Breed and Heterosis Effect

in Crosses among the Angus, Brahman, and Charolais Cattle Breeds

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Institute of Food and Agricultural Sciences
University of Florida, Gainesville
F.A. Wood, Dean for Research

AUTHORS

F. M. Peacock, M. Koger E. M. Hodges, and T. A. Olson

Mr. Peacock is a Professor of Animal Science and Dr. Hodges a Professor of Agronomy at the Agricultural Research Center, Ona. Dr. Koger is a Professor and Dr. Olson an Assistant Professor of Animal Genetics in the Animal Science Department, Gainesville.

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INTRODUCTION

Crossbreeding has long been practiced in commercial beef cattle herds of Florida and has increased rapidly throughout the United States during recent years. Designing effective crossbreeding schemes is dependent upon information with respect to additive breed and heterosis effects exhibited in crosses among the breeds now available for crossbreeding. These breeds can be combined conveniently into three groups with respect to type, size, and origin: (1) the British breeds, (2) the large European breeds, and (3) Zebu and Zebu-derivative breeds. The purpose of this paper is to present average breed (additive genetic) and heterosis effects obtained from crosses among the Angus, Charolais, and American Brahman breeds as representative of the three groups.

The data presented were collected during the second phase of the project, during which Angus, Brahman, and Charolais sires were each mated to Angus, Brahman, Charolais, and reciprocal Angus-Brahman, Angus-Charolais, and Brahman-Charolais F_1 females (Table 1). The data from the first phase were reported previously by Peacock et al. (6, 7, 8). This phase included all possible straightbred and F_1 crossbred matings among purebreds or high grades of each of these breeds, a diallel design. The data presented in this paper include values for reproduction (Peacock and Koger, 9), production traits, and production efficiency, which is estimated as the ratio of calf weight weaned to weight of dam at weaning (Peacock et al., 10).

TABLE 1. Design and number of matings.

	Breed of dam [a]						
Breed of sire	Angus	Brahman	Charolais	AB+BA	AC+CA	BC+CB	Total
Angus	81	76	83	74	65	67	446
Brahman	71	84	73	66	59	62	415
Charolais	75	80	95	78	61	55	444
Total	227	240	251	218	185	184	1305

[a]The data from reciprocal F_1 dams were combined on the basis of preliminary analyses.

MATERIALS AND METHODS

The research was conducted at the University of Florida Agricultural Research Center at Ona, Florida. The center is located 27° 25' north latitude, 81° 55' west longitude at an elevation of 85 feet (26 m) on sandy soils of low fertility. Average annual rainfall is 54 inches (1,397 mm), with 75% of the precipitation occurring between May and October. The climate is considered semitropical; repeated frosts with temperatures at 28°F (-2.2°C) to 34°F (1.1°C) occur briefly during the winter. Lower temperatures occur at less frequent intervals.

The cattle were maintained on moderately fertilized improved grass pastures consisting mostly of Pangola digitgrass *(Digitaria decumbens* L.) and were supplemented with either 5 lb. (2.27 kg) of molasses or citrus pulp-cottonseed meal (4:1 ratio) per head per day for approximately 90 days during the late winter and early spring.

The Angus (A) and Brahman (B) cows used in the trial were purebreds, while the Charolais (C) were high grades (seven-eighths Charolais to purebred Charolais). The original F_1 cows were produced during phase 1 of the project, during which time A, B, and C males and females were mated in a diallel design. Heifers were first bred at 2 years of age. All matings were by natural service. A total of 21 sires (seven per breed) were used in the study. Sires were selected on the basis of a favorable fertility test, above average growth rate and structural soundness. Two sires of each breed were mated annually to A, B, C, and reciprocal AB, AC, and BC dams.

Approximately 16% of the cows were culled annually for unsoundness or reproductive failure. The breeding season was restricted to 90 days beginning March 1. Individual records were maintained for birth, survival, sex, age of calf at weaning, weaning weight, estimated 205-day weight, and condition score of calves. Scores of 6, 7, and 8 were used to designate low, medium, and high Standard; 9 to 11, Good grades; and 12 to 14, Choice grades as defined in the former USDA grade standard for slaughter calves.

Data Analyses

The data analyzed were the individual records for calving, survival and weaning rates, calf age at weaning, condition score, weaning weight, estimated 205-day weight, and cow weight at weaning time, utilizing least squares procedures as outlined by Harvey (2) for both reproduction and production traits. Preliminary analyses showed differences between reciprocal groups of F_1 cows to be small and generally not significant. The reciprocal groups therefore, were combined to improve proportionality of subclass numbers (Table 1).

The analyses of the data were performed on reproduction (Peacock and Koger, 9) and weaning traits (Peacock et al., 10). The first analysis obtained the 18 breed-of-sire x breed-of-dam subclass means nested within purebred, F_1, backcross, and three-breed cross classes. The second analysis was a multiple regression analysis to obtain simultaneous estimates of average breed and heterosis effects for both calf and maternal components as described by Koger et al. (4). The procedure is based on the assumption that calf and maternal components combine additively, and that hybrid vigor is linear with respect to breed heterozygosity

RESULTS AND DISCUSSION

The analyses of variance for reproductive and production traits are included in Tables 2 and 3, respectively. Age of dam had significant effects (P<.01) on all traits. Year effects were significant (P<.01) for all traits except survival rate of calves. Effects of these types are commonly observed and thus will not be discussed further. Significant levels between means were determined by the standard t-test.

The means and genetic effects for both reproductive and weaning performance are shown in Tables 4, 5, 6, 7, 8, and 9. In the evaluation of age of calf at weaning, condition score, estimated 205-day weight, and weaning weight, the average effects for four mating systems as well as specific breed and breed cross combinations were considered. The mating systems included purebreed calves on purebred cows (S_1), F_1 calves on purebred dams (S_2), backcross calves on F_1 dams (S_3), and three-breed cross calves on F_1 cows (S_4).

TABLE 2. Mean squares from analyses of variance for reproduction traits.

Source	df	Pregnancy rate	Survival rate	Weaning rate
Year	6	1.74**	0.007	1.62**
Age of dam	2	1.24**	0.098	1.09**
Breed of sire (S)	1	1.44**	0.021	1.73**
PB vs F_1 dams (C)[a]	2	.64**	.451**	1.36**
PB :C_1	2	0.27	.648**	.47*
F_1:C_2	2	.56**	0.034	.67*
S x C	4	0.07	0.06	0.09
S x PB:C_1	4	0.24	0.037	0.22
S x F_1:C_2	2	0.1	0.147	0.16
Remainder	-[b]	0.12	0.057	0.15
(df in remainder)		(1279)	(1070)	(1279)
*P<.05				

**P<.01
[a] Dam classes, purebred and F_1; PB=C; F_1=C_2
[b] Shown below mean square for error

Table 3. Mean squares from variance analyses for weaning traits.

Source	df	Age at weaning	Condition	Weaning weight[a]	205-day weight[a]
Year	6	8930**	11.9**	100.6**	172.4**
Sex	1	1528	39.2**	411.5**	442.4**
Age of dam	2	8988t*	21.8**	157.0**	43.2**
Mating system (S)	3	3604**	48.5**	447.9**	261.9**
Breed: S_1	2	5600**	2.9	390.5**	384.1**
F_1:S_2	5	2775**	7.6**	92.3**	88.7**
Backcross:S_3	5	1409	12.1**	94.0**	54.7**
3-breed:S_4	2	713	1.6	37.2**	45.1**
Remainder	1002	834	1.7	9.1	4.7
*P<.05					
**P<.01					
[a] (Mean squares) x 10^{-2}					

Reproduction

Calving Rate

The overall least squares mean for calving rate was 84% (Table 4). Individual subclass means varied from *70%* for Angus x Charolais matings to 95% for Charolais sires backcrossed to Brahman Charolais dams. The trait was influenced significantly by breed of sire, class of dam (purebred versus F_1 crosses), and by breed combination within F_1 dams (Table *2).*

Mean calving rates by the different breed of sires were 90%, 83%, and 80% for Brahman, Charolais, and Angus sires, respectively. The lower calving rates for the *Bos taurus* sires are in general agreement with a previous study at this location by Peacock et al. (5) in which pregnancy rates of *76%* and *72%*, respectively, were noted for Brahman and Shorthorn sires; and with the report by Turner et al. (13) from Louisiana. Data from south Florida by Crockett et al. (1), however, showed that Angus and Hereford sired larger calf crops than Brahman sires.

The most significant feature of the calving rate data was the striking superiority of crosses including Brahman over the cross that did not. Calving rates for the Angus-Brahman and Brahman-Charolais crosses were 92% and 90%, respectively, while the rate for the Angus-Charolais crossbred dams was only 82% (P<.01). The estimates for maternal heterosis effects for calving rate for the Angus-Brahman, Brahman-Charolais, and Angus-Charolais crossbred dams were 8.7% (P<.01), 9.2% (P<.01), and 2.2%, respectively (Table 6). The mean rates for purebred dams were not significantly different from each other, being 82%, 84%, and 77%, respectively for Angus, Brahman, and Charolais dams, but were lower (P<.01) than the rates for the Angus-Brahman and Brahman-Charolais crossbred groups. There were no significant breed-of-sire x breed-of-dam interaction effects influencing calving rate.

TABLE 4. Least squares means and standard errors for reproduction traits.

Group or effect[a]	Pregnancy rate	Survival rate	Weaning rate
Mu	84.4 ± 1.1	92.8 ± 1.1	78.3 ± 1.3
Purebred dams, straightbred matings			
Angus (A)	75.3 ± 3.9	89.2 ± 3.1	67.3 ± 4.4
Brahman (B)	89.9 ± 3.8	90.8 ± 2.9	81.9 ± 4.0
Charolais (C)	79.7 ± 3.5	95.0 ± 2.8	75.0 ± 4.0
Purebred dams, crossbred matings			
A x B	78.6 ± 4.0	96.0 ± 3.2	74.1 ± 4.5
B x A	92.4 ± 4.1	84.1 ± 3.1	77.9 ± 4.7
A x C	69.6 ± 3.8	96.8 ± 3.2	67.4 ± 4.4
C x A	78.6 ± 4.0	83.4 ± 3.1	65.6 ± 4.5
B x C	82.5 ± 4.1	96.8 ± 3.1	80.1 ± 4.6
C x B	82.5 ± 3.9	98.8 ± 3.0	81.7 ± 4.4
F_1 dams, backcrossed matings			
A x (AB,BA)	92.8 ± 4.0	94.5 ± 2.9	87.9 ± 4.6

A x (AC,CA)	76.9 ± 4.3	91.6 ± 3.4	70.6 ± 4.8
B x (AB,BA)	93.0 ± 4.2	97.9 ± 3.1	91.0 ± 4.8
B x (BC,CB)	91.3 ± 4.4	93.0 ± 3.2	84.8 ± 5.0
C x (AC,CA)	75.1 ± 4.4	88.6 ± 3.6	66.6 ± 5.0
C x (BC,CB)	94.8 ± 4.6	87.9 ± 3.4	83.5 ± 5.3
F_1 dams, three-breed matings			
A x (BC)	84.7 ± 4.2	97.2 ± 3.2	82.6 ± 4.8
B x (AC)	93.0 ± 4.5	96.3 ± 3.3	89.5 ± 5.1
C x (AB)	89.3 ± 3.9	91.9 ± 2.9	82.1 ± 4.5
Breed of sire			
Angus	79.7 ± 1.7	94.2 ± 1.4	75.0 ± 2.0
Brahman	90.4 ± 1.8	93.1 ± 1.3	84.2 ± 2.0
Charolais	83.3 ± 1.7	90.0 ± 1.4	75.8 ± 2.0
Breed of dam			
Purebred			
Angus	82.1 ± 2.4	85.6 ± 1.8	70.3 ± 2.7
Brahman	83.7 ± 2.3	95.2 ± 1.8	79.2 ± 2.6
Charolais	77.3 ± 2.3	96.2 ± 1.8	74.2 ± 2.6
F_1 dams			
(AB,BA)	91.7 ± 2.4	94.8 ± 1.8	87.0 ± 2.7
(AC,CA)	81.7 ± 2.6	92.2 ± 2.0	75.6 ± 2.9
(BC,CB)	90.3 ± 2.6	92.7 ± 1.9	83.6 ± 2.9
[a] Sire breed is shown first in combinations.			

Survival Rate

The mean survival rate of calves from birth to weaning was 93% (Table 4). Values for the breed group subclass means varied from a high of 99% for calves sired by Charolais mated to Brahman dams, to a low of 83% for calves sired by Charolais sires and out of Angus dams (P<.01). The latter was not surprising in view of the small size of Angus dams and large size of Charolais-sired calves (Sagebiel et al., 11; Smith et al., 12).

The average survival rates by breed of sire were not significantly different but were inversely related to mature size of the breeds, being highest for Angus-sired calves (94%) and lowest for Charolais-sired calves (91%). Conversely, among dam breed groups Angus dams had the lowest calf survival (86%, P<.01). Differences among other dam groups were not significant. The highest calf survival rate (96%) was for calves from Charolais dams.

The estimates for average breed (additive genetic) and heterosis effects influencing the calf component of survival (Table 6) were small and not significant. The only estimate which approached significance was that of 4.5% heterosis for Brahman-Charolais cross calves. The estimate for maternal heterosis in Angus-Brahman dams was 4.2% (P<0.05). Estimates for other maternal components were small and not significant.

TABLE 5. Summary of results by various mating classes.

Class of dams	Calving rate, %	Calf survival, %	Weaning rate, %
Purebred dams, straightbred matings	81.6 ± 2.2	91.7 ± 1.7	74.7 ± 2.4
Purebred dams, crossbred matings	80.7 ± 1.6	92.6 ± 1.3	74.5 ± 1.8
Purebred dam means	81.0 ± 1.8	92.3 ± 1.3	80.7 ± 1.6
F_1 dams, backcross matings	87.3 ± 1.8	92.2 ± 1.3	80.7 ± 1.6
F_1 dams, three-breed cross matings	89.0 ± 2.4	95.1 ± 1.8	84.7 ± 2.8
F_1 dam means	87.9 ± 1.5	93.2 ± 1.1	82.1 ± 1.7

TABLE 6. Estimated additive breed (A) and heterosis (H) effect for calf (O) and maternal (M) components for reproductive traits.

Effect	Pregnancy rate	Calf survival[a]	Weaning rate[a]
	Estimated effects ± SE		
Calf component	%	%	%
Ao (A)	-2.4 ± 2.3	1.6 ± 1.7	-1.00 ± 2.7

Ao (B)	3.5 ± 2.3	-1.3 ± 1.7	3.2 ± 2.7
Ao (C)	-1.1 ± 2.3	-0.3 ± 2.3	-2.2 ± 2.7
Ho (AB)	4.4 ± 3.5	2.1 ± 2.7	4.6 ± 4.0
Ho (AC)	-6.5 ± 3.5	-2.5 ± 2.8	-6.6 ± 3.8
Ho (BC)	0.9 ± 3.4	4.5 ± 2.6	4.9 ± 3.9
Maternal component			
Am (A)	1.5 ± 1.7	-2.6 ± 1.3	-0.6 ± 1.8
Am (B)	-0.1 ± 1.7	0.6 ± 1.3	-0.3 ± 1.8
Am (C)	-1.4 ± 1.7	1.9 ± 1.3	0.9 ± 1.8
Hm (AB)	8.7 ± 2.8**	4.2 ± 2.1*	12.2 ± 3.2**
Hm (AC)	2.2 ± 3.1	1.8 ± 2.4	3.3 ± 3.4
Hm (BC)	9.2 ± 3.0**	-2.4 ± 2.2	6.9 ± 3.4*
	Heterosis as percent of purebred average		
Ho (AB)	5.5 ± 4.3	2.3 ± 3.0	6.2 ± 5.4
Ho (AC)	-8.4 ± 4.5	-2.7 ± 3.1	-9.3 ± 5.3
Ho (BC)	1.1 ± 3.9	4.8 ± 2.8	6.2 ± 4.9
Hm (AB)	10.5 ± 3.4	4.7 ± 2.3	16.4 ± 4.3
Hm (C)	2.8 ± 4.1	1.9 ± 2.6	4.6 ± 4.3
Hm (BC)	10.8 ± 3.5	-2.6 ± 2.3	8.8 ± 4.2
[a] From analysis of individual 1.0 records.			
* P<.05			
** P<.01			

Weaning Rate

Weaning rate is the product of calving rate and calf survival and is the trait of greatest economic importance in beef cattle production. It indicates the percentage of the cows of a particular type that were exposed to breeding that actually weaned live calves. In this study it was influenced by sire breed (P<.01), class of dam (purebred versus crossbred) (P<.01), and by breed groups within both classes of dams (P<.05) (Table 2).

Weaning rates for breed group subclasses varied from a high of *91%* for Brahman sires mated to Angus-Brahman dams, to a low of 66% for Charolais sires mated to Angus dams (Table 4). The latter resulted from a combination of low values for both calving rate and calf survival. Angus dams mated to Angus sires likewise had a low weaning rate of 67%. The overall means by sire breed were 84% for Brahman sires, 76% for Charolais, and 75% for Angus sires. The purebred dams ranked in the same order with rates of 79%,74%, and 70%, respectively. Rates for the F_1 dams were 87%, 84%, and 76%, respectively, for AB, CB, and AC dams. The respective group means for F_1 and purebred dams were 82% and 75% with maternal heterosis amounting to 9.3% (Table 5).

These data are in agreement with other reports from the southeastern United States (Koger et al., 3) which generally show high levels of maternal heterosis for Zebu-European breed crosses. Crosses among European breeds may result in variable heterosis responses depending on trait and compatibility with respect to size or other characteristics.

The reciprocal Angus-Charolais crosses were not a favorable breed combination with respect to reproduction in this study. Weaning rate for the reciprocal F_1 calves was 66% versus an average of 79% for AB and BC calves. The weaning rate for calves from the Angus-Charolais dams was 76% versus 85% (P<.01), for the AB and BC dams combined. Differences in weaning rate of this magnitude are of paramount economic importance in commercial beef cattle production.

Weaning Traits

Age of Calf at Weaning

When matings occur in a restricted season and calves are weaned at one time, age of calf at weaning becomes an important production trait influencing weight of calf at weaning; consequently, age at weaning was analyzed as a production trait in this study. The overall least squares mean for age at weaning was 224 days (Table 7).

Significant (P<.01) differences occurred between mating systems, and between straightbred matings with only small variations among F_1 calves, backcross, or three-breed cross calves (Table 3). Age at weaning among mating groups was 220 days for F_1 calves compared to 223 for straightbred and 227 for backcross and three-breed cross calves (Table 8).Straightbred Brahman calves were youngest at weaning at 215 days of age; Charolais were 220 days of age at weaning; and Angus were oldest at 234 days (Table 7). These results could be due to variations in gestation length among breeds, or could possibly have been influenced by time of conception. Maternal heterosis levels for F_1 cows (Table 9) were positive for age of calves at weaning: 1.3% for AB 3.2% (P<.05) for AC, and 4.5% (P<.01) for BC cows, indicating conception earlier than the average for their parental breeds.

Condition Score

Calf condition score reflects thrift and adaptability of the individual calf and maternal (milking) ability of the cow. The overall least squares mean for condition score was 9.8 (Table 7). Significant (P<.01) variations occurred among mating groups; 9.1 for purebreds, 9.7 for F_1 crosses, 10.0 for backcrosses, and 10.3 for three-breed cross calves. No differences were observed among purebreds or three-breed cross calves (Table 3).

Condition score differences among F_1 and backcross calves were significant (P<.01). Combined reciprocal F_1 calf averages showed both the AB and AC calves with higher (P<.01) condition scores than BC reciprocals. Between reciprocals, A x B calves scored higher (P<.01) than B x A, and C x B calves higher (P<.01) than B x C calves. These results show a positive influence of the Brahman female for calf condition score compared with Angus and Charolais cows. However, additive maternal effects on calf condition score were not shown to be significant (Table 9).

Backcross calves from F_1 AB cows had a higher (P<.01) condition score than calves from either AC or BC cows. There were no differences between backcross calves mothered by the same cow breed, whereas three-breed calves from both F_1 AC and BC cows scored higher than backcross calves from the same dam breeds (Table 7). The coefficients for average breed effects for calf condition scores were negative (P<.05) for the Brahman breed, and slightly positive for Angus and Charolais (Table 9).

The heterosis levels for condition score in reciprocal F_1 calves were 11.1% for AB, 3.6% for AC, and 4.8% for BC calves (Table 9). Maternal heterosis for calf condition scores exhibited by F_1 cows (P<.01) was 9.9% for AB, 4.3% for AC, and 4.9% for BC crosses. These values indicate that all F1 cows provided a more favorable environment for their calves than the average of their parental breeds, with F_1 AB cows especially excelling in these traits.

TABLE 7. Least squares mating group means and standard errors for weaning traits.

Group or effect[a]	Observations, n	Age at weaning, days	Condition score	Weaning weight, lb*	205-day weight, lb*
Mu	1029	224.3 ± 1.12	9.8 ± .05	473.4 ± 2.6	441.0 ± 1.9
Purebreds					
Angus (A)	56	234.1 ± 4.0	9.2 ± .18	403.8 ± 9.1	366.6 ± 6.6
Brahman (B)	69	215.6 ± 3.6	8.8 ± .16	398.5 ± 8.3	384.7 ± 6.0
Charolais (C)	73	220.2 ± 3.5	9.2 ± .16	491.7 ± 8.0	465.5 ± 5.8
F_1 calves, purebred dams					
A x B	57	220.7 ± 3.9	10.3 ± .17	452.9 ± 8.9	427.5 ± 6.5

B x A	54	217.0 ± 4.0	9.6 ± .18	428.0 ± 9.2	412.9 ± 6.7
A x C	58	216.3 ± 3.9	9.9 ± .17	477.6 ± 9.0	457.1 ± 6.5
C x A	51	233.0 ± 4.1	9.4 ± .18	449.5 ± 9.4	406.3 ± 6.8
B x C	60	211.8 ± 3.8	9.6 ± .17	464.0 ± 8.7	454.7 ± 6.3
C x B	66	219.7 ± 3.6	9.6 ± .16	503.4 ± 8.3	474.8 ± 6.1
Backcross calves on F_1 dams					
A x (AB,BA)	67	230.9 ± 3.6	10.7 ± .16	495.5 ± 8.3	450.6 ± 6.0
A x (AC,CA)	45	226.7 ± 4.3	9.6 ± .19	449.4 ± 10.0	415.8 ± 7.2
B x (AB,BA)	60	224.5 ± 3.8	10.4 ± .17	488.1 ± 8.7	454.1 ± 6.3
B x (BC,CB)	52	218.5 ± 4.0	9.8 ± .18	467.5 ± 9.3	445.9 ± 6.8
C x (AC,CA)	41	232.6 ± 4.6	9.7 ± .20	507.1 ± 10.5	457.0 ± 7.6
C x (BC,CB)	46	231.0 ± 4.3	9.6 ± .19	540.1 ± 9.9	491.1 ± 7.2
Three-breed calves on F_1 dams					
A x (BC,CB)	56	230.3 ± 3.9	10.5 ± .17	501.4 ± 8.9	456.4 ± 6.5
B x (AC,CA)	52	227.1 ± 4.1	10.2 ± .18	495.3 ± 9.3	455.8 ± 6.8
C x (AB,BA)	66	223.4 ± 3.6	10.2 ± .16	528.0 ± 8.3	488.9 ± 6.1
Breed of sire					
Angus	339	228.2 ± 1.6	10.0 ± .07	463.5 ± 3.7	428.9 ± 2.6
Brahman	347	219.1 ± 1.6	9.7 ± .07	456.9 ± 3.7	434.8 ± 2.6
Charolais	343	226.6 ± 1.6	9.6 ± .07	503.4 ± 3.7	463.9 ± 2.6
Breed of dam					
Purebred					
Angus	161	228.0 ± 2.3	9.4 ± .10	427.1 ± 5.3	395.4 ± 4.2
Brahman	192	218.7 ± 2.1	9.6 ± .09	451.6 ± 5.0	429.1 ± 3.5
Charolais	191	216.1 ± 2.2	9.5 ± .10	477.8 ± 5.0	459.1 ± 3.5
F_1 dams					
(AB,BA)	193	226.3 ± 2.1	10.4 ± .09	503.8 ± 5.0	464.4 ± 4.0
(AC,CA)	138	228.8 ± 2.5	9.8 ± .11	484.0 ± 5.7	442.8 ± 4.2
(BC,CB)	154	226.6 ± 2.3	10.0 ± .10	503.0 ± 5.5	464.4 ± 4.0

* Kg = mean x 0.454

TABLE 8. Least squares mating group means and standard errors for weaning traits.					
Mating Systems	Observations	Age at weaning, days	Condition score	Weaning weight, lb*	205-day weight, lb*
Purebred calves	198	223.3 ± 2.2	9.1 ± .10	431.3 ± 5.1	405.6 ± 3.7
F_1 calves, PB dams	346	219.7 ± 1.7	9.7 ± .08	462.6 ± 3.9	438.9 ± 2.8
Backcross calves F_1 dams	311	227.4 ± 1.8	10.0 ± .08	491.3 ± 4.0	452.4 ± 2.9
Three-breed calves F_1 dams	174	226.9 ± 2.6	10.3 ± .10	508.2 ± 5.2	467.0 ± 3.8
* Kg = mean x 0.454					

Estimated 205-day Weight and Weaning Weight

Estimated 205-day weight is a measure of growth rate, while weaning weight reflects differences in both growth rate and age. Since these two traits are highly correlated, only weaning weight will be discussed.

Differences among mating groups for weaning weight were significant (P<.01): 431 lb (196 kg) for purebreds, 463 lb (210 kg) for F_1, 491 lb (223 kg) for backcross, and 508 lb (231 kg) for three-breed cross calves (Table 8). Among the straightbreds, the Charolais calves were heaviest (P<.01) at 492 lb (223 kg), with Angus and Brahman calves at 404 lb (183 kg) and 399 lb (181 kg), respectively. Significant differences (P<.01) were also observed between F_1 calves (Table 3). The combined reciprocal F_1 BC calves weighed 43 lb (20 kg) (P<.01) more than the AB and 20 lb (9 kg) more than reciprocal AC calves. These results express the large breed effects for growth of the Charolais in breed crosses (Table 7).

Significant differences (P<.01) were observed between backcross calves for weaning weight (Table 3). Although no differences were observed between A x AB and B x AB calves, C x AC calves were heavier (P<.01) at 507 lb (203 kg) than the A x AC calves at 449 lb (204 kg). The C x BC calves were also heavier (P<.01) at 540 lb (245 kg) than B x BC calves at 468 lb (212 kg). These data also express the large additive genetic potential for growth in the Charolais when compared to the Angus and Brahman breeds. The only difference between cow breed type nursing backcross calves was that F_1 BC cows weaned heavier calves than F_1 AC cows (P<.05) (Table 7).

Variations among weaning weights of three-breed cross calves were significant (P<.05) at 501 lb (227 kg), 495 lb (225 kg), and 528 lb (240 kg) for A x BC, B x AC, and C x AB calves, respectively. These results again demonstrate the genetic potential for growth in the Charolais.

The coefficients for additive breed effects (Table 9) for weaning weight of calves were large and negative (P<.01) for Brahman, large and positive (P<.01) for Charolais, and negative but not significant for Angus. These results for Angus and Charolais calves would be anticipated considering the general characteristics of the two breeds. The large negative value for Brahman calves is explained by the slow growth rate in purebred Brahman calves, coupled with large heterosis values for Brahman crosses.

Heterosis levels for F_1 calf weights were all positive: 11.6% (P<.01) for AB and BA crosses, 8.2% for BC and CB crosses (P<.01), and 0.7% (not significant) for AC and CA crosses (Table 9). These values show the importance of including the Brahman breed in crossbreeding systems in Florida.

Average maternal effects were positive (P<.01) for Brahman and negative (P<.05) for Charolais, with Angus slightly negative but not significant. Estimated heterosis for maternal performance for weaning weight of calves in F_1 cows was 14.5% (P<.01) for AB, 8.9% (P<.01) for BC, and 7.6% (P<.01) for AC. Those F_1 cows with Brahman as one of the breeds were superior to the all-European crosses, with the highest heterosis being observed in the F_1 AB cow.

TABLE 9. Estimated additive breed and heterosis effects for weaning traits.

Effect	Age at weaning, days	Condition score	Weaning weight, lb*	205-day weight, lb*
Calf component				
Ao (A)	1.6 ± 3.0	.13 ± .09	-6.6 ± 7.1	-7.9 ± 5.3
Ao (B)	-8.4 ± 2.9**	-.22 ± .09*	-58.7 ± 6.8**	-39.7 ± 5.1**
Ao (C)	6.8 ± 3.1*	.09 ± .09	65.3 ± 7.3**	47.6 ± 5.3**
Ho (AB)	-2.7 ± 3.4	1.00 ± .09**	46.7 ± 7.9**	45.6 ± 5.7**
Ho (AC)	-4.8 ± 3.5	.33 ± .10**	3.1 ± 8.2	8.4 ± 6.0
Ho (BC)	-3.2 ± 3.2	.43 ± .09**	36.4 ± 7.5**	38.6 ± 5.5**
Maternal component				
Am (A)	1.7 ± 2.3	.11 ± .09	-3.7 ± 5.3	-6.0 ± 4.0*
Am (B)	4.0 ± 2.2	.09 ± .09	17.2 ± 5.1**	7.3 ± 3.5*

Am (C)	-5.7 ± 2.5*	.01 ± .09	-13.5 ± 5.7*	-1.3 ± 4.2
Hm (AB)	2.9 ± 2.6	.94 ± .07**	63.7 ± 6.0**	53.6 ± 4.4**
Hm (AC)	7.1 ± 3.1	.41 ± .09**	34.4 ± 7.1**	19.0 ± 5.1**
Hm (BC)	9.7 ± 2.8**	.47 ± .08**	41.2 ± 6.4**	21.8 ± 4.6**
	Heterosis as percent of purebred average			
Ho (AB)	-1.2 ± 1.5	11.1 ± 1.0	11.6 ± 2.0	12.1 ± 1.5
Ho (AC)	-2.1 ± 1.5	3.6 ± 1.1	.7 ± 1.8	2.0 ± 1.5
Ho (BC)	-1.5 ± 1.5	4.8 ± 1.0	8.2 ± 1.7	9.1 ± 1.3
Hm (AB)	1.3 ± 1.2	9.9 ± .7	14.5 ± 1.4	13.0 ± 1.1
Hm (AC)	3.2 ± 1.4	4.3 ± .9	7.6 ± 1.6	4.5 ± 1.2
Hm (BC)	4.5 ± 1.3	4.9 ± .8	8.9 ± 1.4	4.9 ± 1.0
* Kg = mean x 0.454				

Efficiency of Production

Significant differences (P<.01) were found among weights of purebred cows; as would be expected, Angus were lowest and Charolais highest (Table 10). Among crossbreds the F_1 BC cows were heavier (P<.01) than AB and AC cows. The F_1 cow weight average was larger (P<.01) than the purebred cow average. Heterosis levels for weights of F_1 cows were 8.7% for AB, 2.3% for AC, and 4.1% for BC cows. These results are interesting since they parallel the relative ranking calf weights of the three F_1 crosses.

A measure of production efficiency can be expressed as a ratio of calf weaning weight to cow weight. These ratios for each mating system and each specific cross within each system are shown in Table 11. An additional important component of overall production efficiency is weaning rate. Therefore, the calf weight to cow weight ratio was multiplied by weaning rate to provide a measure of production per unit of cow weight exposed to breeding (Table 11).

Average production efficiency ratios were 0.34, 0.36, 0.40, and 0.43 for purebred, F_1, backcross, and three-breed cross production, respectively. Using the average value for purebreds (0.34) as the basis for comparison, the advantages for the F_1 calves on purebred dams, backcross calves on F_1 dams, and three-breed calves on F_1 dams were 5.9, 17.6, and 26.5%, respectively. The mean ratios for Brahman-Angus and Brahman-Charolais F_1 females were 0.45 and 0.40, respectively. Both surpass that of the Charolais-Angus crosses (0.33). These values reemphasize both the importance of crossbreeding and the effect of the Brahman breed for improvement of production efficiency in beef cattle.

TABLE 10. Least squares means for cow weights and condition score recorded when their calves were weaned.		
Breed Group	Weight, lb* --------- Mean ± SE	Condition --------- Mean ± SE
Purebreds		
Angus	856 ± 7.7	5.3 ± .09
Brahman	946 ± 8.2	5.7 ± .08
Charolais	1076 ± 8.4	5.4 ± .09
F_1 crosses		
(AB,BA)	979 ± 7.9	5.8 ± .08
(AC,CA)	988 ± 8.6	5.8 ± .09
(BC,CB)	1052 ± 8.4	5.6 ± .09
* Kg = mean x 0.454		

TABLE 11. Relative production effciency.			
Group	Calf weaning weight / cow weight	Weaning rate, %	Productive efficiency ratio[a]
Purebreds			
Angus (A)	.47	67.3	.32
Brahman (B)	.42	81.9	.34
Charolais	.46	75.0	.35

(C)			
System mean	.45	74.7	.34
Purebred dams with F_1calves			
A x B	.48	74.1	.36
B x A	.50	77.9	.39
A x C	.44	67.4	.30
C x A	.53	65.6	.35
B x C	.43	80.1	.34
C x B	.53	81.7	.43
System mean	.49	74.5	.36
F_1 dams with backcross calves			
A x (AB,BA)	.51	87.9	.45
A x (AC,CA)	.45	70.6	.32
B x (AB,BA)	.50	91.0	.46
B x (BC,CB)	.44	84.8	.37
C x (AC,CA)	.51	66.6	.34
C x (BC,CB)	.51	83.5	.43
System mean	.49	80.7	.40
F_1 dams with three-breed calves			
A x (BC,CB)	.48	82.6	.40
B x (AC,CA)	.50	89.5	.45
C x (AB,BA)	.54	82.1	.44
System	.51	84.7	.43

mean			
[a] Efficiency = (Calf weaning weight/cow weight) x weaning rate.			

SUMMARY AND CONCLUSIONS

Additive breed and heterosis effects for maternal and calf components for reproductive and weaning traits were examined by the mating of Angus (A), Brahman (B), and Charolais (C) sires to A, B, C, and reciprocal AB, AC, and BC dams. Each sire breed was mated to all breed groups of cows.

The most important influences on calving rate were breed of sire (90%, 83%, and 80% for B, C, and A sires, respectively) and class of dam (88% versus 81% for F_1 versus purebreds). The highest calving rate among dam groups was 92% for reciprocal F_1 AB crossbreds; the lowest was 82% for A and F_1 AC dams. Survival rate of calves from Angus dams was 86% compared to 95% and 96% for Brahman and Charolais dams, respectively. Calf survival rates were 94% for A sires, 93% for B, and 91% for C sires. The most important influence on weaning rate was breed group of dams. Means varied from 70% for Angus to 87% for AB dams. The mean weaning rate of F_1 dams was 82% versus 75% for purebreds. Among crossbred cows, the two groups of Brahman crosses, AB and CB (86%), had higher weaning rates than the AC crosses *(76%).*

There were no significant additive breed or maternal effects for reproductive traits. Estimates for maternal heterosis for calving rate of F_1 dams were 8.7% ($P<.01$), 9.2% ($P<.01$), and 2.2% for AB, BC, and AC dams, respectively. The only significant ($P<.05$) estimate of heterosis for calf survival rate was 4.2% for the F_1 AB dams. Heterosis estimates for weaning rate were 12.2% ($P<.01$), 6.9% ($P<.05$), and 3.3% for F_1 AB, BC, and AC dams, respectively.

Heterosis for early calving was negative for straightbred cross matings, but positive for F_1 dams at 9.7 ($P<.01$) for BC dams, 7.1 ($P<.05$) for AC, and 2.9 for F_1 AB dams. Calf condition scores were negatively ($P<.01$) influenced by Brahman breeding; whereas heterosis for condition score was positive ($P<.01$) for all F_1 calves and calves on F_1 dams, with the F_1 AB calf and dam highest.

Estimates for additive breed effects on weaning weights were negative for Brahman ($P<.01$) and positive for Charolais ($P<.01$); whereas maternal effects were positive for Brahman dams ($P<.01$) and negative for Charolais ($P<.01$). Heterosis estimates for weaning weight were 12% ($P<.01$), 1%, and 8% ($P<.01$), for F_1 AB, AC, and BC calves, respectively. Maternal heterosis estimates were 15% ($P<.01$), 8% ($P<.01$), and 9% ($P<.01$) for F_1 AB, AC, and BC dams.

Approximate relative production efficiency ratios were computed for different mating groups as (calf weight/cow weight) x weaning rate. Using the average value of purebred (0.34) as a basis of comparison, the advantages for F_1 calves on purebred dams, backcross calves on F_1 dams, and three-breed calves on F_1 dams were 5.9, 17.6, and 26.5%, respectively. The mean efficiency ratios for the Brahman-Angus and Charolais-Brahman F_1 females were 0.45 and 0.40, respectively, both values surpassing that of the Angus-Charolais The value of incorporating Zebu (Brahman) germ plasm into crossbreeding systems in this region is made very clear in this study; it is also becoming apparent that Zebu germ plasm can have application in more temperate areas (14).

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