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Breed Comparisons for Growth Traits Adjusted for Within-Breed Genetic Trend Using Expected Progeny Differences[1]

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ABSTRACT: Records (2,910) of birth (BWT), weaning (WW), and yearling weight (YW) of F_1 calves produced in a top-cross experiment involving Angus, Hereford, Pooled Hereford, Charolais, Limousin, Simmental, Gelbvieh, Maine-Anjou, Chianina, Tarentaise, Shorthorn, and Salers bulls mated to Hereford and Angus cows and records (4, 592) of WW on three-breed-cross calves out of 986 F_1 females of the same breed crosses were used in this study. The purposes were to estimate how much of the EPD of the sires was realized in crossbred calves and to estimate sire breed effects for the traits adjusted for genetic trend and sire sampling. Published EPD for BWT, WW, YW, net maternal ability (MLK), and maternal WW (MAT) were used. Average regressions (kilograms/kilogram ± SE) of BWT, WW, and YW of F_1 calves on EPD of the sire were 1.04 ± .10, .88 ± .11, and 1.40 ± .11, respectively. The regressions (b, kilograms/kilogram) were similar to the expected values of 1.0 except for YW. For WW of three-way-cross calves on MLK EPD of the maternal grandsire, b was 1.02 ± .11, which was not different from the expected value of 1.0. Estimated sire-breed means were adjusted to a 1982 genetic base by adding b times the difference of the 1982-breed-mean EPD and mean EPD of sires used in the study. Three different adjustments were compared using the b pooled across breeds, a separate b for each breed, and the expected b of 1.0. In general, the adjustments tended to regress breed of sire means toward the average of all breeds, particularly for BWT and WW of F_1 calves, and for WW of three-breed crosses. The effect of type of adjustment varied among breeds, but in most cases small differences resulted from using average or expected b. For WW, the range for net maternal effects among breeds was larger than that for direct breed effects.

Key Words: Expected Progeny Differences, Breed Differences, Beef Cattle, Growth Traits, Genetic Trend

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Introduction

Sire evaluation in beef cattle is currently based on information primarily taken on purebred progeny, and comparisons among EPD of sires are only valid within a particular breed. However, proven sires from the various breeds are used in crossbreeding systems by commercial beef cattle producers. Thus, across-breed comparison of sire EPD potentially would allow commercial beef cattle producers to make appropriate choices of breeds as well as sires to better fit a particular production environment. Notter (1989) listed the problems to be solved and the information required to select sires from multiple breeds for use in crossbreeding. Necessary information includes estimates of mean breed differences, after taking into account genetic trend and differences among breeds in the genetic base for EPD.

Recently, a discussion about genetic bases for cattle evaluation took place in relation to the use of across-breed EPD (BIF, 1990; Pollak, 1990). After considering the desirability of having a common base year for all breeds, Pollak (1990) recommended setting the average estimated genetic merit of all animals of a breed born in the year 1982 to zero. The purposes of this study were to estimate how much of the predicted EPD of a sire was realized in his crossbred calves and to estimate sire breed effects for growth traits using within-breed EPD to adjust breed comparisons for both sire sampling and genetic trends to the 1982 genetic base.

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Table 1. Number of F_1 progeny weaned having sires with weaning weight expected progeny differences, by breed of sire, cycle, and year

	Cycle I			Cycle II		Cycle III		Cycle IV					
Breed	1970	1971	1972	1973	1974	1975	1976	1986	1987	1988	1989	1990	Total
Angus	13	33	23	23	27	46	22	33	13	12	14	10	269
Hereford	41	28	10	13	31	40	33	19	13	10	17	11	266
P. Hereford	0	0	29	15	18	44	33	21	8	12	16	7	203
Charolais	125	65	109	0	0	0	0	22	14	12	8	9	364
Limousin	130	85	131	0	0	0	0	0	0	0	0	0	346
Simmental	142	127	107	0	0	0	0	0	0	0	0	0	376
Gelbvieh	0	0	0	92	101	0	0	0	0	0	0	0	193
Maine-Anjou	0	0	0	50	105	0	0	0	0	0	0	0	155
Chianina	0	0	0	79	137	0	0	0	0	0	0	0	216
Tarentaise	0	0	0	0	0	80	111	0	0	0	0	0	191
Shorthorn	0	0	0	0	0	0	0	36	29	14	33	43	155
Salers	0	0	0	0	0	0	0	49	33	31	37	26	176
Total	451	338	409	272	419	210	199	180	110	91	125	106	2,910

Materials and Methods

Description of Data. Records of F_1 and three-breed-cross calves produced in the Germ Plasm Evaluation (**GPE**) Program conducted at the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**), Clay Center, NE were used. First-cross calves were produced in Cycles I (1970 to 1972), II (1973 and 1974), III (1975 and 1976), and IV (1986 to 1990) of the GPE program (Table 1). Certain reference sires of the Hereford, Angus, and Polled Hereford breeds were used in all cycles of the GPE program to provide ties for estimation of breed of sire differences. New samples of Hereford, Angus, Polled Hereford, and Charolais bulls born since 1982 were used in Cycle IV.

Traits analyzed on F_1 calves were weights at birth (**BWT**, n = 2,883), 200 d (**WW**, n = 2,910), and 365 d (**YW**, n = 2,357). All F_1 calves with records included in this analysis were by sires with a published EPD for BWT, WW, or YW. Sire breeds represented in the F_1 calves (number of sires with available EPD given in parentheses) were Angus (36), Hereford (23), Polled Hereford (20, 19 for BWT), Charolais (42), Limousin (20), Simmental (28, 27 for WW), Gelbvieh (11), Maine-Anjou (15), Chianina (20), Tarentaise (7), Shorthorn (23), and Salers (27). Maine-Anjou EPD were available only for BWT and WW, and Chianina EPD were available only for WW. Thus, total numbers of sires were 251, 271, and 236 for BWT, WW, and YW, respectively. All calves were F_1 crosses out of Hereford or Angus dams.

First-cross calves were born in the spring, males were castrated within 24 h, and all calves were weaned at approximately 200 d of age, except that calves born in 1974 were weaned at 167 d of age because of drought conditions. After weaning, heifers were managed to calve first at 2 yr of age and were fed with a diet of approximately 50% corn silage and 50% alfalfa or grass haylage, plus protein and mineral supplement. Steers received a high-energy-density diet for approximately 196 d, after a preconditioning period of 25 to 40 d (58 d in 1974). Averaged across years and feeding periods, the diets contained (DM basis) approximately 12.8% CP, 9.2% digestible protein, and 2.79 Mcal of ME/kg. Detailed information on management of these animals has been reported (e.g., Smith et al., 1976; Laster et al., 1979; Cundiff et al., 1984).

Three-breed-cross progeny were produced by mating 986 of the F_1 females described above to unrelated sire breeds (Table 2). For Cycle I, the F_1 females were mated to Hereford, Angus, Brahman, Devon, and Holstein bulls for their first potential calving, to Hereford, Angus, Maine-Anjou, Chianina, and Gelbvieh for their second potential calving, and subsequently to Brown Swiss bulls. Cycle II females were mated to Hereford, Angus, Brangus, and Santa Gertrudis bulls for their first potential calving and were subsequently mated to 3/4 or 7/8 Simmental bulls. Cycle III and IV females were mated to Red Poll bulls for their first potential calving and were subsequently mated to Simmental bulls. Only WW was analyzed on these three-breed-cross calves. Preweaning management of three-way-cross calves was similar to that of F_1 calves and has been described for Cycle I females by Notter et al. (1978).

All three-breed-cross calves were out of maternal grandsires with a published net maternal EPD, also referred to as milk (**MLK**) EPD in the sire summaries. The MLK EPD represents the additive contribution of the sire to the weaning weight of calves of its daughters that is attributable to the maternal environment provided by its daughters. Milk EPD of a sire is free of direct effects on growth passed to the grandprogeny through its daughters. Maternal grandsire breeds included in the analysis, with number of maternal grandsires with MLK EPD available given in parentheses, were Angus (20), Hereford (19), Polled Hereford (14), Charolais (33), Limousin (20), Simmental (27), Gelbvieh (11), Chianina (19),

Table 2. Number of three-breed-cross progeny weaned having maternal grandsires with milk and weaning weight expected progeny differences, by breed of maternal grandsire and year

	Year														Total	
Breed	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1988	1989	1990	Calves	Dams
Angus	0	12	18	27	33	43	41	43	25	29	23	13	25	25	357	86
Hereford	13	14	22	27	34	49	55	42	32	33	28	10	14	22	395	89
P. Hereford	0	0	6	15	19	41	46	45	38	39	29	9	11	18	316	74
Charolais	26	42	80	86	80	79	77	40	0	0	0	4	9	15	538	119
Limousin	35	56	123	117	121	122	115	77	0	0	0	0	0	0	766	150
Simmental	34	77	122	122	128	116	117	80	0	0	0	0	0	0	796	152
Gelbvieh	0	0	0	32	68	68	67	59	57	57	31	0	0	0	439	77
Chianina	0	0	0	22	67	78	78	70	74	70	36	0	0	0	495	87
Tarentaise	0	0	0	0	0	29	60	63	63	65	61	0	0	0	341	78
Shorthorn	0	0	0	0	0	0	0	0	0	0	0	12	21	27	60	29
Salers	0	0	0	0	0	0	0	0	0	0	0	18	32	39	89	45
Total	108	201	371	448	550	625	656	519	289	293	208	66	112	146	4,592	986

Tarentaise (6), Shorthorn (17), and Salers (20), a total of 206 maternal grandsires.

The EPD for bulls used at MARC were obtained from the 1990 or 1991 national cattle evaluations of each breed. Mean EPD for all animals born in 1982 (or adjustment factors to the 1982 EPD base) were obtained from the breed associations (BIF, 1991).

The present study is an update of the analysis done by Notter and Cundiff (1991). This reanalysis was done on completion of Cycle IV of Phase 2 of the GPE Program. The new data for analysis included records from four additional breeds, Maine-Anjou and Chianina from Cycle II and Shorthorn and Salers from Cycle IV. These additional data represent an increase of 56 and 25% in number of records on F_1 and three-breed-crosses, respectively.

Models to Evaluate Breed of Sire Effects in F_1 Progeny. For F_1 progeny data, Model 1 included the effects of breed of dam × cow age × birth year × sex subclasses and breed of sire. The continuous effect of calendar day of birth was included in the analysis of BW. Ages of cows were classified as 2, 3, 4, or ≥ 5 yr. In Model 2, the EPD of the calf's sire was also included as a covariate, and homogeneity of regressions of performance traits on sire EPD across sire breeds, dam breeds, and sexes was tested by fitting the interaction of the covariate with sire breed, dam breed, and sex, respectively. The deviation of the regression coefficient from its expected value of 1.0 was also tested using the *t*-test statistic.

Sire breed means at MARC were then adjusted for sire sampling and genetic trend to a 1982 fixed base, as recommended for the purposes of research at the 1990 Beef Improvement Federation meeting, using the following procedure (Notter and Cundiff, 1991): Adjusted 1982 mean = breed mean at MARC + b (1982 mean breed EPD − mean EPD at MARC), where b = regression coefficient (kilograms/kilogram) of calf performance on the EPD of the sire, for the respective trait; breed mean at MARC = estimates of sire breed effects from least squares analysis; mean 1982 breed EPD = mean EPD of animals born in 1982; and mean EPD at MARC = Mean EPD of bulls of the same breed used at MARC.

Three types of adjustments were made by using 1) separate regression coefficients by breed, 2) pooled across-breeds regression, and 3) the expected regression of 1.0 kg/kg of EPD.

Models to Evaluate Breed of Maternal Grandsire Effects in Three-Breed-Cross Progeny. For three-breed-cross progeny data, Model 1 included the effects of cycle, age of dam (2-yr-old, 3-yr-old, and older), cycle × age of dam, birth year nested in cycle × age of dam, sex, grandsire breed, grandam breed, and sire breed nested in cycle × age of dam. In Model 2, the previous model of three-breed-cross calf data was augmented with either the continuous effect of the total maternal weaning weight (**MAT**) EPD of the maternal grandsire or simultaneous continuous effects of both the MLK and WW EPD of the maternal grandsire. The MAT EPD results from adding one-half of the WW EPD to the MLK EPD. This model allows testing whether the regression coefficients of weaning weight on either MAT, EPD, WW EPD, or MLK EPD are different from their expectations (1.0, .5, and 1.0, respectively). Also, homogeneity of these regression coefficients across breeds of maternal grandsire and grandam was tested.

The following procedure would adjust weaning weight of the maternal grandsire breeds at MARC to the 1982 base year: adjusted 1982 mean = breed mean at MARC + b_{WW} (1982 mean breed WW EPD − mean WW EPD at MARC) + b_{MLK} (1982 mean breed MLK EPD − mean MLK EPD at MARC), where b_{WW} = regression coefficient (kilograms/kilogram) of calf weaning weight on the direct weaning weight EPD of the maternal grandsire, b_{MLK} = regression coefficient (kilograms/kilogram) of calf weaning weight on MLK EPD of the maternal grandsire, and breed mean at MARC = estimates of maternal grandsire breed effects from least squares analysis.

Maternal grandsire breed means were also adjusted by using 1) separate regression coefficients by breed, 2) regressions pooled across breeds, and 3) the expected regressions of 1.0 and .5 kg/kg of MLK and WW EPD, respectively.

Analysis of Residuals. Notter and Cundiff (1991) suggested analyzing the residuals from analyses with and without adjustment for the EPD of the sire (or maternal grandsire) to compare sire variance components and heritabilities before and after adjustment. Thus, a model including breed of sire and sire nested within breed of sire was applied to the residuals from F_1 analyses. For the residuals from three-breed-cross analyses, a model including effects of breed of sire of the cow, sire of the cow nested within breed of sire of cow, and cow nested within sire of cow was fitted. Estimates of the variance components were obtained using Henderson's Method 3 (SAS, 1990). If accuracies of sire EPD are high, significant sire effects after adjustment for sire EPD would indicate either reranking of sires or contrasting differences among sires when mated to GPE cows compared with their ranking or differences in herds used to predict their EPD.

Results and Discussion

Means for EPD and accuracies and ranges in accuracy by trait and breed for sires of F_1 progeny and maternal grandsires of three-breed-cross progeny at MARC are shown in Tables 3 and 4. Accuracies for the various traits of sires used at MARC were high ($\geq .80$) for Limousin, Simmental, Gelbvieh, Chianina, and Tarentaise, intermediate (.50 to .75) for Angus, Hereford, and Charolais, and low (.25 to .45) for Polled Hereford and Maine-Anjou, Accuracy of EPD was not reported in Shorthorn and Salers breeds for all traits or in Hereford and Tarentaise for MLK.

F_1 Progeny. Regression coefficients of calf performance on sire EPD across sire breeds, dam breeds, and sexes were homogenous, except for YW, for which different slopes ($P < .05$) were found for steers and heifers. Within-sex regressions were obtained by analyzing two separate data sets composed of steer and heifer data. Pooled within dam breed × cow age × birth year subclass and sire-breed regression coefficients of YW on YW EPD were 1.57 ± .14 and 1.18 ± .16 kg/kg for steers and heifers, respectively. Steers at MARC were fed a diet with a relatively high energy density. In contrast, bulls in many purebred herds are fed diets of modest energy density. Heifers at MARC were managed to be bred at 15 mo of age, and thus their treatment was more similar to that experienced by purebred herds than to that experienced by males. Possibly, heritability of healing weight is greater in steers sampled from MARC than in bulls sampled from purebred herds produced in diverse environments. Heritability of yearling weight for females at MARC may be more similar to that for bulls and heifers in purebred herds.

Table 5 shows the estimates of regression coefficients of calf performance on sire EPD for the different traits and breeds. Regression coefficients for BWT and WW were not significantly different ($P > .05$) from their expected values of 1.0 and averaged 1.04 ± .10 and .88 ± .11 kg/kg of EPD, respectively. However, regression coefficients for Charolais, Limousin, and Shorthorn were greater ($P < .05$) than 1.0 for YW. The pooled, across-breed regression coefficient for YW was 1.40 ± .11 kg/kg of EPD, also greater ($P < .05$) than expected.

These results are similar to those reported by Notter and Cundiff (1991), who estimated regression coefficients of 1.09 ± .12, .79 ± .14, and 1.44 ± .16 for BWT, WW, and YW, respectively, based on data from the first three cycles of the GPE program. Wright and

Table 3. Mean sire expected progeny difference (EPD) (kg) and accuracy (ACC) and range in accuracy for each trait and sire breed[a]

	Birth wt			Weaning wt			Yearling wt		
Breed	Mean EPD	Mean ACC	Range ACC	Mean EPD	Mean ACC	Range ACC	Mean EPD	Mean ACC	Range ACC
Angus	.34	.58	.09–.93	2.35	.60	.08–.92	3.80	.54	.07–.85
Hereford	.32	.57	.27–.90	2.91	.67	.24–.92	3.19	.56	.08–.89
P. Hereford	.18	.41	.12–.92	–.14	.45	.32–.89	.33	.25	.11–.79
Charolais	.49	.75	.25–.92	.94	.75	.25–.92	1.98	.73	.24–.92
Limousin	–.11	.99	.97–.99	–2.81	.99	.96–.99	–4.02	.99	.94–.99
Simmental	.79	.91	.68–.97	–2.26	.91	.65–.97	–4.32	.88	.59–.97
Gelbvieh	–.18	.92	.74–.96	.46	.93	.76–.96	.72	.92	.68–.96
Maine-Anjou	1.17	.34	.05–.80	2.05	.37	.10–.80	—	—	—
Chianina	—	—	—	–.84	.89	.08–.96	—	—	—
Tarentaise	1.12	.98	.77–.99	.17	.98	.77–.99	.56	.98	.75–.99
Shorthorn	.62	—	—	2.76	—	—	6.16	—	—
Salers	.37	—	—	2.36	—	—	1.35	—	—

[a]Weighted by number of progeny at MARC.

Table 4. Mean maternal grandsire expected progeny difference (EPD) (kg) and accuracy (ACC) for direct weaning weight and milk and range in accuracy by maternal grandsire breed[a]

	Direct weaning wt			Milk		
Breed	Mean EPD	Mean ACC	Range ACC	Mean EPD	Mean ACC	Range ACC
Angus	1.26	.57	.08–.90	.84	.50	.09–.84
Hereford	2.75	.67	.24–.92	.01	—	—
P. Hereford	−1.48	.45	.32–.89	−.68	.35	.20–.82
Charolais	.02	.75	.25–.92	−.45	.72	.24–.91
Limousin	−2.86	.99	.96–.99	.20	.98	.84–.99
Simmental	−2.29	.92	.65–.97	−.71	.90	.59–.97
Gelbvieh	.47	.94	.76–.96	.75	.91	.59–.95
Chianina	−.99	.91	.67–.96	−.67	.80	.45–.91
Tarentaise	−.18	.98	.96–.99	.69	—	—
Shorthorn	2.95	—	—	2.37	—	—
Salers	1.57	—	—	.40	—	—

[a]Weighted by number of grandprogeny at MARC.

Pollak (1991) estimated regressions of calf performance on Simmental sire EPD for two regions and for calves out of Hereford and Angus dams. Their estimates ranged from .75 ± .06 to .92 ± .01 for BWT, from .54 ± .03 to .81 ± .01 for WW, and from .33 ± .15 to .86 ± .05 for YW, across regions and dam breeds, which are smaller than those obtained from the GPE data. They obtained larger regressions when calves were from Hereford dams than when calves were from Angus dams. Notter and Mahrt (1991), with data from Polled Hereford-sired calves out of Angus dams, reported regressions of BWT, WW, and YW on EPD of 1.13 ± .16, .55 ± .16, and 1.14 ± .22, respectively. The present results suggest that prediction of BWT based on published sire EPD agrees closely with the expected value of 1.0 kg/kg of EPD. There is an indication that sire EPD differences for WW are not completely expressed, perhaps due to a poorer nutritional preweaning environment at MARC than that of the purebred herds. The estimates of the regression of YW on YW EPD reported in other studies have been smaller than those observed at MARC.

Table 5. Regression coefficients (kg/kg) for weights at birth (BWT), 200 days (WW), and 365 days (YW) of F_1 progeny on their respective sire expected progeny differences

Breed	BWT	WW	YW
Angus	1.2 ± .3	.7 ± .3	1.1 ± .2
Hereford	.6 ± .4	1.0 ± .3	1.4 ± .2
P. Hereford	1.4 ± .3	.8 ± .3	.8 ± .3
Charolais	1.2 ± .2	.6 ± .3	1.8 ± .3[a]
Limousin	1.3 ± .4	1.5 ± .5	2.4 ± .5[a]
Simmental	1.2 ± .3	1.1 ± .3	1.4 ± .3
Gelbvieh	1.0 ± .3	.8 ± .7	1.7 ± .6
Maine-Anjou	.5 ± .4	1.0 ± .6	—
Chianina	—	.9 ± .7	—
Tarentaise	1.0 ± .9	1.5 ± .8	2.3 ± .9
Shorthorn	.7 ± .5	.7 ± .5	1.6 ± .3[a]
Salers	.7 ± .5	1.2 ± .7	1.8 ± .9
Pooled	1.04 ± .10	.88 ± .11	1.40 ± .11[a]

[a]Regression coefficients different ($P < .05$) from 1.0.

Comparison of regression coefficients across studies may be influenced by heterogeneity of variances, which may be associated with differences in management. Estimates of the regression of calf performance in one environment on sire EPD predicted in another environment may be different from their expectations due to scaling effects and(or) to sire × dam breed interaction (Notter, 1989). Usually, higher means are associated with higher variances, and these may affect the estimates of the regression coefficients. Higher mean performance than that observed in purebred herds in which sires were evaluated may be the result of better management or of heterosis in crossbred calves. Differences in heritability among herds used to evaluate the sires and the population at MARC may affect the estimates of regression, especially when accuracy of EPD is low. In this experiment the males were all steers. Treating bulls and steers as separate contemporary groups in purebred herds may reduce genetic variance among contemporaries and reduce heritability in these herds. Additionally, the regression coefficients may be different among sire breeds, as in the case of YW, indicating that the effects of scaling and reranking of sires may have a differential influence depending on the sire breeds. These results suggest that scaling and the genotype × environment interaction may be affecting the estimates of regressions for YW of calf on YW EPD of the sire.

Table 6 shows the mean within-breed EPD for animals born in 1982 for the different traits and breeds. The difference between mean EPD of sires used at MARC (Tables 3 and 4) and the 1982 mean EPD reported by a breed association includes the effect of sire sampling and genetic change due to intrabreed selection. Assuming representative sampling of sires for each breed, the deviations observed in

Table 6. Average within breed expected progeny differences (kg) in 1982 for weight at birth (BWT), 200 days (WW), and 365 days (YW) for milk and for milk + growth (MAT)[a]

Breed	BWT	WW	YW	Milk	MAT
Angus	.41	2.99	5.26	.23	—
Hereford	.16	4.03	6.01	1.86	3.87
P. Hereford	.36	2.68	3.81	.64	2.00
Charolais	.18	−.05	.59	−.73	—
Limousin	−.05	−.50	−.64	.09	—
Simmental	.16	.93	2.88	.55	.65
Gelbvieh	−.36	.18	.36	.36	.45
Maine-Anjou	.14	.95	—	—	—
Chianina	—	−.66	—	−.68	—
Shorthorn	.09	.56	.77	.57	—
Salers	−.84	.33	.32	.09	—

[a]Genetic trend for Tarentaise was not available.

Table 7. Mean birth weight (kg) by breed of sire for calves at MARC and means adjusted to the mean birth weight expected progeny difference (EPD) for 1982 of each breed

Breed	MARC	Adj. 1982[a]	Adj. 1982[b]	Adj. 1982[c]
Angus	35.0 ± .3	35.1 ± .3	35.1 ± .3	35.1 ± .3
Hereford	37.2 ± .3	37.1 ± .3	37.0 ± .3	37.0 ± .3
P. Hereford	36.2 ± .4	36.4 ± .4	36.3 ± .4	36.3 ± .4
Charolais	39.7 ± .3	39.4 ± .3	39.4 ± .3	39.4 ± .3
Limousin	37.2 ± .3	37.3 ± .3	37.3 ± .3	37.3 ± .3
Simmental	39.4 ± .3	38.7 ± .4	38.8 ± .3	38.8 ± .3
Gelbvieh	38.5 ± .5	38.4 ± .5	38.4 ± .5	38.4 ± .5
Maine-Anjou	40.6 ± .5	40.1 ± .6	39.5 ± .5	39.5 ± .5
Tarentaise[d]	37.7 ± .5	—	—	—
Shorthorn	37.7 ± .4	37.3 ± .5	37.2 ± .4	37.2 ± .4
Salers	37.3 ± .4	36.4 ± .7	36.0 ± .4	36.1 ± .4

[a]Adjusted means using separate regressions of actual birth weight on birth weight EPD for each breed.
[b]Adjusted means using the pooled regression (kilograms/kilogram) of actual birth weight on birth weight EPD (1.04 ± .10).
[c]Adjusted means using the expected regression (kilograms/kilogram) of actual birth weight on birth weight EPD (1.0).
[d]The 1982-mean EPD was not available from the breed association.

Table 8. Mean 200-day weight (kg) by breed of sire for calves at MARC and means adjusted to the mean weaning weight expected progeny difference (EPD) of 1982 for each breed

Breed	MARC	Adj. 1982[a]	Adj. 1982[b]	Adj. 1982[c]
Angus	204.6 ± 1.7	205.1 ± 1.7	205.2 ± 1.7	205.3 ± 1.7
Hereford	202.5 ± 1.6	203.5 ± 1.6	203.4 ± 1.6	203.6 ± 1.6
P. Hereford	203.2 ± 1.8	205.4 ± 2.0	205.6 ± 1.9	206.0 ± 1.9
Charolais	214.0 ± 1.5	213.4 ± 1.5	213.1 ± 1.5	213.0 ± 1.5
Limousin	205.9 ± 1.6	209.4 ± 2.0	207.9 ± 1.7	208.2 ± 1.7
Simmental	212.4 ± 1.6	215.8 ± 1.9	215.2 ± 1.6	215.5 ± 1.6
Gelbvieh	216.3 ± 2.5	216.1 ± 2.5	216.0 ± 2.5	216.0 ± 2.5
Maine-Anjou	214.8 ± 2.6	213.8 ± 2.7	213.9 ± 2.6	213.7 ± 2.6
Chianina	215.4 ± 2.4	215.6 ± 2.5	215.6 ± 2.4	215.6 ± 2.4
Tarentaise[d]	208.4 ± 2.4	—	—	—
Shorthorn	211.6 ± 2.2	210.2 ± 2.5	209.7 ± 2.2	209.4 ± 2.2
Salers	213.9 ± 2.1	211.5 ± 2.5	212.1 ± 2.1	211.9 ± 2.1

[a]Adjusted means using separate regressions of actual 200-d weight on weaning weight EPD for each breed.
[b]Adjusted means using the pooled regression (kilograms/kilogram) of actual 200-d weight on weaning weight EPD (.88 ± .11).
[c]Adjusted means using the expected regression (kilograms/kilogram) of actual 200-d weight on weaning weight EPD (1.0).
[d]The 1982-mean EPD was not available from the breed association.

Table 9. Mean 365-day weight (kg) by breed of sire for calves at MARC and means adjusted to the mean yearling weight expected progeny difference (EPD) of 1982 for each breed

Breed	MARC	Adj. 1982[a]	Adj. 1982[b]	Adj. 1982[c]
Angus	351.2 ± 2.5	352.8 ± 2.5	353.2 ± 2.5	352.7 ± 2.5
Hereford	346.6 ± 2.4	350.4 ± 2.5	350.5 ± 2.4	349.4 ± 2.4
P. Hereford	345.1 ± 2.8	348.0 ± 2.9	350.0 ± 2.8	348.6 ± 2.8
Charolais	371.7 ± 2.2	369.3 ± 2.2	369.8 ± 2.2	370.3 ± 2.2
Limousin	349.5 ± 2.4	357.6 ± 2.9	354.3 ± 2.4	352.9 ± 2.4
Simmental	368.3 ± 2.4	378.1 ± 3.1	378.4 ± 2.5	375.5 ± 2.5
Gelbvieh	368.1 ± 3.7	367.5 ± 3.7	367.6 ± 3.7	367.7 ± 3.7
Tarentaise[d]	347.2 ± 3.6	—	—	—
Shorthorn	363.1 ± 3.2	354.5 ± 3.7	355.6 ± 3.3	357.7 ± 3.3
Salers	361.6 ± 3.0	359.8 ± 3.2	360.2 ± 3.1	360.6 ± 3.1

[a]Adjusted means using separate regressions of actual 365-d weight on yearling weight EPD for each breed.
[b]Adjusted means using the pooled regression (kilograms/kilogram) of actual 365-d weight on yearling weight EPD (1.40 ± .11).
[c]Adjusted means using the expected regression (kilograms/kilogram) of actual 365-d weight on yearling weight EPD (1.0).
[d]The 1982-mean EPD was not available from the breed association.

this study generally correspond with genetic trends for the time period when these sire breeds were used at MARC. For example, negative deviations for Limousin and Simmental indicate that average EPD for calves born in 1982 in these breeds were heavier than those for sires used to produce progeny at MARC between 1970 and 1972.

Mean performance by breed of sire for calves at MARC and mean performances adjusted to a common 1982-EPD base are presented in Tables 7, 8, and 9 for BWT, WW, and YW, respectively. The 1982 base is that recommended for purposes of research by the Beef Improvement Federation to study the effect of a common base on interbreed evaluations (BIF, 1990). For unadjusted MARC means, Angus and Polled Hereford had the lowest BWT and Simmental, Charolais, and Maine-Anjou had the highest. At weaning, Hereford, Polled Hereford, and Angus were ≥ 5 kg lighter than the average of all breeds and Maine-Anjou, Chianina, and Gelbvieh were ≥ 4.5 kg above the average. Ranking of breeds was similar to that reported by Cundiff et al. (1986) from data of the first three cycles of this experiment. For YW, Polled Hereford, Hereford, and Tarentaise averaged > 10 kg below the mean of all breeds, and Gelbvieh, Simmental, and Charolais ranked highest, being ≥ 10 kg above the mean.

In general, adjustment of MARC means by the regression of calf performance on EPD tended to regress the sire-breed means toward the average of all breeds, especially for BWT and WW. Results indicate that breeds of small or medium frame size have placed more emphasis on selection for heavier weights at all ages, whereas breeds of larger size have emphasized calving ease and reduction of BWT. The effect of the type of adjustment on sire-breed means varied across breeds, but in most cases only small differences were observed between using either the average or the expected regression coefficients. The question is, Which adjustment is the correct one?

For BWT and WW no regression coefficient differed ($P > .05$) from its expected value and slopes were not statistically different among breeds. For these two traits, the use of either the pooled regression coefficient or the expected regression coefficient had a similar effect on adjusted breed means. However, for YW several breeds had regressions larger ($P < .05$) than 1.0, and so it is more difficult to decide which adjustment should be used. As mentioned before, factors such as scaling and possible genotype × sex or genotype × environment interaction may influence the magnitude of performance realized under the environment at MARC for each kilogram of EPD predicted under the environmental conditions of purebred herds. If the purpose of these adjustments is to quantify the additive genetic differences among breeds that commercial producers may realize, can scaling and interaction effects be assumed to be the same for

Table 10. Regression coefficients (kg/kg) of 200-day weight of three-breed-cross progeny on total maternal, weaning weight, and milk maternal grandsire expected progeny differences (EPD)

	Maternal grandsire regression		
Breed	Total maternal	Weaning wt EPD	Milk EPD
Angus	1.3 ± .3	.5 ± .3	1.4 ± .5
Hereford	1.1 ± .2	.1 ± .3	1.6 ± .3[a]
P. Hereford	.6 ± .3	.9 ± .3	.4 ± .3
Charolais	.1 ± .2[a]	.3 ± .3	−.1 ± .3[a]
Limousin	2.6 ± .3[a]	.7 ± .3	2.6 ± .6[a]
Simmental	.7 ± .3	.4 ± .2	.8 ± .5
Gelbvieh	2.5 ± .5[a]	.8 ± .5	3.0 ± .7[a]
Chianina	1.6 ± .3	.9 ± .5	1.6 ± .3
Tarentaise	1.6 ± 1.3	1.0 ± 1.1	1.7 ± 1.4
Shorthorn	−.2 ± .5[a]	1.1 ± .8	−.2 ± .5[a]
Salers	1.7 ± .8	1.0 ± .8	1.6 ± 1.0
Pooled	.99 ± .09	.44 ± .09	1.02 ± .11

[a]Regression coefficients differ ($P < .05$) from 1.0.

commercial herds and for MARC? Or, under commercial production systems, can 1.0 kg of calf performance be expected for each 1.0 kg of EPD? Obviously, more research based on records of crossbred calves out of sires with published EPD produced in representative commercial herds would be required to address these questions.

Three-Breed-Cross Progeny. Regression coefficients of WW of three-breed-cross progeny on EPD for MAT, WW, and MLK of maternal grandsires are shown in Table 10. Estimates of regression coefficients were not heterogeneous across grandam breeds, but different ($P < .05$) slopes across grandsire breeds were observed for MLK and MAT EPD. Heterogeneous slopes may be the result of scaling effects and(or) reranking of maternal grandsires across environments. Large differences in regressions of WW on MLK (ranging from –.2 to 3.0) and on MAT (ranging from –.2 to 2.6) were observed, along with large standard errors. On the average, however, the pooled regressions of WW on EPD for WW, MLK, and MAT (.44, 1.02, and .99, respectively) were close to their expected values (.5, 1.0, and 1.0). These results are consistent with those of Notter and Cundiff (1991), who estimated regressions of WW on EPD for WW, MLK, and MAT of .42 ± .10, .95 ± .14, and .93 ± .12, respectively. Also, Diaz and Notter (1991) reported a regression of progeny WW on MLK EPD of the maternal grandsire of .69 ± .19 for Polled Herefords, which was not significantly different from its expected value of 1.0. The regression of WW on WW EPD of the maternal grandsire corresponds to the regression of .88 kg/kg of EPD observed on F_1 calves (Table 5).

Table 11 shows the means for WW of three-breed-cross calves at MARC and the means adjusted to 1982-EPD base. As for F_1 progeny, the means were adjusted using either separate regressions by breed, pooled within-breed regressions, or expected regressions of WW of three-breed-cross calves on EPD for WW and MLK of the maternal grandsires. Among unadjusted MARC means, Polled Hereford, Angus, and Hereford were ≥ 10 kg below the average for all breeds, and Simmental and Gelbvieh were ≥ 9 kg above the average. The range in breed means was larger than that observed for F_1 crosses. In general the adjustments tended to reduce the variability among breeds and the effect of type of adjustment was small.

Differences among breed means of maternal grandsire for WW include differences in MLK EPD, plus one-half of the direct WW EPD, as well as differences in direct and maternal heterosis among crosses. Means of WW for F_1 and three-way-cross calves deviated from the respective mean of all breeds were used to estimate differences in net maternal effects, assuming that specific direct and maternal heterosis effects are approximately the same for all crosses. Cundiff et al. (1986) indicated that the assumption of comparable heterosis effects among *Bos taurus* crosses is reasonably valid. Net maternal effects were estimated by subtracting one-half of the (direct) WW breed effect in F_1 data from the WW effect of the maternal grandsire breed in three-breed-cross progeny.

Estimates of net maternal breed effects on WW are shown in Figure 1. Among continental European breeds, Gelbvieh, Tarentaise, and Simmental had the largest and Limousin and Charolais the smallest maternal effects. These results were expected because the first three breeds have a history of selection for milk production, whereas Limousin and Charolais have been selected for meat production or draft (Cundiff et al., 1986). The breed maternal EPD for Hereford was larger than that for Angus. As discussed by Notter and Cundiff (1991), this result was not

Table 11. Mean 200-day weight (kg) by breed of maternal grandsire for calves at MARC and means adjusted to the mean weaning weight expected progeny difference (EPD) and milk EPD of 1982 for each breed

Breed	MARC	Adj. 1982[a]	Adj. 1982[b]	Adj. 1982[c]
Angus	200.6 ± 1.2	200.7 ± 1.3	200.7 ± 1.2	200.8 ± 1.2
Hereford	202.7 ± 1.1	205.8 ± 1.3	205.1 ± 1.2	205.2 ± 1.2
P. Hereford	193.5 ± 1.3	197.7 ± 1.8	196.7 ± 1.3	196.9 ± 1.3
Charolais	215.6 ± 1.3	215.6 ± 1.3	215.3 ± 1.3	215.3 ± 1.3
Limousin	205.6 ± 1.2	207.0 ± 1.5	206.5 ± 1.3	206.7 ± 1.3
Simmental	222.5 ± 1.2	224.7 ± 1.5	225.3 ± 1.3	225.4 ± 1.3
Gelbvieh	227.1 ± 1.4	225.7 ± 1.5	226.5 ± 1.4	226.5 ± 1.4
Chianina	222.0 ± 1.4	222.3 ± 1.4	222.1 ± 1.4	222.1 ± 1.4
Tarentaise[d]	221.0 ± 1.6	—	—	—
Shorthorn	218.2 ± 2.9	215.8 ± 3.5	215.3 ± 2.9	215.2 ± 2.9
Salers	220.5 ± 2.5	218.8 ± 2.7	219.6 ± 2.5	219.5 ± 2.5

[a]Adjusted means using separate regressions of actual 200-d weight on weaning weight and milk EPD of the maternal grandsires for each breed.
[b]Adjusted means using the pooled regressions (kilograms/kilogram) of actual 200-d weight on weaning weight and milk EPD (.44 ± .09 and 1.02 ± .11, respectively).
[c]Adjusted means using the expected regressions (kilograms/kilogram) of actual 200-d weight on weaning weight and milk EPD (.5 and 1.0, respectively).
[d]The 1982-mean EPD was not available from the breed association.

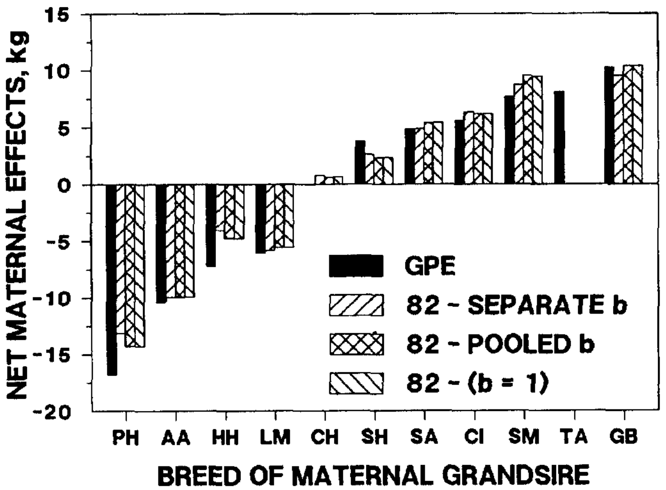

Figure 1. Estimates of net maternal breed effects on weaning weight for Polled Hereford (PH), Angus (AA), Hereford (HH), Limousin (LM), Charolais (CH), Shorthorn (SH), Salers (SA), Chianina (CI), Simmental (SM), Tarentaise (TA), and Gelbvieh (GB) using means at MARC and means adjusted to a 1982-base by separate, pooled, or expected regression of weaning weight on expected progeny difference of the maternal grandsire. GPE = Germ Plasm Evaluation.

expected. Previous results (Gregory et al., 1965; Gaines et al., 1966; Alenda et al., 1980) have shown a larger maternal effect for Angus than for Hereford. There is, however, some indication of greater genetic trend for milk in the Hereford breed than in the Angus breed, particularly during the period 1975 to 1985 (AAA, 1991; AHA, 1991). Also, the average maternal effects of Herefords were higher than those of Polled Herefords. As indicated by the American Polled Hereford Association (APHA, 1991), selection in this breed has emphasized growth and therefore little change has accrued in milking ability.

Comparison of Sire Variances. Table 12 shows the estimates of sire variance components and heritabilities for the residuals of the analysis for the various traits obtained before and after adjustment for sire or maternal grandsire EPD. Although sire variances and heritabilities were reduced after adjustment for EPD of the sires, significant variation remained in the sire component for all traits. Because heterogeneity of regressions on MLK and MAT EPD across grandsire breeds for WW of three-way-crosses was observed, residuals were also obtained and analyzed after fitting maternal grandsire EPD for MLK and WW within grandsire breeds. In these analyses maternal grandsire variances were reduced to 7.16 kg^2 and heritabilities were reduced to .07 for WW. Notter and Cundiff (1991) mentioned that, if accuracy of sire EPD is close to 1.0, residual sire effects can be used to evaluate the presence of sire × environment interaction. However, in this study average accuracies among breeds and traits ranged from .25 to .99, and thus residual sire effects observed could be due to either sire × environment interaction or to sampling errors in predicting EPD.

Across-Breed Expected Progeny Difference. The breed of sire effects (breed of sire means deviated from the mean of all breeds) can be used to estimate across-breed EPD adjusted to a fixed genetic base of 1982. If within-breed EPD were all expressed relative to a 1982 base, the sire breed effects for each trait could be added to the within-breed EPD to compare animals on the same scale regardless of breed. Even if the genetic bases were not fixed to a common point in time such as 1982, if the mean EPD for each breed in 1982 (BIF, 1991) were subtracted from the within-breed EPD of each animal, the remainder could be added to the sire breed effects for each trait to estimate across-breed EPD adjusted to a 1982 base.

A limitation of across-breed EPD is that errors of estimating sire breed effects are repeated every time the breed mean deviations are used to estimate across-breed EPD. Such errors can arise from random sources of experimental error in the experimental (or field) data used to compare breeds, or they can result from errors in estimation of genetic trend and genetic parameters in each breed. The EPD are expected to be more compressed when low estimates of heritability are used than when high estimates of heritability are used. The consequence of such errors is amplified if

Table 12. Estimates of sire variances (kg^2) and heritabilities (h^2) for birth, weaning, and yearling weight of F_1 calves and for weaning weight of three-way-crosses, before and after adjustment for sire (or maternal grandsire) expected progeny difference

	Before		After	
Trait	Sire variance	h^2	Sire variance	h^2
Birth wt	1.71	.36	.99	.22
Weaning wt	29.16	.25	20.25	.18
Yearling wt	105.33	.45	40.09	.19
Maternal weaning wt	23.86	.24	14.85	.15

breed mean deviations are applied to compare animals of different breeds. Then, every animal in a breed can falsely benefit from a favorable error and every animal in another breed can be handicapped by an unfavorable error in estimation of sire breed effects. Also, the different regressions of performance on EPD estimated in this study indicate the possibility of sire × breed of dam interactions. Therefore, it is doubtful that the estimates of sire breed effects from the present study are estimated with sufficient precision to justify their use to compare all animals on the same scale regardless of breed.

Implications

Within-breed expected progeny differences of sires can be used in a top-cross breed evaluation experiment to adjust sire breed mean performance for genetic trend and sire sampling. These analyses show that an amount of performance equal to or greater than that predicted by the expected progeny differences of sires was realized for birth, weaning, and yearling weights, when these sires were used to produce crossbred calves. Results indicate that breeds of medium frame size have placed more emphasis on growth, whereas breeds of larger frame size have emphasized calving ease and reduction of birth weight.

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