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BREEDING BETTER BEEF. 3. INFLUENCE OF MATING SYSTEM ON PREWEANING PERFORMANCE OF CALVES

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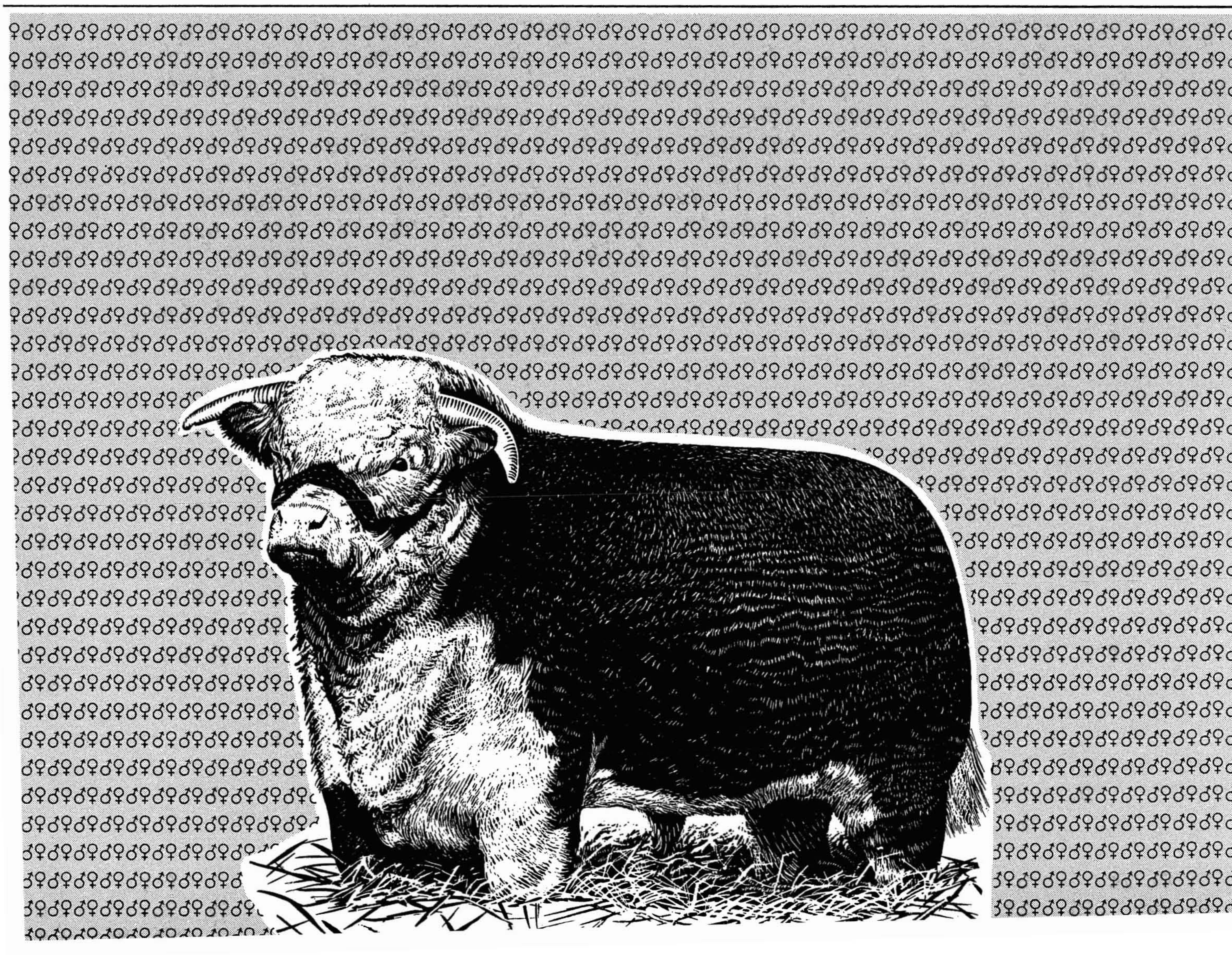

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BREEDING BETTER BEEF. 3. INFLUENCE OF MATING SYSTEM ON PREWEANING PERFORMANCE OF CALVES

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INTRODUCTION

The majority of commercial beef production units in both temperate and tropical environments use some form of crossbreeding. Koch et al. (1985) state that crossbreeding is a widely accepted practice that influences about 70 percent of the beef cattle marketed in the United States. A wide variety of crossbreeding systems have been and continue to be evaluated for production efficiency and for adaptability by the commercial beef producer. A number of reports indicate that higher productivity is realized from the use of two-breed crossbred cows mated to bulls of a third breed compared with straightbreeding or the use of only two breeds in a crossing program (Gaines et al., 1978; Franke, 1979*a,b*; Gregory and Cundiff, 1980; Nelson et al., 1982; Neville et al., 1984; Anderson et al., 1986).

The primary objective of this study was to compare preweaning performance of calves produced under Hawaiian range conditions by five different mating systems: straightbreeding, backcrossing, two-breed crossing, three-breed crossing, and four-breed crossing. Secondary objectives were to estimate the effects of breed of sire, breed of dam, age of dam, year of birth, and heterosis on preweaning performance of calves.

MATERIALS AND METHODS

The data for this study were collected over a six-year period from 1980 to 1985 at the Mealani Experiment Station, Kamuela, Hawaii. The station is 5.5 miles inland from the ocean coastline at an elevation of 2800 feet above sea level. The average annual rainfall during the period of the study was 55.8 inches, ranging from a low of 29.9 inches in 1984 to a high of 86.5 inches in 1982. Average annual maximum and minimum temperatures recorded were 69.9° F and 55.4° F, respectively; the extremes ranged from a high of 76.2° F to a low of 45.5° F. Average relative humidity ranged from 97.8 percent to 65.2 percent; relative humidity levels of 100 percent were recorded during seven months of the six-year study.

The study consisted of 488 male and 532 female calves. The foundation cow herd of grade Angus (A) and Hereford (H) females was obtained from local ranches in 1964; grade Santa Gertrudis (SG) females from local sources were added in 1982. All females were bred to produce their first calf at two years of age. Cows were culled if they failed to calve for two consecutive years or if they sustained physical injury or were diseased. Angus, Hereford, Holstein (Ho), Limousin (L), and Santa Gertrudis bulls were obtained from local and U.S. mainland sources and were used to breed by both natural service and artificial insemination. Breeding to Brahman (B) and Tarentaise (T) sires was by artificial insemination only by bulls from the U.S. mainland. Breeding to Maine Anjou (MA) sires was by natural service only by bulls imported from the U.S. mainland.

Calves produced in the various mating systems were all sired by straightbred or purebred bulls and out of either straightbred, two-breed, or three-breed crossbred cows, as called for in each mating system. The straightbred mating system included calves from A, H, and SG cows bred to bulls of their own breed. Two-breed crossbreds resulted from the mating of A, B, H, Ho, L, MA, SG, and T bulls to A and H cows. Backcross calves were produced by mating A, H, and SG bulls with AH, HA, SGA, and SGH cows. Females from the two-breed mating system were bred to bulls of a third breed to produce three-breed crossbred progeny. Four-breed crossbred calves were sired by Ho, L, and MA bulls and out of A(SGH) and H(SGA) cows.

Cows were allotted at random to mating groups. Breeding was by artificial insemination for 42 days beginning on April 1 each year, followed by a 33-day period of natural service. Calves were born from January to March and remained with their dams on pasture until weaning in early September. Body weights were obtained on all calves within 24 hours after birth. Males were castrated at about three months of age. Weaning weights were taken at about seven months of age and were adjusted to 205 days of age using the calf's preweaning daily gain. Weaning weight and average daily gain were further adjusted for age of dam; additive correction factors used for weaning weight were, for male and female calves, respectively, 60 and 54 lb for calves out of two-year-old dams, 40 and 36 lb for calves out of three-year-old dams, and 20 and 18 lb for calves out of dams aged four years and 11+ years. No age-of-dam adjustments were made for calves out of dams in the five-to-10-year age group. Weaning conformation scores were assigned to each calf, representing the average grade given by three graders. Score values for feeder calves, ranging from 9 to 11 for good, 12 to 14 for choice, and 15 to 17 for prime, were based on skeletal soundness and development and on indications of carcass quality.

All cows and calves were maintained on pasture and handled under the management system described above until weaning. Pastures consisted of pangola grass (*Digitaria decumbens*) and kikuyu grass (*Pennisetum clandestinum*) fertilized with urea to provide approximately 200 lb N per acre per year. The average annual stocking rate during the period of the study was 2.2 animal units per acre. A mineral mixture containing salt, Ca, P, and trace minerals was available to all animals at all times.

Estimates of heterosis, the difference between the performance of crossbred calves and the average performance of calves from the straightbred parental breeds, were obtained by comparing the performance of AH reciprocal cross calves with the average performance of straightbred A and H calves. Reciprocal cross calves were not available among SGA and SGH calves because all of these crossbreds were sired by SG bulls and out of A and H cows. The heterotic effects shown for the SG-sired crossbreds are therefore based on one-way crosses between the SG and A and the SG and H breeds.

The data were analyzed by analysis of variance using GLM procedures to fit least squares means for unequal subclass numbers (SAS, 1982). Differences between means were tested for significance by Duncan's multiple range test. The model for all traits included the effects of year, breed of sire, breed of dam, age of dam, and mating system. The traits under study included birth weight, 205-day adjusted weaning weight, average daily gain (ADG) from birth to weaning, and weaning conformation score.

RESULTS AND DISCUSSION

Mating System

System of mating had a significant effect on all traits, as shown in Table 1. Calves produced in the three-breed mating system ranked at or near the top for all traits measured, straightbreds and backcrosses generally shared the lower end of the performance scale, and two-breed and four-breed crosses were intermediate.

The straightbred and backcross mating systems produced calves that were the lightest at birth, whereas calves from the two-breed and three-breed systems were the heaviest. Heifer calves from the three-breed mating system were the heaviest ($P < .05$) at weaning and gained the most rapidly ($P < .05$) from birth to weaning. Straightbred steers were consistently lower in weaning weight and in ADG from birth to weaning. Differences in weaning conformation grade among steer calves were not significant. Grade differences observed among heifer progeny were significant; calves from the three-breed system graded the highest, straightbred and two-breed progeny were intermediate, and four-breed and backcross calves graded the lowest.

Neville et al. (1984), in a three-generation study of rotational crossbreeding with the Angus (A), Polled Hereford (PH), and Santa Gertrudis (SG) breeds producing straightbreds, two-breed, and three-breed crossbred progeny, reported that birth weight, weaning weight, and ADG were higher for calves produced in the three-breed and two-breed mating systems than in straightbred systems. These authors found that the PH-SG cross generally performed the best and the A-SG cross generally performed the poorest.

Anderson et al. (1986) bred Hereford (H), Angus-Hereford (AH), and Simmental-Hereford (SH) cows to Charolais and Tarentaise bulls to produce two-breed and three-breed crossbred calves. The SH cows in this study carried either 25, 50, or 75 percent Simmental (S) breeding. These authors found that three-breed crossbred calves from SH cows with either 50 or 75 percent S breeding weaned the heaviest calves. Two-breed crossbreds from H cows were the lightest, and three-breed crossbreds from AH and SH cows with 25 percent S breeding were intermediate. They reported that cow productivity, in terms of pounds of calf weaned per cow exposed to breeding, was higher for crossbred cows producing three-breed crossbred calves than for straightbred cows producing two-breed crossbred progeny. Kress et al. (1986) concluded that, under Montana range conditions, crossbred cows have the greatest productivity per pound of cow weight, and that the biological types of cows with the greatest productivity are intermediate in weight and milk production and early in sexual maturity.

Franke (1979*a*), in a study with Angus, Hereford, Brahman, and Charolais straightbreds versus two-, three-, and four-breed rotation crosses of these breeds, reported that crossbreds were superior to

Table 1. Preweaning performance of calves by mating system

(Means ± standard errors)

Mating system[a]	N	Birth weight	205-day weaning weight	Average daily gain	Conformation score
		lb	lb	lb	units
			STEERS		
ST	131	72.4 ± 1.0[d]	408 ± 5[c]	1.64 ± .02[c]	14.1 ± .1
BX	47	68.7 ± 1.4[e]	448 ± 9[b]	1.85 ± .04[b]	13.9 ± .1
2X	133	76.8 ± 1.0[bc]	449 ± 6[b]	1.82 ± .03[b]	14.2 ± .1
3X	156	78.3 ± .8[b]	461 ± 5[b]	1.86 ± .02[b]	14.3 ± .1
4X	21	73.7 ± 2.2[cd]	456 ± 10[b]	1.86 ± .05[b]	14.2 ± .2
Total	488	75.2 ± .5	442 ± 3	1.79 ± .01	14.2 ± .05
			HEIFERS		
ST	164	67.2 ± .8[c]	406 ± 5[d]	1.65 ± .02[c]	14.0 ± .1[c]
BX	43	65.2 ± 1.3[c]	417 ± 9[cd]	1.72 ± .04[c]	13.6 ± .2[d]
2X	161	72.4 ± .8[b]	427 ± 5[c]	1.73 ± .02[c]	14.2 ± .1[c]
3X	144	72.4 ± .9[b]	449 ± 5[b]	1.84 ± .02[b]	14.5 ± .1[b]
4X	20	71.4 ± 1.9[b]	425 ± 9[c]	1.72 ± .04[c]	13.6 ± .3[d]
Total	532	70.2 ± .4	426 ± 3	1.73 ± .01	14.1 ± .1

[a]ST = straightbred; BX = backcross; 2X = 2-breed cross; 3X = 3-breed cross; 4X = 4-breed cross.

[b,c,d,e]Column means within sex groups with different superscripts are different, $P < .05$.

Table 2. Preweaning performance of calves by breed of sire

(Means ± standard errors)

Breed of sire[a]	N	Birth weight	205-day weaning weight	Average daily gain	Conformation score
		lb	lb	lb	units
			STEERS		
A	146	68.0 ± .7[e]	425 ± 5[c]	1.74 ± .02[b]	14.0 ± .1[de]
B	13	89.5 ± 2.7[b]	453 ± 9[bc]	1.77 ± .04[b]	14.9 ± .2[b]
H	128	74.2 ± 1.0[de]	435 ± 7[bc]	1.76 ± .03[b]	14.2 ± .1[cde]
Ho	53	79.3 ± 1.3[cd]	469 ± 6[b]	1.90 ± .03[b]	13.9 ± .1[e]
L	43	78.0 ± 1.4[cd]	466 ± 7[b]	1.89 ± .03[b]	14.8 ± .1[bc]
MA	6	70.7 ± 2.8[e]	455 ± 18[bc]	1.87 ± .09[b]	14.7 ± .3[bcd]
SG	90	82.2 ± 1.0[c]	477 ± 8[bc]	1.78 ± .04[b]	14.1 ± .1[de]
T	9	80.0 ± 5.1[cd]	459 ± 13[bc]	1.85 ± .07[b]	14.6 ± .2[bcde]
			HEIFERS		
A	147	63.9 ± .7[e]	412 ± 5[cd]	1.70 ± .02[bc]	14.0 ± .1[def]
B	8	83.0 ± 4.4[b]	447 ± 11[bc]	1.78 ± .05[bc]	15.5 ± .2[b]
H	165	69.8 ± .7[cd]	411 ± 5[d]	1.66 ± .02[c]	14.0 ± .1[ef]
Ho	38	72.8 ± 1.4[cd]	443 ± 9[bcd]	1.81 ± .04[bc]	13.2 ± .2[f]
L	46	75.8 ± 1.3[c]	458 ± 8[b]	1.86 ± .04[b]	14.7 ± .1[cde]
MA	8	69.2 ± 5.4[de]	437 ± 21[bcd]	1.79 ± .08[bc]	14.9 ± .3[bcd]
SG	105	75.2 ± .9[cd]	443 ± 6[bcd]	1.80 ± .03[bc]	14.3 ± .1[cde]
T	15	70.1 ± 2.6[cd]	440 ± 10[bcd]	1.80 ± .04[bc]	15.0 ± .2[bc]

[a]A = Angus (19); B = Brahman (2); H = Hereford (19); Ho = Holstein (13); L = Limousin (8); MA = Maine Anjou (1); SG = Santa Gertrudis (16); T = Tarentaise (4). Numbers in parentheses indicate number of sires used.

[b,c,d,e,f]Column means within sex groups with different superscripts are different, $P<.05$.

straightbreds in birth weight, weaning weight, ADG, calf condition, and in calf weight to cow weight ratio at 205 days. He found that heterosis for two- and three-breed crosses was similar and greater than for four-breed crosses. In a companion study, Franke (1979*b*) observed that the three-breed crosses had higher calving and weaning rates than the other crosses. Gregory and Cundiff (1980) estimated that weight of calf marketed per cow exposed to breeding was increased by 24.7 percent in a three-breed and 20.8 percent in a two-breed rotation crossing system. Nelson et al. (1982) reported that calves from a three-breed mating system involving the Angus, Hereford, Charolais, and Brown Swiss breeds were heavier at weaning than backcross calves, and backcrosses were heavier than two-breed crossbred calves. Gaines et al. (1978) reported heavier weaning weights for three-breed crossbred calves of Angus, Hereford, and Shorthorn breeding than for backcrosses.

Breed of Sire

Breed of sire had a significant effect (P<.05) on all calf performance traits (Table 2). Calves sired by B bulls were heavier at birth than those sired by any other breed. Birth weights did not differ significantly among calves sired by SG, T, Ho, and L bulls; male progeny of these sire breeds were heavier at birth than those sired by MA and A bulls, and heifer calves by these sire breeds were heavier than those sired by A bulls. Marlowe and Tolley (1982) reported that large breeds, including the B, experienced greater dystocia (calving difficulties) than smaller sire breeds. Calving difficulties resulting from the use of B bulls were not encountered in this study.

Steers sired by Ho and L bulls were heavier at weaning than those sired by A bulls. Heifers sired by L bulls outweighed those sired by A and H bulls; B-sired heifers were heavier at weaning than H-sired heifers. Limousin bulls sired heifers that gained more rapidly from birth to weaning than did H bulls. Differences in weaning weight and daily growth rate among calves sired by T, MA, SG, and B bulls were not significant. Results from other studies indicate that Ho-sired calves grow more rapidly than calves sired by the British breeds (Gifford et al., 1976; Barlow and O'Neill, 1978; Morgan et al., 1978; Baker and Carter, 1982). Cundiff et al. (1985) reported that T bulls sired calves that were heavier at weaning than HA crossbreds, and that L-sired crossbreds were similar to HA crossbreds.

Weaning conformation score was higher for B-sired heifers than for those sired by L, SG, A, and Ho bulls; steers sired by B bulls had a higher conformation score than those sired by SG, A, H, and Ho bulls. Significant differences in weaning conformation score were also noted for the following breed-of-sire comparisons: L-sired steers graded higher than those sired by SG, A, and Ho bulls; MA-sired steers graded higher than Ho-sired steers; T-sired heifers averaged higher grades than those sired by A, H, and Ho bulls; MA-sired heifers graded higher than H- and Ho-sired heifers; and L bulls produced heifers with higher conformation grades than did Ho bulls.

Breed of Dam

Differences in birth weight, weaning weight, ADG, and weaning conformation score due to breed of dam were significant (P<.05) only among heifer progeny (Table 3). Hereford-Angus, SGA, H(SGA), and SG dams produced calves that were heavier at birth than calves out of A and A(SGH) cows. Calves from H, SGH, and AH dams were intermediate in birth weight. Ranking of dam breeds was identical for 205-day weight and ADG from birth to weaning, with SGA, SG, and HA dams producing the heaviest and fastest growing calves. Calves out of SGH and A dams ranked the next highest in weaning weight and in growth rate. Hereford cows produced calves that were the lowest in weaning weight and in ADG from birth to weaning. Calves from dam breeds producing heavier weaning and faster growing progeny also ranked in the upper half of the scale in weaning conformation score. Calves from SGA cows ranked the highest in conformation score, followed by calves from SGH, SG, A, and HA cows. Because of limited numbers, all SG cows in this study were bred to produce straightbred calves, whereas A and H cows produced both straightbred and crossbred calves. Given the opportunity to produce crossbred calves, these SG cows might well have had higher performing progeny.

Three of the two-way crossbred dam breeds (SGA, HA, and SGH) outperformed three-breed crossbreds in that progeny from the latter dam breeds generally ranked near the lower end of the performance scale, within the same range as straightbred H cows. Numerous studies have shown that two-breed crossbred cows have a distinct advantage over straightbreds in total calf production (e.g., Gaines et al., 1966; Cundiff, 1970; Franke,

Table 3. Preweaning performance of calves by breed of dam

(Means $\pm$ standard errors)

Breed of dam[a]	N	Birth weight	205-day weaning weight	Average daily gain	Conformation score
		lb	lb	lb	units
			STEERS		
A	121	71.5 ± 1.1	439 ± 6	$1.80 \pm .02$	$14.3 \pm .1$
H	117	76.5 ± 1.1	420 ± 6	$1.67 \pm .03$	$14.1 \pm .1$
SG	25	80.8 ± 1.7	420 ± 12	$1.65 \pm .06$	$13.8 \pm .2$
AH	47	73.2 ± 1.5	451 ± 9	$1.84 \pm .04$	$14.0 \pm .1$
HA	19	78.4 ± 3.0	480 ± 9	$1.96 \pm .04$	$14.5 \pm .2$
SGA	61	77.2 ± 1.5	474 ± 6	$1.94 \pm .03$	$14.5 \pm .1$
SGH	56	76.9 ± 1.3	458 ± 8	$1.86 \pm .03$	$14.2 \pm .1$
A(SGH)	22	74.8 ± 2.1	439 ± 12	$1.78 \pm .06$	$14.1 \pm .2$
H(SGA)	20	74.1 ± 2.2	419 ± 16	$1.68 \pm .07$	$13.5 \pm .3$
			HEIFERS		
A	144	$67.1 \pm .9^{cd}$	431 ± 5^{cd}	$1.77 \pm .02^{cd}$	$14.3 \pm .1^{bc}$
H	156	$71.9 \pm .8^{bc}$	398 ± 5^{e}	$1.59 \pm .02^{e}$	$13.9 \pm .1^{def}$
SG	25	72.1 ± 2.2^{b}	451 ± 12^{bc}	$1.85 \pm .06^{bc}$	$14.4 \pm .2^{b}$
AH	39	69.4 ± 1.6^{bcd}	423 ± 10^{cd}	$1.73 \pm .04^{cd}$	$13.9 \pm .2^{cde}$
HA	23	72.8 ± 2.7^{b}	449 ± 10^{bc}	$1.84 \pm .04^{bc}$	$14.3 \pm .2^{bcd}$
SGA	64	72.7 ± 1.3^{b}	463 ± 7^{b}	$1.91 \pm .03^{b}$	$14.7 \pm .1^{b}$
SGH	45	70.1 ± 1.3^{bcd}	435 ± 9^{cd}	$1.78 \pm .04^{cd}$	$14.4 \pm .1^{b}$
A(SGH)	24	66.3 ± 1.8^{d}	415 ± 13^{de}	$1.70 \pm .06^{d}$	$13.6 \pm .3^{ef}$
H(SGA)	12	72.3 ± 2.9^{b}	426 ± 15^{cd}	$1.73 \pm .07^{cd}$	$13.3 \pm .3^{f}$

[a] A = Angus; H = Hereford; SG = Santa Gertrudis. Breed of sire is listed first in all crosses. A(SGH) denotes progeny sired by an A bull and out of a SGH cow, which in turn was sired by a SG bull and out of a H cow.

[b,c,d,e,f] Column means within sex groups with different superscripts are different, $P < .05$.

Table 4. Preweaning performance of calves by age of dam

(Means $\pm$ standard errors)

Age of dam	N	Birth weight	205-day weaning weight	Average daily gain	Conformation score
yr		lb	lb	lb	units
			STEERS		
2	71	67.3 ± 1.2^b	421 ± 8^b	$1.77 \pm .04^b$	$13.9 \pm .1^b$
3	74	73.9 ± 1.1^a	450 ± 7^b	$1.83 \pm .04^b$	$13.9 \pm .1^b$
4	90	77.9 ± 1.2^a	439 ± 6^b	$1.76 \pm .03^b$	$14.0 \pm .1^b$
5 - 10	237	$76.7 \pm .8^a$	441 ± 4^b	$1.78 \pm .02^b$	$14.4 \pm .1^a$
11+	16	78.7 ± 2.8^a	488 ± 12^a	$2.00 \pm .06^a$	$14.6 \pm .2^a$
			HEIFERS		
2	63	60.7 ± 1.3^c	402 ± 8^b	$1.67 \pm .04^b$	$13.3 \pm .1^b$
3	86	69.7 ± 1.1^a	441 ± 6^a	$1.81 \pm .03^a$	$13.8 \pm .1^{ab}$
4	73	72.4 ± 1.2^a	432 ± 7^a	$1.76 \pm .03^{ab}$	$14.2 \pm .1^a$
5 - 10	297	$71.9 \pm .6^a$	423 ± 4^{ab}	$1.71 \pm .02^{ab}$	$14.4 \pm .1^a$
11+	13	66.3 ± 2.8^b	451 ± 12^a	$1.87 \pm .06^a$	$14.6 \pm .3^a$

[a,b,c]Column means within sex groups with different superscripts are different, $P<.05$.

1979*a,b*; Arthur et al., 1982; Marlowe and Tolley, 1982).

Age of Dam

Age of dam had a significant effect ($P<.05$) on all performance traits, as shown in Table 4 and illustrated in Figure 1. Birth weight was lowest for calves out of two-year-old cows. Heifer calves from cows in the three-, four-, and five-to-10-year age brackets were heavier at birth than calves from cows 11 years old and older. Birth weights of male calves from cows three years old and older were not significantly different. Steers from cows in the 11+ age group were the heaviest at weaning and gained the most rapidly from birth to weaning. Average daily gain and weaning weight of heifer calves from cows aged three years old and older did not differ significantly. Heifer progeny from two-year-old cows were lighter at weaning than calves from cows aged three, four, and 11+ years. Steers from cows in the 11+ and five-to-10-year age groups had higher weaning conformation scores than those from cows aged four, three, and two years. Conformation scores for heifers from cows three years old and older did not differ significantly; heifers from two-year-old cows had conformation scores lower than heifers from

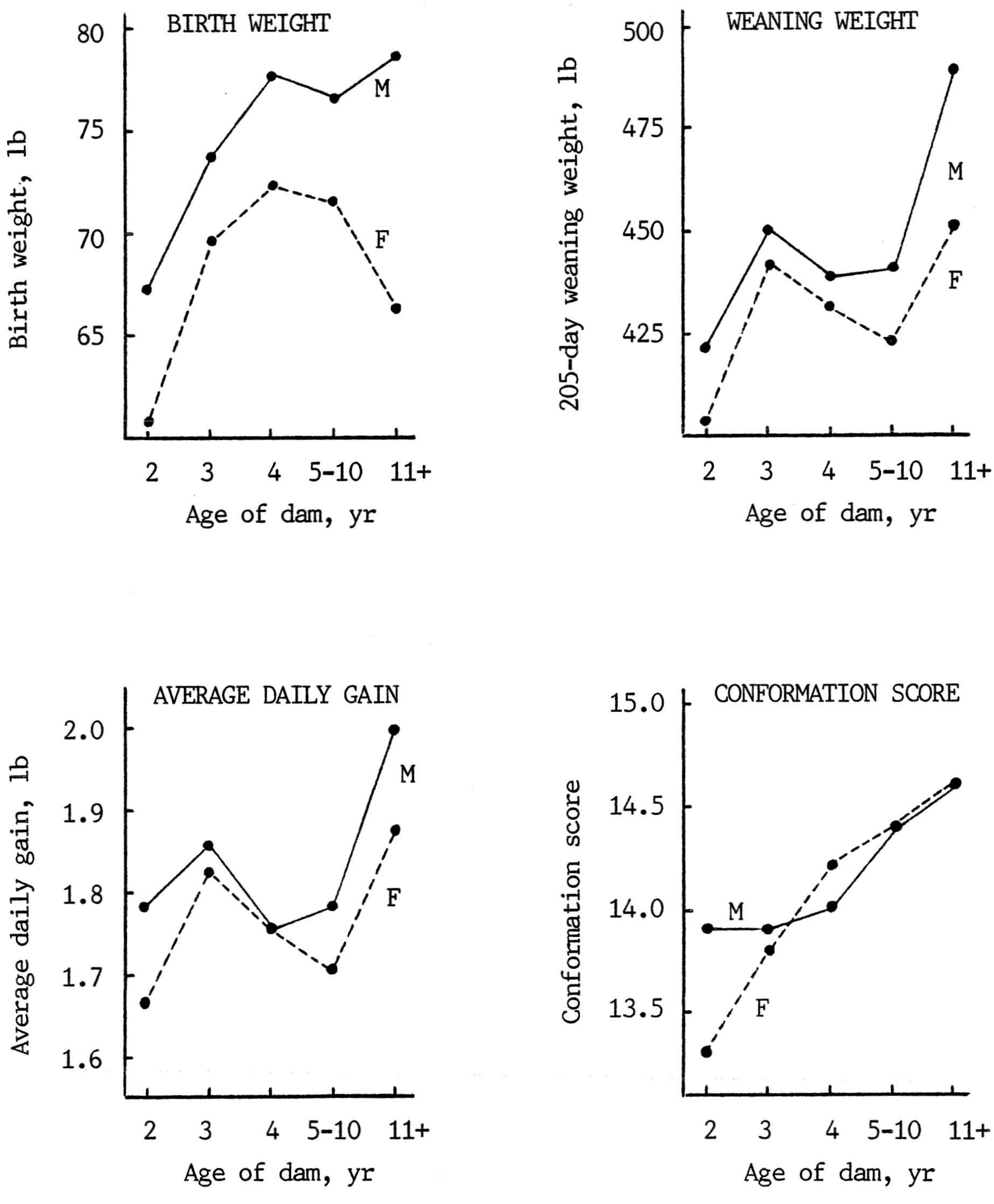

Figure 1. Effect of age of dam on preweaning traits of calves (M = males, F = females).

Table 5. Preweaning performance of calves by year born

(Means ± standard errors)

Year born	N	Birth weight	205-day weaning weight	Average daily gain	Conformation score
		lb	lb	lb	units
			STEERS		
1980	56	73.1 ± 1.5^{b}	447 ± 8^{b}	$1.83 \pm .04^{b}$	$14.4 \pm .1^{a}$
1981	103	72.7 ± 1.2^{b}	404 ± 7^{c}	$1.61 \pm .03^{c}$	$14.0 \pm .1^{b}$
1982	84	$75.3 \pm .9^{ab}$	484 ± 6^{a}	$1.99 \pm .03^{a}$	$14.0 \pm .1^{b}$
1983	81	77.0 ± 1.1^{a}	473 ± 5^{a}	$1.93 \pm .02^{a}$	$14.1 \pm .1^{b}$
1984	77	76.4 ± 1.1^{a}	408 ± 6^{c}	$1.62 \pm .03^{c}$	$14.0 \pm .1^{b}$
1985	87	76.7 ± 1.4^{a}	444 ± 5^{b}	$1.79 \pm .02^{b}$	$14.5 \pm .1^{a}$
			HEIFERS		
1980	89	70.7 ± 1.1^{ab}	433 ± 5^{bc}	$1.77 \pm .02^{c}$	$14.5 \pm .1^{a}$
1981	113	$66.3 \pm .9^{c}$	374 ± 6^{e}	$1.50 \pm .03^{e}$	$13.8 \pm .1^{b}$
1982	79	69.5 ± 1.2^{b}	447 ± 6^{b}	$1.84 \pm .03^{b}$	$13.9 \pm .1^{b}$
1983	110	$71.9 \pm .9^{ab}$	468 ± 5^{a}	$1.93 \pm .02^{a}$	$13.8 \pm .1^{b}$
1984	64	72.7 ± 1.3^{a}	423 ± 7^{cd}	$1.71 \pm .03^{cd}$	$14.5 \pm .1^{a}$
1985	77	71.4 ± 1.3^{ab}	412 ± 6^{d}	$1.66 \pm .03^{d}$	$14.5 \pm .1^{a}$

[a,b,c,d,e]Column means within sex groups with different superscripts are different, $P<.05$.

Table 6. Heterosis for preweaning traits in Angus, Hereford, and Santa Gertrudis crosses

Cross[a]	Birth weight	205-day weaning weight	Average daily gain	Conformation score
	%	%	%	%
		STEERS		
HA	2.5	11.2**	13.5**	1.4
AH	-4.5	5.1	7.4	1.4
SGA	12.6**	15.3**	16.1**	3.6*
SGH	10.7**	10.6**	10.7*	2.2
		HEIFERS		
HA	3.9	11.7**	13.0**	2.9
AH	1.5	-.3	.6	.7
SGA	12.2**	0	-2.2	-.7
SGH	12.0**	10.7**	9.6*	3.6

[a]A = Angus; H = Hereford; SG = Santa Gertrudis. Breed of sire is listed first in all crosses.

*P<.05
**P<.01

cows four years old and older. Other studies have reported comparable increases in birth weight, weaning weight, and ADG as age of dam advanced from two to four years (Marlowe and Gaines, 1958; Swiger, 1961; Hamann et al., 1963).

Year Born

Year of birth was a significant (P<.05) source of variation for all traits (Table 5). This is not unexpected because annual fluctuations in climatic conditions may have a profound effect on available feed supplies and this, in turn, directly influences animal performance and productivity. A prolonged drought in 1981 and substantially lower than average rainfall in 1984 were at least partially responsible for the significantly lower weaning weights recorded for those years.

Heterosis

Heterosis effects, shown in Table 6, were significant (P<.01) among HA calves for weaning weight (11.2 percent for males; 11.7 percent for females) and for ADG (13.5 percent for males; 13.0 percent for females); AH males showed significant (P<.05) heterotic effects for weaning weight (7.4 percent). Previous studies by Reimer and Nolan (1982) and Reimer et al. (1983) showed a similar pattern, i.e., higher levels of heterosis for HA than for AH crosses. Reimer et al. (1985) reported significant levels of heterosis for all preweaning traits among HA calves, while differences between AH and straightbred calves were nonsignificant. These authors concluded that the differential response in hybrid vigor between reciprocal crosses indicates higher maternal ability for A females. The results of the present study are considerably higher for weaning weight and ADG than those recorded by Dillard et al. (1980), who reported 1.2 and 7.5 percent heterosis for weaning weight and 1.4 and 6.9 percent for ADG for AH and HA crosses, respectively. Heterotic effects among crosses of the A and H breeds reported by Gray et al. (1978) were 0, 4.8, and 1.8 percent for birth weight, weaning weight, and conformation score, respectively.

Heterotic effects for SGA calves were significant ($P<.01$) for all traits among male calves, but significant only for birth weight among heifer calves. The performance of SGA males is consistent with results obtained in previous studies in Hawaii by Reimer et al. (1985), but the nonsignificant differences in weaning weight and ADG observed between SGA heifers and calves of the straightbred parental breds are not in agreement with earlier studies. Both male and female calves of SGH breeding exhibited significant ($P<.01$) levels of heterosis for all preweaning traits except conformation score.

Results of the present study and related studies by Reimer (1985) and Reimer et al. (1982, 1983, 1985) indicate that profitable beef production in the future under Hawaiian range conditions will rely heavily upon crossbreeding as a means of attaining maximum productivity. Since crossbreeding systems are virtually unlimited, the producer is faced with the bewildering task of selecting the system most appropriate for his or her management program and environmental conditions. Some of the breeding systems that offer substantial advantages in terms of hybrid vigor are not readily acceptable to the producer because they may be too complicated for application to commercial ranch operations.

In the present study the three-breed cross appears to be the most efficient of the mating systems evaluated. In order to use this type of mating system to best advantage, the authors recommend a three-breed rotation crossing program. The procedure for initiating and operating this type of breeding plan is simple and readily accomplished. In natural breeding herds three separate breeding pastures are required, each headed by a different breed of sire. The system generates its own replacement females, and heifers selected for breeding rotate to an unrelated sire breed group and remain there for life. All cows in the system are crossbred, thereby providing maternal heterosis in addition to individual heterosis in the progeny. Purebred bulls are purchased and can remain in the herd as long as they produce desirable offspring. The cumulative advantage to be realized from a three-breed rotation mating system is about 20 percent (Gregory and Cundiff, 1980).

A simple system of sire-rotation crossbreeding is outlined by Clarke (1984), who demonstrated that up to a 16 percent advantage can be maintained by merely changing the breed of sire every two to four years.

The producer needs to determine what type of mating system is best suited to the particular situation, based on his or her objectives and the resources available. Whatever system is chosen today may have to be modified in the future to accommodate changes in objectives, resources, and market demands.

SUMMARY AND CONCLUSIONS

This study was designed to evaluate the effects of mating system, breed of sire, breed of dam, age of dam, year of birth, and heterosis on preweaning performance of calves raised under Hawaiian range conditions. Calf performance traits measured included birth weight, 205-day adjusted weaning weight, average daily gain from birth to weaning, and weaning conformation score. The study involved 488 steers and 532 heifers born over a six-year period from 1980 to 1985. All of the main effects were found to have a significant ($P<.05$) influence on calf performance traits. The three-breed mating system produced calves that ranked at or near the top for all traits measured, calves from the two-breed and four-breed mating systems were intermediate, and backcross and straightbred calves generally ranked the lowest. Brahman-sired calves were the heaviest at birth, while A-sired calves ranked at the lower end of the birth scale. Breed-of-dam effects were significant only for heifer calves; the heaviest birth weights were recorded by calves out of HA, SGA, H(SGA), and SG dams, the heaviest weaning and fastest growing calves were out of SGA, SG, and HA dams, and weaning conformation scores were the highest for calves from SGA, SG, SGH, HA, and A cows. Two-year-old dams had the lightest calves at birth; steers from

cows three years old and older did not differ significantly in birth weight, while heifer calves from three- to 10-year-old cows were heavier than those from cows 11 years old and older. Steers from cows in the 11+ age group were the heaviest at weaning and highest in ADG; heifer calves from dams three years old and older did not differ significantly in these traits. Year of birth was a significant factor influencing calf performance traits. Heterosis was significant ($P<.01$) for HA calves for weaning weight and ADG; AH steers showed heterosis ($P<.05$) only for weaning weight. Heterotic effects were significant ($P<.01$) for all traits among SGA males, but significant only for birth weight among heifer calves. SGH calves exhibited significant ($P<.01$) levels of heterosis for all traits except conformation score.

The authors recommend a three-breed rotation crossing system for commercial beef production under Hawaiian range conditions.

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