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EVALUATION OF CROSSBREEDING SYSTEMS FOR PREWEANING TRAITS IN BEEF CATTLE

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SUMMARY

Data from a four-generation crossbreeding experiment with Hereford, Angus and Shorthorn cattle were analyzed. Individual, maternal, and grand-maternal additive and heterotic effects on the composite trait of calf weight weaned per cow exposed to breeding and its component traits were evaluated. The parameter estimates were then used to project performance at equilibrium under rotation crossbreeding. The average of two-breed cross rotations is expected to increase calf weight weaned per cow exposed by 18 percent above the average of the three straight breeds. The three-breed cross rotation is expected to increase calf weight weaned per cow exposed by 23 percent above the average of the three straight breeds. For the average of all two-breed cross rotations combined with a terminal sire crossbreeding system, the expected increase in calf weight weaned per cow exposed above the average of all straight breeds is 24 percent. On the same basis, the expectation for a three-breed cross rotation combined with a terminal sire crossbreeding system is 28 percent.

INTRODUCTION

Income to commercial cow-calf operators is determined largely by the total weight of weaned calves. Capital and feed costs associated with maintenance of a production unit are highly related to the number of cows. Therefore, the composite trait, weaning weight per cow exposed to breeding, is indicative of both biological and economic efficiency of a cow-calf enterprise.

Crossbreeding offers opportunities to improve upon performance of straightbred populations. Exploitation of additive genetic variation among breeds can result in a mid-parent more desirable for composite traits than either parent (Moav, 1966). Important differences exist among breeds for most of the components of weaning weight per cow exposed (Long, 1980) and between breed differences may be highly heritable for some component traits. Favorable heterosis for components of weaning weight per cow exposed to breeding presents a further opportunity to improve the efficiency of cow-calf enterprises. The objective of crossbreeding systems is to optimize the use of heterosis and additive breed effects simultaneously (Gregory and Cundiff, 1980).

This study utilized data from a four generation crossbreeding experiment to estimate breed specific additive and heterotic effects on weaning weight per cow exposed to breeding and its component traits. Systematic breeding programs which utilize the additive and heterotic effects are then examined.

MATERIALS AND METHODS

The experiment was initiated in 1957 with the Angus, Hereford and Shorthorn

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ds at the Fort Robinson Beef Cattle Research Station in northwest Nebraska. tation in this area is composed primarily of native short and intermediate ses. Calves were born from mid-February to early May. Birth weight was ined within 24 h after birth and male calves were castrated and dehorned. calves ran with their dams on the range and were weighed and weaned in early ober at an average age of approximately 200 days. When the calves were ned, cows were palpated to determine their pregnancy status.

In phase I, Angus, Hereford and Shorthorn bulls were mated to Angus, eford and Shorthorn cows to produce straightbred (n=360) and two-way cross 393) progeny (Gregory et al., 1965; Wiltbank et al., 1967). These calves e produced in years 1960 through 1963 when the cows were 3 through 6 years of e, respectively.

In phase II, the straightbred heifers produced in phase I were mated to lls of a different breed to produce two-breed cross calves (n=420) and the ntemporary two-breed cross heifers were mated to produce three-breed cross lves (n=555) (Cundiff et al., 1974a,b). Heifers born in 1960 and 1961 were anaged to calve first at 3 years of age. Heifers born in 1962 and 1963 were anaged to calve first as 2 year-olds. The first calves in phase II were born n 1963. Phase II calves were produced through 1968.

In 1969 through 1972 the cows which had produced phase II calves were used o produce phase III calves (unpublished). The mating plan was to produce ackcross (n=325) and three-breed cross (n=175) calves from the two-breed cross cows establishing the basis for two- and three-breed rotation crossbreeding systems in all possible breed rotations. Contemporary straightbred calves (n=312) were produced from the straightbred cows.

At weaning the heifer calves born in all years of phase III were transferred to the Roman L. Hruska U.S. Meat Animal Research Center (MARC) at Clay Center in south-central Nebraska. Cows were transferred to MARC before calving in 1972 and were maintained continuously on improved cool-season and warm-season grass pastures and provided supplemental feed as conditions warranted. Otherwise, the cattle were managed in a similar manner at both locations.

Phase IV (unpublished) was the continuation for another generation of the mating systems established in phase III. Thus, the two-breed rotation system was carried on for two generations beyond the initial two-breed cross cows and the first backcross progeny were produced in the three-breed rotation system. The first calf crop in phase IV was born in 1971 and a total of five calf crops were produced. Two-hundred-four straightbred calves, 194 two-breed cross calves and 155 three-breed cross calves were weaned in phase IV.

The data for component traits of weaning weight per cow exposed to breeding used in this report are least squares means for calf breed groups from the analyses of the individual phases. Weaning weight per cow exposed to breeding (W) was calculated from the trait means for each breed group:

$$W = P_1 * (1 - P_2) * (1 - P_3) * [BW + (289 - BD) \times ADG].$$

Where: P_1 is the probability of a detectable pregnancy at palpation;
P_2 is the probability of a calf's death prior to parturition;
P_3 is the probability of a calf's death between birth and weaning;
BW is the weight of the calf at birth;
BD is the julian day of the calf's birth; and
ADG is the average daily gain of the calf between birth and weaning.

This formulation assumes weaning occurs on julian day 289 each year.

The breed group means were equated to their genetic expectations of individual, maternal and grandmaternal additive and heterotic effects (Dickerson, 1969) and a block effect for phase of the experiment. Since no crossbred males ... maternal and grandmaternal heterotic effects are completely confounded with individual and maternal epistatic recombination effects, respectively. The estimates of heterosis are estimates of the effective heterosis in rotation crossbreeding systems. Standard regression theory was used to predict the performance of straightbred and rotation mating systems and estimate the standard errors (Kinghorn, 1982).

RESULTS AND DISCUSSION

Parameter estimates for breed additive and heterotic effects are presented in table 1. Table 2 contains predicted levels of performance for various straightbred and rotation mating systems.

Predicted performance of a straightbred is the sum of the overall mean performance and respective breed individual, maternal and grandmaternal breed additive effects. It is projected that Hereford straightbreds would be intermediate for weaning weight per cow exposed to breeding between Angus and Shorthorn and not significantly different from either. Angus are projected to significantly exceed Shorthorn for weaning weight per cow exposed to breeding. The relatively poor performance of the straightbred Shorthorn appears due to the reduced pregnancy rate resultant from the individual breed additive effect on pregnancy rate. In crossing, the Shorthorn individual breed additive effect was partially offset by larger than average, but non-significant individual breed specific heterotic effects on pregnancy rate.

On average, the two breed rotation systems significantly exceeded the straightbred systems in production of weaning weight per cow exposed to breeding. Accumulated favorable heterotic effects under the rotation system add approximately 27 kg (18 pct) of weaning weight per cow exposed to the average of the straightbreds. The increment due to heterosis under the two-breed rotation system offset the reduced additive genetic merit from the use of a second breed of lesser genetic merit than the best straightbred.

The three-breed rotation system yielded 34 kg (23 pct) more weaning weight per cow exposed than the average of the three straightbreds. Addition of a third breed to a two-breed rotation system to form a three-breed rotation depends on benefits from an additional 19 percent (67 pct for two-breed vs 86 pct for three-breed rotations) of the accumulated heterotic effects being sufficient to offset any reduction in additive genetic merit from the third breed. Based on these data the expected 19 percent increase in heterosis should increase weaning weight per cow exposed by an average of 7 kg. Addition of either Shorthorn or Hereford to the Angus-Hereford and Angus-Shorthorn rotation systems, respectively, was not rewarded with a significant increase in productivity. Addition of the most favorable straightbred, Angus to the two-breed rotation composed of Hereford and Shorthorn did significantly increase weaning weight per cow exposed for breeding.

Knowledge of additive effects of a terminal sire breed on component traits of weaning weight per cow exposed to breeding is required to implement crossbreeding systems which make use of a terminal sire breed (table 2). Data were not available for the component traits pregnancy rate and mortality to birth. It is assumed that effects of the hypothetical terminal sire breed on these two components of weaning weight per cow exposed were nil. Predicted individual additive effects for the other components of weaning weight per cow exposed to breeding were a: 6.4 percent increase in calf mortality to weaning, 1.75 d later calving date, 4.3 kg increase in birth weight, and 29.5 g/d increase in preweaning daily gain. Use of a terminal sire breed also enables full use of individual heterosis in the progeny produced.

The hypothetical terminal sire breed was used on simulated two- and three-breed rotation cows. Two- and three-breed rotation systems combined with the terminal sire breed produced, respectively, 24 pct and 28 pct more calf weight

TABLE 1. BREED ADDITIVE AND HETEROSIS EFFECTS ON WEANING WEIGHT PER COW EXPOSED TO BREEDING AND ITS COMPONENT TRAITS

Effect[a]	Breed[b]	Pregnancy rate, %	Mortality to birth, %	Calving date, d	Birth weight, g	Mortality to weaning, %	Preweaning growth rate, g/d	Weaning weight per cow exposed, kg
Additive								
Individual	A	.3±2.3	-1.6±1.6	-.8±1.5	-121±36	.7±2.2	43±13	8.1±5.8
	H	4.9±2.3	.4±1.6	1.8±1.5	167±36	-.1±2.2	5±13	9.5±5.8
	S	-5.2±2.3	1.2±1.6	-1.0±1.5	-46±36	-.6±2.2	-49±13	-17.6±5.8
Maternal	A	.4±2.1	.6±1.5	-1.6±1.4	-10±34	.9±2.1	36±12	4.9±5.4
	H	-2.0±2.1	1.2±1.5	1.1±1.4	7±34	2.3±2.1	-63±12	-20.0±5.4
	S	1.6±2.1	-1.8±1.5	.6±1.4	4±34	-3.1±2.1	27±12	15.0±5.4
Grand-maternal	A	1.2±1.5	-.3±1.1	-.3±1.0	-37±25	.1±1.5	-22±9	-.9±3.9
	H	.6±1.5	-.8±1.1	1.3±1.0	25±25	-3.2±1.5	18±9	9.9±3.9
	S	-1.8±1.5	1.1±1.1	-1.0±1.0	12±25	3.0±1.5	4±9	-8.9±3.9
Heterosis								
Individual	A x H	-1.1±3.3	3.4±2.3	3.7±2.1	1722±524	-4.1±3.2	49±18	8.1±8.4
	A x S	3.4±3.3	2.3±2.3	-.9±2.1	1150±524	-4.2±3.2	14±18	13.7±8.4
	H x S	1.9±3.3	-.8±2.3	-.1±2.1	2814±524	-.2±3.2	61±18	18.7±8.4
Maternal	A x H	4.5±2.5	-2.0±1.8	-2.9±1.7	571±407	1.0±2.5	47±14	19.8±6.5
	A x S	4.6±2.5	-2.3±1.8	-1.0±1.7	-135±407	.8±2.5	25±14	15.5±6.5
	H x S	3.8±2.5	1.8±1.8	-5.0±1.7	538±407	3.5±2.5	46±14	9.2±6.5
Grand-maternal	A x H	-3.0±4.1	.7±2.8	-5.8±2.7	-684±657	-5.3±4.0	9±23	3.6±10.5
	A x S	2.0±4.1	-2.4±2.8	-4.1±2.7	342±657	-4.6±4.0	35±23	20.3±10.5
	H x S	-2.6±4.1	-1.2±2.8	-4.3±2.7	-402±657	-7.2±4.0	-1±23	8.8±10.5

[a]Effects estimated simultaneously by multiple regression methods.

[b]A=Angus, H=Hereford, S=Shorthorn.

TABLE 2. ESTIMATES OF WEANING WEIGHT PER COW EXPOSED TO BREEDING AND ITS COMPONENTS FOR STRAIGHTBRED AND TWO- AND THREE-BREED ROTATION MATING SYSTEMS AT EQUILIBRIUM

TABLE 2. ESTIMATES OF WEANING WEIGHT PER COW EXPOSED TO BREEDING AND ITS COMPONENTS FOR STRAIGHTBRED AND TWO- AND THREE-BREED ROTATION MATING SYSTEMS AT EQUILIBRIUM

Mating system	Breeds[a]	Pregnancy rate, %	Mortality to birth, %	Calving date	Birth weight, kg	Mortality to wean-ing, %	Preweaning growth rate, g/d	Weaning weight per cow exposed, kg
Straightbred	A	90.7±2.7	2.6±1.9	76.8±1.8	30.7±.4	9.9±2.7	808±15	161±7
	H	92.4±2.7	4.8±1.9	83.5±1.8	34.4±.4	7.3±2.7	713±15	148±7
	S	83.4±2.7	4.5±1.9	77.9±1.8	32.1±.4	7.5±2.7	732±15	137±7
	Average	88.8±1.7	4.0±1.2	79.4±1.1	32.4±.3	8.2±1.7	751±10	148±4
Two-breed rotation	A H	91.8±2.3	5.1±1.6	76.8±1.5	33.7±.4	3.0±2.2	830±13	176±6
	A S	93.7±2.3	1.9±1.6	73.3±1.5	32.3±.4	3.3±2.2	819±13	182±6
	H S	90.0±2.3	4.5±1.6	74.4±1.5	35.2±.4	4.7±2.2	793±13	167±6
	Average	91.8±1.8	3.8±1.3	74.8±1.2	33.7±.3	3.7±1.8	814±10	175±5
Three-breed rotation	A H S	92.7±2.2	3.8±1.6	73.6±1.5	34.1±.4	2.4±2.2	832±13	182±6
Two-breed maternal rotation with a terminal sire breed[b]	A H	92.7±2.1	4.8±1.5	78.7±1.4	38.6±.3	9.1±2.1	856±12	183±5
	A S	94.0±2.1	2.1±1.5	79.0±1.4	38.2±.3	9.7±2.1	882±12	192±5
	H S	90.2±2.1	6.3±1.5	79.0±1.4	39.3±.3	8.6±2.1	834±12	175±5
	Average	92.3±1.6	4.4±1.1	78.9±1.0	38.7±.3	9.1±1.5	858±9	183±4
Three-breed maternal rotation with a terminal sire breed[b]	A H S	92.9±2.1	4.0±1.5	76.9±1.4	38.7±.3	8.4±2.1	868±12	189±5

[a] A=Angus, H=Hereford, S=Shorthorn.

[b] Direct effects for the terminal sire breed were the average of the direct effects for Brown Swiss, Gelbvieh, Maine Anjou, Simmental, Limousin, Charolais and Chianina breeds from the Germ Plasm Evaluation Program (Smith et al., 1976; Gregory et al., 1978). Data were not available to estimate the direct effects of the terminal sire breed for pregnancy rate and mortality to birth. The deviations attributed to the terminal sire breed for pregnancy rate and mortality to birth were assumed to be zero.

weaned per cow exposed than the average of the three straightbreds. Relative to the two- and three-breed rotation systems, the two- and three-breed maternal rotation systems in conjunction with the terminal sire breed produced seven to eight kg more calf at weaning per cow exposed for breeding. These results are indicative of maximum productivity of a terminal sire system with these breed resources as no cows are used to simulate production of replacement females. If replacement females are saved from the two- or three-breed rotation phase of a combined system the advantage indicated for adding the terminal sire component to the system would be reduced by about one-half (Gregory and Cundiff, 1980). The cost of achieving this additional output through use of a terminal sire system as assumed in this analysis may exceed the value of the increased output for many production situations. Results reported here are limited to preweaning traits and do not take into consideration any improvement in postweaning growth rate, feed efficiency or carcass composition as usually expected from using a terminal sire breed.

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