4	-8.04	54.89	4.95
BREED 1	92	9.94	72.87	1.18
BREED 1	149	-2.31	60.63	0.91
BREED 1	72	3.10	66.04	1.33
BREED 1	26	5.31	68.24	1.98
BREED 1	112	-0.12	62.82	1.02
BREED 1	1416	1.03	63.96	0.40
BREED 2	6	-5.27	60.04	4.23
BREED 2	55	0.65	65.95	1.49
BREED 2	22	8.81	74.11	2.15
BREED 2	40	-2.33	62.97	1.64
BREED 2	514	-1.87	63.43	0.56

TABLE XVI

CONSTANTS, MEANS AND STANDARD ERRORS (WEANING WEIGHT)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
MU	2708	428.70	428.70	3.27
YEAR GP 1	1320	-7.54	421.16	3.41
YEAR GP 2	1388	7.54	436.24	3.59
BRD GRP 1	2071	9.88	438.58	3.46
BRD GRP 2	637	-9.88	418.82	5.35
AGE DAM 1	575	-27.21	401.48	3.72
AGE DAM 2	417	-7.54	421.16	3.95
AGE DAM 3	712	10.30	439.00	3.57
AGE DAM 5	103	9.83	438.52	5.65
AGE DAM 4	901	14.62	443.32	3.41
YR/GP 1	34	-16.24	404.91	9.52
YR/GP 1	37	-17.18	403.98	9.15
YR/GP 1	32	-0.09	421.06	9.54
YR/GP 1	37	-8.52	412.64	10.01
YR/GP 1	32	33.65	454.81	9.49
YR/GP 1	42	53.23	474.39	8.23
YR/GP 1	62	0.08	421.24	7.06
YR/GP 1	60	-33.88	387.27	7.09
YR/GP 1	45	4.64	425.80	8.03
YR/GP 1	71	12.05	433.20	6.73
YR/GP 1	66	29.27	450.43	6.96
YR/GP 1	86	11.40	432.56	6.25
YR/GP 1	101	-27.13	394.03	6.09
YR/GP 1	102	-52.18	368.98	6.09
YR/GP 1	84	-20.88	400.28	6.47
YR/GP 1	99	19.51	440.67	6.13
YR/GP 1	116	17.32	438.48	5.87
YR/GP 1	112	-20.11	401.05	5.87
YR/GP 1	102	15.06	436.22	6.03
YR/GP 2	98	21.84	458.08	6.09
YR/GP 2	126	33.85	470.09	5.65
YR/GP 2	106	11.78	448.01	5.93
YR/GP 2	139	14.45	450.69	5.48
YR/GP 2	155	-9.57	426.67	5.28
YR/GP 2	145	-39.52	396.71	5.38
YR/GP 2	138	-19.80	416.44	5.38
YR/GP 2	155	4.12	440.35	4.97
YR/GP 2	152	-4.33	431.91	5.08
YR/GP 2	174	-12.83	423.41	4.91
SEX/Y 1	278	35.84	457.00	4.30
SEX/Y 1	377	-13.20	407.96	3.97

TABLE XVI (continued)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
SEX/Y 1	665	-22.64	398.52	3.69
SEX/Y 2	748	18.99	455.22	3.81
SEX/Y 2	640	-18.99	417.25	3.84
BREED 1	150	-44.17	394.41	4.28
BREED 1	50	19.20	457.78	7.16
BREED 1	4	28.88	467.46	24.87
BREED 1	92	11.73	450.31	5.88
BREED 1	149	-54.11	384.46	4.49
BREED 1	72	-19.24	419.33	6.69
BREED 1	26	26.51	465.09	9.79
BREED 1	112	22.03	460.61	5.17
BREED 1	1416	9.16	447.74	1.81
BREED 2	6	-9.71	409.10	21.13
BREED 2	55	-5.27	413.55	7.54
BREED 2	22	30.33	449.15	10.69
BREED 2	40	-1.44	417.38	8.09
BREED 2	514	-13.90	404.91	2.56
RGRSN AGE CLF LINEAR		1.30		0.06
RGRSN AGE CLF QUAD		-0.01		0.00
RGRSN AGE CLF CUBIC		-0.00		0.00

TABLE XVII

CONSTANTS, MEANS AND STANDARD ERRORS (WEANING TYPE)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
Mean	2708	10.78	10.78	0.10
YEAR GP 1	1320	0.70	11.49	0.10
YEAR GP 2	1388	-0.70	10.08	0.11
BRD GRP 1	]071	0.17	10.96	0.10
BRD GRP 2	637	-0.17	10.61	0.16
AGE DAM 1	575	-0.45	10.33	0.11
AGE DAM 3	712	0.23	11.02	0.11
AGE DAM 5	103	0.07	10.85	0.17
AGE DAM 4	901	0.19	10.98	0.10
YR/GP 1	34	0.47	11.96	0.29
YR/GP 1	37	1.10	12.59	0.27
YR/GP 1	32	1.66	13.15	0.29
YR/GP 1	37	1.29	12.78	0.30
YR/GP 1	32	1.73	13.22	0.28
YR/GP 1	42	1.61	13.10	0.25
YR/GP 1	62	-0.45	11.04	0.21
YR/GP 1	60	-0.89	10.60	0.21
YR/GP 1	45	-1.06	10.43	0.24
YR/GP 1	71	-0.15	11.34	0.20
YR/GP 1	66	-0.07	11.42	0.21
YR/GP 1	86	-0.00	11.49	0.19
YR/GP 1	101	-0.24	11.25	0.18
YR/GP 1	102	-1.08	10.41	0.18
YR/GP 1	84	-0.57	10.91	0.19
YR/GP 1	99	-0.24	11.25	0.18
YR/GP 1	116	-0.74	10.75	0.18
YR/GP 1	112	-1.41	10.08	0.18
YR/GP 1	102	-0.96	10.53	0.18
YR/GP 2	98	2.65	12.73	0.18
YR/GP 2	126	3.56	13.64	0.17
YR/GP 2	106	-0.51	9.57	0.18
YR/GP 2	139	1.00	11.08	0.16
YR/GP 2	155	-0.90	9.18	0.16
YR/GP 2	145	-1.54	8.54	0.16
YR/GP 2	138	-1.72	8.37	0.16
YR/GP 2	155	-1.16	8.92	0.15
YR/GP 2	152	-1.16	8.92	0.15
YR/GP 2	174	-0.23	9.85	0.15

TABLE XVII (continued)

Class	No. of Obs.	Constant Estimate	Least-Squares Mean	Standard Error
SEX/Y 1	278	0.74	12.22	0.13
SEX/Y 1	377	-0.43	11.06	0.12
SEX/Y 1	665	-0.31	11.18	0.11
SEX/Y 2	748	-0.10	9.97	0.11
SEX/Y 2	640	0.10	10.18	0.12
BREED 1	150	-0.65	10.31	0.13
BREED 1	50	0.32	11.28	0.21
BREED 1	4	0.14	11.10	0.75
BREED 1	92	-0.12	10.84	0.18
BREED 1	149	1.09	12.05	0.13
BREED 1	72	-0.56	10.40	0.20
BREED 1	26	-0.85	10.11	0.29
BREED 1	112	0.83	11.78	0.15
BREED 1	1416	-0.19	10.76	0.05
BREED 2	6	0.26	10.87	0.63
BREED 2	55	0.02	10.64	0.23
BREED 2	22	-0.66	9.95	0.32
BREED 2	40	0.88	11.49	0.24
BREED 2	514	-0.49	10.12	0.08
RGRSN AGE CLF LINEAR		0.02		0.00
RGRSN AGE CLF QUAD		0.00		0.00
RGRSN AGE CLF CUBIC		0.00		0.00

VITA

David Clyde Meyerhoeffer was born in Augusta County, Virginia, February 26, 1932, the son of Clyde E. and Louella S. Meyerhoeffer. He attended Verona and New Hope elementary schools and was graduated from Wilson Memorial High School, Fisherville, Virginia, in 1949. He entered Virginia Polytechnic Institute, Blacksburg, Virginia, in 1950 and received the Bachelor of Science degree in 1954. He accepted an Instructor's position with the Virginia Agricultural Experiment Station after graduation. In January, 1955, he was called to active duty in the United States Army. He served two years as an artillery officer and in January, 1957, was honorably released from active duty and returned to the employment of the Virginia Agricultural Experiment Station at Blacksburg, Virginia. He holds a retired Captain's commission with the Army Reserve.

He received the Master of Science degree in Animal Science from the Virginia Polytechnic Institute in 1960. He was promoted to Assistant Professor in the Animal Science Department, taught and did research there until 1964 when he accepted the position of Superintendent of Iberia Livestock Experiment Station, Jeanerette, Louisiana, with the U. S. Department of Agriculture, Agricultural Research Service, Animal Science Research Division.

In August, 1969, he took leave for one year to complete the formal requirements for the Doctor of Philosophy degree in Animal Breeding and Genetics at the University of Tennessee, Knoxville, Tennessee.

In August, 1970, he returned to Iberia Livestock Experiment Station, Jeanerette, Louisiana, as Superintendent.

On September 5, 1953, the author married Barbara Crosby of Augusta County, Virginia, in that county. They have three children, Carlyle, Kent and Jane, born in 1956, 1959, 1962, respectively.

He is a member of the Baptist faith, a deacon and teacher; a member of the American Society of Animal Science, Phi Sigma, Sigma Xi, American Genetic Society, American Association for Advancement of Science, and is a charter member of the Louisiana Animal Science Association.