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ABSTRACT: Heterosis, assumed proportional to expected breed heterozygosity, was calculated for 4,835 individuals with birth, weaning and yearling weight records from Cycle VII of the U.S. Meat Animal Research Center Germplasm Evaluation Program. Heterosis was further estimated by proportions of British x British (BxB), British x Continental (BxC) and Continental x Continental (CxC) crosses. Angus and Red Angus were considered a single breed for estimation of heterosis. Direct heritability estimates (SE) for birth, weaning and yearling weight were 0.39 (0.05), 0.18 (0.04) and .40 (0.06), respectively. The BxB covariate was significant and BxC approached significance for weaning weight. The BxB proportion was significant for yearling weight. Heterosis in BxB tended to be higher at yearling than CxC and BxC.
Keywords: beef cattle; heterosis; growth traits

Introduction

The benefits of crossbreeding and the effects of heterosis on growth traits have been well documented. The cumulative effects of heterosis on individual and maternal traits obtained from breed crosses have been shown to be of great economic importance (Gregory and Cundiff, 1980; Long, 1980). Heterosis achieved through crossbreeding can increase weaning weight per cow exposed by 20% (Gregory et al., 1991). Crossing breeds that are more divergent generates increased levels of heterosis as compared to crossing breeds that are more closely related. Cartwright et al (1964) and Koger et al. (1975) presented results that suggested the cumulative effects of heterosis contributing to calf weaning weight per cow exposed may be more than twice as great for crosses of *Bos indicus* breeds with *Bos taurus* breeds than among *Bos taurus* breeds.

Specific estimates of heterosis for various crosses of breeds could be useful when selecting breeds for a crossbreeding system and developing composite populations for various production environments. Differences in estimates of heterosis based on breed composition could be useful in multi-breed evaluations as heterosis and breed differences are used in the genetic predictions. The objective of this study was to calculate direct and maternal breed and heterosis effects by breed type for birth, weaning and yearling weight.

Materials and Methods

Animals. In Cycle VII of the U.S. Meat Animal Research Center (USMARC) Germplasm Evaluation (GPE) Project, purebred Angus (AN), Hereford (HH), Simmental (SM), Limousin (LM), Charolais (CH), Gelbvieh (GV), and Red Angus (AR) sires were mated by artificial insemination (AI) to composite MARC III- [1/4 AN, 1/4 HH, ¼ Pinzgauer (PZ), 1/4 Red Poll (RP)], AN- and HH-base cows to produce progeny designated as F_1, born in 1999, 2000, and 2001. The 1999- and 2000-born male calves were castrated and fed for slaughter. Female F_1 and the 2001-born F_1 males were kept for breeding, and mated in multiple-sire pastures to produce 2-, 3-, and 4-breed cross progeny designated F_1^2. The F_1^2 calves were born from 2003 to 2007 from 3-yr-old and older dams. Male calves were castrated within 24 h after birth. Calves were weaned in September at approximately 165 d of age. After weaning, steers were managed and fed for slaughter, and heifers were developed for breeding starting the following May (Snelling et al., 2010).

Data. Birth, weaning and yearling weights were recorded for 4,845 animals. Outliers were identified and removed if the record was three standard deviations away from the mean, fitting sex, age of dam and year of birth as fixed effects. After outliers were removed, there were 4809 birth weight records, 4,620 weaning weight records and 4,501 yearling weight records. Contemporary groups were formed based on year and season of birth, location of birth and age of dam. All AI sires were assigned a genetic group according to their breed of origin. Dams mated to AI sires and natural service sires mated to F_1 females were also assigned to different genetic groups (i.e., Hereford dams were assigned to different genetic groups than Hereford AI sires). The genetic groups included in cycle VII of the GPE included AI Angus, AI Hereford, AI Red Angus, AI Gelbvieh, AI Charolais, AI Limousin, AI Simmental, commercial Hereford, commercial Angus and MARC III.

Statistical analysis. Breed fractions were assigned for each individual based on pedigree information. The proportions were then grouped into biological type, British or Continental. Expected breed heterozygosity was calculated for each individual as one minus the proportion of the same breed from the sire and dam. Proportions of heterozygosity were then assigned to the fraction from a British cross, Continental cross or British x Continental cross. Angus and Red Angus were considered a single breed. The proportion of Angus x Red Angus represented in the British x British covariate was 0.15 averaged over all three traits.

All traits were analyzed using ASReml (Gilmour et al., 2009). Fixed effects included sex; the covariates of expected breed heterozygosity from British x British, Continental x Continental, and British x Continental from the cross; and contemporary group (birth year and season, birth location and age of dam). Random effects included direct and maternal additive genetic effects, maternal permanent environmental effect, and a residual.

Results and Discussion

Genetic parameters. The birth, weaning and yearling weight means (SE) were 40.6 (5.8) kg, 244.3 (34.3) kg, and 424.7 (51.71) kg, respectively (Table 1). Variance components and parameter estimates are presented in Table 2. The direct heritability estimates (SE) of birth, weaning and yearling weight were 0.39 (0.05), 0.18 (0.04) and 0.40 (0.06), respectively. These estimates were slightly lower than previous estimates of birth weight recorded at USMARC of 0.44, (Bennett and Gregory, 1996). Maternal heritability estimates were 0.09 (0.05), 0.17 (0.06) and 0.06 (0.04) for birth, weaning and yearling weight respectively. These estimates correspond closely to the estimates of maternal heritability for birth, weaning and yearling weight from Koch et al. (1994). Sex had a significant effect on all traits ($P < 0.001$). As expected, heifers were lighter at birth, weaning, and yearling ages and steers were intermediate to bulls and heifers at weaning and yearling ages.

Table 1. Number of observations (N) and mean (±SE) (kg) for birth, weaning and yearling weight.

Trait	N	Mean (kg)
Birth weight	4807	40.6 (5.8)
Weaning weight	4618	244.3 (34.3)
Yearling weight	4499	424.7 (65.3)

Table 2. Variance component and parameter estimates (SE) for birth weight (BWT), weaning weight (WT205D) and yearling weight (WT365D)

§Model item	¥BWT	WT205D	WT365D
&Variance Component			
V_p	25.4 (0.63)	571.1 (14.7)	1504.7 (39.3)
V_a	9.9 (1.49)	102.6 (21.8)	603.5 (104)
$Cov_{a,m}$	0.5 (0.80)	-30.5 (20.8)	-57.0 (60.4)
V_m	2.4 (1.01)	96.5 (34.7)	85.3 (68.3)
V_{pe}	0.3 (0.65)	139.8 (24.0)	166.9 (45.8)
V_e	12.8 (0.93)	262.6 (14.8)	706.1 (63.8)
Heritabilities			
h^2_a	0.4 (0.05)	0.18 (0.04)	0.40 (0.06)
h^2_m	0.1 (0.04)	0.17 (0.06)	0.05 (0.04)
c^2	0.0 (0.03)	0.24 (0.04)	0.11 (0.03)

§V_p = phenotypic variance, V_a = direct genetic variance, $Cov_{a,m}$ = direct by maternal covariance, V_m = maternal genetic variance, V_{pe} = permanent environmental variance, V_e = residual variance, h^2_a = direct heritability, h^2_m = maternal heritability, c^2 = proportion of phenotypic variance due to permanent environmental effects.
¥BWT=birth weight, WT205D= weaning weight, WT365D= yearling weight.
&units = kg^2

Heterosis effects. The heterosis estimates for British x British, Continental x Continental, and British x Continental proportions were not significantly different from zero for birth weight. The British x British heterosis was significant and British x Continental approached significance for weaning weight. The British x British heterosis was significant for yearling weight. Heterosis estimates are lower than expected (Gregory et al., 1991). Given the structure of this data, strong estimates of overall heterosis were not expected. This could explain why some of the CxC estimates are negative (Table 3).

Table 3. Estimates of breed specific heterosis (±SE) (British x British, British x Continental and Continental x Continental heterozygosity) (kg) for birth, weaning and yearling weight.

§Covariate	¥BWT	WT205D	WT365D
BxB	0.2 (0.5)	7.6 (2.3)	15.6 (3.9)
BxC	0.1 (0.8)	6.8 (3.5)	3.8 (6.21)
CxC	-0.8 (1.3)	6.2 (5.9)	-3.7 (10.6)

§B=British, C=Continental, BWT=birth weight, WT205D= weaning weight, WT365D= yearling weight.
¥BWT=birth weight, WT205D= weaning weight, WT365D= yearling weight.

Contrasts among the estimates of British x British, British x Continental and Continental x Continental are presented in Table 4. Heterosis due to British x British and Continental x Continental differed by 19.4 (11.3) kg of yearling weight. The contrast between British x Continental and Continental x Continental was 11.8 (6.8) kg.

Table 4. Estimates of differences among heterosis (±SE) of breed groups (British x British, British x Continental and Continental x Continental) (kg) for birth, weaning and yearling weight.

§Contrast	¥BWT	WT205D	WT365D
BxB - CxC	1.0 (1.4)	1.4 (6.4)	19.4 (11.3)
BxC - CxC	1.0 (1.0)	0.6 (4.2)	7.5 (7.5)
BxB - BxC	0.0 (0.9)	0.8 (3.9)	11.8 (6.8)

§B=British, C=Continental, BWT=birth weight, WT205D= weaning weight, WT365D= yearling weight.
¥BWT=birth weight, WT205D= weaning weight, WT365D= yearling weight.

Conclusion

Differences between breeds and biological type exist and provide an opportunity to utilize specific breeds and exploit heterosis in a crossbreeding system to achieve production goals in various environments. Specific estimates of heterosis will also provide valuable estimates for multi-breed evaluations. Growth traits provide a valuable starting point in estimating breed-specific heterosis because of the availability of the data and the traits are moderately heritable. Further investigation of specific heterosis by breeds will provide useful estimates for the comparison and estimation of breeding values for various crosses.

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