Effect of Ignoring Random Sire and Dam Effects on Estimates and Standard Errors of Breed Comparisons

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Effect of Ignoring Random Sire and Dam Effects on Estimates and Standard Errors of Breed Comparisons[1]

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ABSTRACT: Data were weights of F_1 calves and weaning weights of top-cross progeny from sires and maternal grandsires of 13 breeds. Three analyses were performed on each trait to obtain estimates and standard errors of breed effects needed to calculate across-breed EPD and accuracies. Model (R) for records of F_1 progeny contained fixed effects for birth year and date of birth, sex, age and breed of dam, and breed of sire, and a random residual effect. The second analysis included random effects for sires (RS), and the third analysis included random effects for sires and dams (RSD). In maternal analysis of top-cross progeny, model (R_m) contained fixed effects for cycle of experiment, age of dam, year of birth, sex, breeds of maternal grandam and grandsire, and breed of sire, and a random residual effect. In addition, the second and third analyses fit random effects for maternal grandsires (RS_m) and for maternal grandsires and daughters of maternal grandsires (RSD_m). Estimates of breed of sire effects changed only slightly for different models. Total variance increased in RSD and RS relative to R. Standard errors of breed of sire comparisons were underestimated with Model R, compared to Models RS and RSD. Standard errors of other contrasts were generally not affected. Variance components, breed effects, and standard errors followed patterns for R_m, RS_m, and RSD_m similar to those for R, RS, and RSD. Ignoring random variation due to sires and dams underestimated standard errors of breed of sire comparisons.

Key Words: Growth, Breeds, Beef Cattle, Breeding Value

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Introduction

Procedures to calculate adjustment factors to add to within-breed EPD to allow comparisons across breeds rely on estimates of differences among breeds of sire. One limitation of across-breed EPD is the precision with which these differences are estimated.

Previous analyses of data from the Germ Plasm Evaluation (**GPE**) program conducted at the U. S. Meat Animal Research Center (**MARC**) in Clay Center, Nebraska, estimated breed of sire differences and then adjusted these differences for sire sampling and genetic trend (Notter and Cundiff, 1991; Cundiff, 1993; Núñez-Dominguez et al., 1993). The adjusted breed of sire differences are used with within-breed EPD to predict across-breed EPD. These analyses accounted for various fixed effects but did not include terms to account for variance due to effects of sires and dams.

Ignoring random effects will result in underestimation of standard errors for breed of sire contrasts (Komender and Hoeschele, 1989; Gill, 1991). The objective of this paper, therefore, was to determine the effect of ignoring variation due to sires and dams on estimates and standard errors of differences among breeds of sire.

Materials and Methods

Data on birth weight (**BWT**), weaning weight at 205 d (**WWT**), and 365 d weight (**YWT**) were available from Cycles I through V of the GPE program conducted at MARC. Data were obtained for two analyses: records of first-cross progeny of 13 breeds of sires and records of three-breed-cross grand-progeny of maternal grandsires from the 13 breeds.

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Table 1. Number of MARC sires and number of F_1 progeny weaned by breed of sire and cycle of GPE

		Number of progeny				
Breed	No. of sires	Cycle I	Cycle II	Cycle III	Cycle IV	Cycle V
P. Hereford	30	36	29	79	68	202
Hereford	36	74	53	91	96	86
Angus	56	51	32	44	83	254
Shorthorn	25	0	0	0	170	0
Brahman	26	0	0	119	0	215
Simmental	27	366	0	0	0	0
Limousin	20	338	0	0	0	0
Charolais	60	308	0	0	175	0
Maine-Anjou	15	0	155	0	0	0
Gelbvieh	24	0	193	0	143	0
Pinzgauer	16	0	0	353	62	0
Tarentaise	7	0	0	191	0	0
Salers	26	0	0	0	175	0
Total	368	1,173	462	877	972	757

[a]Calves were born from 1970 to 1972 in Cycle I, 1973 to 1974 in Cycle II, 1975 to 1976 in Cycle III, 1986 to 1990 in Cycle IV, and 1992 to 1994 in Cycle V.

First-Cross Progeny

First-cross calves resulted from mating 13 breeds of sire to Hereford, Angus, or MARC III composite (1/4 Angus, 1/4 Hereford, 1/4 Pinzgauer, 1/4 Red Poll) cows. Angus, Hereford, and Polled Hereford sires were used across all cycles. Totals of 15 Hereford, 15 Polled Hereford, 36 Angus, and 13 Brahman bulls produced progeny in two or more cycles. Records of purebred calves were deleted from the data set, as were those of calves resulting from matings between Polled Hereford and Horned Hereford, due to a presumed lack of heterosis. The remaining progeny were from crosses with MARC III Composite cows and would exhibit at least 75% of individual heterosis. Further edits to the data removed records of animals raised by a foster dam or those with abnormal birth or rearing codes. For BWT, measurements on bull and heifer calves were used in the analyses, and for WWT and YWT, measurements on steers and heifers were used. Only records of those with sires having reported EPD for BWT, WWT, or YWT were used. Edits resulted in 4,703 BWT records, 4,241 WWT records, and 3,917 YWT records. Table 1 shows the number of sires and number of F_1 progeny weaned by cycle and breed of sire.

Calves were born in late February through early May. All calves were weighed and dehorned, and male calves were castrated within 24 h after birth. Calves were creep-fed through weaning, which occurred at approximately 200 d of age so that direct effects of sire and sire breed would be fully expressed. After weaning, heifers were managed to produce their first calf by 2 yr of age. Heifers and steers were fed ad libitum after weaning. Detailed descriptions of management procedures have been reported by Smith et al. (1976) and Gregory et al. (1978, 1979).

Three-Breed-Cross Progeny

Weaning weight (205-d) records (n = 6,576) of progeny produced by F_1 cows (**MWWT**, as a trait of the calf) were available from the GPE program. Three-breed-cross progeny were produced by pasture (multisire) mating a portion of the F_1 females in the former data set to unidentified sires of an unrelated breed. In Cycle I, F_1 heifers were pasture-mated to Hereford, Angus, Brahman, Devon, and Holstein sires, to Hereford, Angus, Maine-Anjou, Chianina, or Gelbvieh sires for their second potential calvings, and to Brown Swiss sires for subsequent calvings. Cycle II heifers were pasture-mated to Hereford, Angus, Brangus, or Santa Gertrudis sires and to Simmental-cross bulls for subsequent calvings. Cycle III and IV heifers were pasture-mated to Red Poll bulls and to Simmental bulls for subsequent calvings. Records of progeny from matings exhibiting less than 100% of individual and maternal heterosis were deleted. Records of progeny of Polled Hereford × Hereford cows were deleted because heterosis of Polled Hereford × Hereford crosses was assumed to be zero. Other edits were similar to those for records of first-cross progeny. Table 2 shows the number of maternal grandsires and number of three-breed-cross progeny weaned by year of birth and breed of maternal grandsire. Preweaning management was similar to that described for the first-cross progeny except that they were not creep-fed (Notter et al., 1978).

Statistical Analyses

Records of F_1 progeny and three-breed-cross calves were analyzed using three models. In both cases, the models represented sequential changes in sources of variance. Models were compared by examination of components of variance, solutions (e.g., breed of sire

Table 2. Number of maternal grandsires (MGS) and number of three-breed-cross progeny weaned by breed of MGS and year

		Year																
Breed	MGS	72	73	74	75	76	77	78	79	80	81	82	88	89	90	91	92	93	94
P. Hereford	26	—	1	9	14	22	43	49	48	38	40	32	10	12	19	26	31	29	42
Hereford	26	8	12	18	24	34	55	62	53	41	43	34	10	14	27	32	35	31	27
Angus	38	1	11	8	19	21	29	26	30	16	19	14	19	27	27	38	43	39	37
Shorthorn	22	—	—	—	—	—	—	—	—	—	—	—	12	23	28	39	59	58	36
Brahman	19	—	—	—	—	—	24	27	34	34	35	32	—	—	—	—	—	—	32
Simmental	27	34	77	122	122	128	116	117	80	—	—	—	—	—	—	—	—	—	—
Limousin	20	35	56	123	116	121	122	115	76	—	—	—	—	—	—	—	—	—	—
Charolais	54	26	45	84	88	84	82	81	44	—	—	—	16	26	42	57	65	70	44
Maine-Anjou	14	—	—	—	16	51	54	58	54	47	48	29	—	—	—	—	—	—	—
Gelbvieh	24	—	—	—	32	68	68	67	59	57	57	31	6	14	29	40	50	42	24
Pinzgauer	15	—	—	—	—	—	58	87	86	79	80	67	—	—	3	15	22	25	23
Tarentaise	6	—	—	—	—	—	29	60	63	63	65	61	—	—	—	—	—	—	—
Salers	24	—	—	—	—	—	—	—	—	—	—	—	18	32	39	61	78	75	51
Total	315	104	202	364	431	529	680	749	626	375	387	300	91	148	214	308	383	365	316

contrasts), and apparent standard errors of contrasts. The word “apparent” indicates standard errors calculated from a model that might not be complete.

First-Cross Progeny

The first model (**R**) included fixed class effects for year of birth (**BYR**), sex of calf (**SEX**), age of dam (**AOD**), breed of dam (**BOD**), and breed of sire (**BOS**), as well as a fixed covariate for Julian birth date (**JBD**). Residual effects represented the only random effects in this model. The second model (**RS**) was the same as R but included random effects due to sires nested within breed of sire. The final model (**RSD**) added a third random effect for dams nested within breed of dam.

All models were analyzed using a derivative-free algorithm to obtain REML estimates (Boldman et al., 1993). Solutions for fixed effects were obtained from the mixed-model equations, and contrasts and apparent standard errors were obtained from the appropriate portions of the inverse of the coefficient matrix.

Three-Breed-Cross Progeny

The purpose of these analyses was to estimate effects of the breeds of the maternal grandsires. All models included fixed effects for cycle of GPE (**C**), AOD, C × AOD, BYR nested within C × AOD, SEX, breed of maternal grandam (**MGD**), breed of maternal grandsire (**MGS**), and BOS nested within C × AOD. The experimental units were three-way-cross progeny out of F_1 females. Year of birth of the three-way-cross progeny was partially cross-classified with cycle. Thus, year of birth included all effects of cycle in the F_1 data set, but it was necessary to nest year in cycle to account for cycle and year effects combined for the three-way crosses. The first model (R_m) included residual effects as the only source of variation. The second model (RS_m) included an additional random effect for maternal grandsires nested within breed of MGS, and the third model (RSD_m) also included a third source of variation due to dams (daughters of maternal grandsires) nested within maternal grandsire. Models were analyzed as described for the F_1 data.

Results and Discussion

True comparisons of models are impossible because true variances and solutions are not known. However, RSD will be considered the most complete and, therefore, the most correct model for these comparisons.

Components of Variance

Table 3 shows components of variance obtained from the three models for BWT, WWT, YWT, and MWWT. For all traits, changes in total phenotypic variance across models were trivial, indicating that components of variance in R (R_m) and RS (RS_m) represented a redistribution of total variance, primarily affecting residual variances. For the most complete models, sire variance accounted for between 5 and 12% of total variance in all traits. When dams were ignored, sire variance increased slightly for BWT, WWT, and YWT, and nearly doubled for MWWT, indicating confounding between direct and maternal effects of maternal grandsires. The increase in sire variance from RSD to RS for BWT, WWT, and YWT seems to be a result of variation due to dams being distributed more heavily to sire variance than to residual variance, indicating that confounding between effects of sires and unrelated dams was present, though negligible, as indicated by the magnitude of

Table 3. Components of variance (kg^2) for sire (σ_s^2) and dam (σ_d^2) for birth weight (BWT), weaning weight (WWT), and yearling weight (YWT) and for maternal grandsire (σ_{mgs}^2), and daughter within maternal grandsire ($\sigma_{d|m}^2$), for maternal weaning weight (MWWT), and for total variance (σ_T^2) for models ignoring random effects (R and R_m), including random sire or maternal grandsire effects (RS and RS_m) and including random dam or daughter within maternal grandsire effects (RSD and RSD_m)

Trait	R (R_m)	RS (RS_m)	RSD (RSD_m)
BWT			
σ_s^2	—	2.5	2.3
σ_d^2	—	—	6.6
σ_e^2	22.6	20.4	14.0
σ_T^2	22.6	22.9	22.9
WWT			
σ_s^2	—	34	31
σ_d^2	—	—	233
σ_e^2	580	549	322
σ_T^2	580	583	586
YWT			
σ_s^2	—	167	156
σ_d^2	—	—	329
σ_e^2	1,353	1,199	878
σ_T^2	1,353	1,366	1,363
MWWT			
σ_{mgs}^2	—	81	38
$\sigma_{d\|m}^2$	—	—	171
σ_e^2	448	392	256
σ_T^2	448	473	465

the differences. When effects of sires and dams were ignored, residual variance was overestimated by as much as 80% relative to the complete models.

Mixed-Model Solutions

Breed of sire solutions for BWT, WWT, YWT, and MWWT are given in Tables 4, 5, 6, and 7, respectively. Breed of sire differences are expected to estimate half of the direct additive genetic differences among sire breeds assuming heterosis effects are equal for all crosses. The assumption of equal heterosis is reasonably valid for comparisons among *Bos taurus* breeds (i.e., all sire breeds except Brahman) but may not be valid for comparison between *Bos taurus* and *Bos indicus* breeds from crosses with *Bos taurus* dams. Estimates of heterosis in *Bos indicus* × *Bos taurus* crosses are generally about twice as great as those found in *Bos taurus* × *Bos taurus* crosses (e.g., Long, 1980). Thus, sire breed effects are expected to overestimate additive direct breed effects of the Brahman relative to those for all other breeds. All other breeds are expected to have benefited about the same amount from *Bos taurus* × *Bos taurus* heterosis effects. Inferences from this experiment involving F_1 crosses out of Hereford and Angus dams, the two most prominent breeds used in U.S. beef cow herds, judging from registration numbers, can be drawn to the commercial industry using Hereford and Angus in crossing systems for commercial production.

With all models, Brahman and Maine-Anjou sires had the heaviest progeny at birth, and Angus had the lightest. Rankings were similar for RS and R, with less than half of the 13 breeds changing rank as compared to rankings with RSD, and none by more than two places. Brahman, Gelbvieh, and Charolais sires produced the heaviest calves at weaning, and

Table 4. Solutions (Sol) for birth weight and rankings for breed of sire (kg, Angus as constraint) for models ignoring random effects (R), including random sire effects (RS), and including random sire and dam effects (RSD)

	R		RS		RSD	
Breed of sire	Sol.	Rank	Sol.	Rank	Sol.	Rank
P. Hereford	1.5	12	2.1	10	2.0	10
Hereford	2.0	10	2.0	11	1.8	12
Angus	0	13	0	13	0	13
Shorthorn	3.8	5	3.5	5	3.3	5
Brahman	6.0	1	6.3	1	6.3	1
Simmental	4.0	4	4.0	4	3.8	4
Limousin	2.0	10	1.9	12	2.0	11
Charolais	4.3	3	4.2	3	4.3	3
Maine-Anjou	5.5	2	5.4	2	5.0	2
Gelbvieh	3.3	7	2.9	7	3.0	6
Pinzgauer	3.6	6	3.0	6	2.5	8
Tarentaise	2.5	9	2.4	9	2.2	9
Salers	3.3	7	2.7	8	2.6	7

Table 5. Solutions (Sol.) for weaning weight and rankings for breed of sire (kg, Angus as constraint) for models ignoring random effects (R), including random sire effects (RS), and including random sire and dam effects (RSD)

	R		RS		RSD	
Breed of sire	Sol.	Rank	Sol.	Rank	Sol.	Rank
P. Hereford	2	11	4	11	3	11
Hereford	–4	13	0	12	–1	13
Angus	0	12	0	12	0	12
Shorthorn	9	7	8	7	8	6
Brahman	12	1	12	1	12	1
Simmental	11	5	11	3	10	4
Limousin	5	10	5	8	4	9
Charolais	12	2	12	1	11	3
Maine-Anjou	10	6	10	5	10	4
Gelbvieh	12	2	11	3	12	1
Pinzgauer	6	8	5	8	4	9
Tarentaise	6	8	5	8	5	8
Salers	11	4	10	5	8	6

Angus calves remained among the lightest. Rankings remained relatively consistent when random effects were deleted from the models. None of the 13 breeds changed rank by more than two places.

For all models, Charolais sires were ranked as having progeny with the heaviest yearling weights, whereas Brahman sires were ranked as having the lightest. The considerable change in ranking of Brahman sires from first for BWT and WWT to last for YWT is a result of differences in postweaning gain being reflected in yearling weights, in addition to differences in WWT. Souza (1993) reported that progeny of *Bos indicus* sires, such as Brahman, had significantly lower postweaning gains than progeny of *Bos taurus* sires at MARC. Four breeds changed rank from RSD to RS, all by one place. Rankings changed more substantially for R, with four breeds changing one place, three breeds changing two places, and one breed changing three places.

Rankings of maternal grandsire breeds were relatively consistent with all models. Brahman maternal grandsires produced the heaviest grandprogeny at weaning, and Polled Hereford maternal grandsires produced the lightest as estimated with all models.

In general, differences in breed of sire solutions remained similar in all models. Any changes seemed to occur in a relatively random manner. Rankings for all traits were generally consistent with those reported by Barkhouse et al. (1994). These results were from progeny raised under MARC conditions and may not be the same under all environmental conditions.

Solutions for BOD, SEX, and AOD are shown in Table 8 for BWT, WWT, and YWT.

Table 6. Solutions (Sol.) for yearling weight and rankings for breed of sire (kg, Angus as constraint) for models ignoring random effects (R), including random sire effects (RS), and including random sire and dam effects (RSD)

	R		RS		RSD	
Breed of sire	Sol.	Rank	Sol.	Rank	Sol.	Rank
P. Hereford	–3	9	–2	8	–1	8
Hereford	–5	12	–4	10	–5	10
Angus	0	8	0	7	0	7
Shorthorn	15	3	12	3	12	3
Brahman	–11	13	–12	13	–12	13
Simmental	15	3	12	3	11	4
Limousin	–3	9	–4	10	–6	11
Charolais	18	1	16	1	16	1
Maine-Anjou	15	3	13	2	13	2
Gelbvieh	10	6	6	6	8	6
Pinzgauer	1	7	–2	8	–3	9
Tarentaise	–4	11	–5	12	–6	11
Salers	16	2	11	5	10	5

Table 7. Solutions (Sol.) for maternal weaning weight and rankings for breed of maternal grandsire (kg, Angus as constraint) for models ignoring random effects (R_m), including random maternal grandsire effects (RS_m), and including also random daughter within maternal grandsire effects $(RSD)_m$

	R_m		RS_m		RSD_m	
Breed of sire	Sol.	Rank	Sol.	Rank	Sol.	Rank
P. Hereford	−8	13	−5	13	−6	13
Hereford	−1	12	−1	12	−1	12
Angus	0	11	0	11	0	11
Shorthorn	18	4	14	7	15	6
Brahman	24	1	22	1	23	1
Simmental	18	4	19	2	19	2
Limousin	1	10	2	10	1	10
Charolais	10	9	10	9	10	9
Maine-Anjou	17	7	16	4	16	4
Gelbvieh	21	2	18	3	19	2
Pinzgauer	15	8	11	8	12	8
Tarentaise	20	3	15	5	16	4
Salers	18	4	15	5	15	6

Standard Errors of Contrasts

Standard errors of BOS contrasts are given in Table 9 for BWT, WWT, YWT, and MWWT. Standard errors of contrasts of differences of BOS solutions from Angus solutions from models ignoring random effects were underestimated as compared to complete models for all traits. In fact, standard errors were underestimated by as much as 50% in R (R_m) relative to RSD (RSD_m). In general, results were consistent with those reported by Gill (1991). Apparent standard errors from RS were larger than those from RSD in all cases. This is a direct result of the larger sire components of variance for the RS model relative to the RSD model because the sire component of variance contributes heavily to the standard errors. For MWWT, standard errors with RSD were similar to those with RS but were slightly larger than with RS for four maternal grandsire breeds. The lack of consistency must be due to the data structure and repartitioning of components of variance for maternal grandsire and residual effects when effects of daughters within maternal grandsire are included. Underestimation of standard errors of breed differences resulting from the use of incorrect models may result in underestimation of prediction error variances associated with across-breed EPD obtained from breed comparisons (Van Vleck and Cundiff, 1994). Komender and Hoeschele (1989) reported similar patterns when models including or ignoring sires and dams were compared.

Ranges for standard errors of BOD, SEX, and AOD contrasts are given in Table 10. All traits showed similar patterns in standard errors across models.

Table 8. Estimates (kg) for birth weight, weaning weight, and yearling weight of contrasts for fixed effects for models ignoring random effects (R), including random sire effects (RS), and including random sire and dam effects (RSD)

	Birth weight			Weaning weight			Yearling weight		
Fixed effect	R	RS	RSD	R	RS	RSD	R	RS	RSD
Breed of dam									
Hereford	0	0	0	0	0	0	0	0	0
Angus	−1.7	−1.7	−1.7	18	18	19	16	16	16
MARC III	.7	1.0	1.2	13	13	15	10	9	11
Sex of calf									
Heifer	0	0	0	0	0	0	0	0	0
Steer	3.5	3.5	3.4	14	14	14	105	105	105
Age of dam, yr									
2	0	0	0	0	0	0	0	0	0
3	2.0	1.9	1.9	25	25	24	24	24	24
4	4.1	4.1	4.1	39	40	39	35	35	35
>4	4.4	4.4	4.5	44	44	44	37	37	37

Table 9. Apparent standard errors (kg) of breed of sire contrasts for birth weight, weaning weight, and yearling weight for models ignoring grandam effects (R and R_m), including random sire or maternal grandsire effects (RS and RS_m), and also including random dam or daughter within maternal grandsire effects (RSD and RSD_m)

	Birth weight			Weaning weight			Yearling weight			Maternal weaning weight		
Breed of sire	R	RS	RSD	R	RS	RSD	R	RS	RSD	R_m	RS_m	RSD_m
P. Hereford	.25	.40	.40	1.7	2.3	2.1	2.8	4.1	4.0	1.6	3.2	3.2
Hereford	.29	.40	.40	1.8	2.4	2.2	2.9	4.3	4.2	1.5	3.1	3.1
Angus	0	0	0	0	0	0	0	0	0	0	0	0
Shorthorn	.36	.51	.47	2.5	3.0	2.7	3.9	5.1	5.0	1.8	3.2	3.3
Brahman	.29	.40	.40	1.9	2.4	2.3	3.2	4.5	4.4	2.1	3.9	3.8
Simmental	.36	.51	.47	2.3	2.9	2.7	3.6	5.1	5.0	1.5	3.1	3.2
Limousin	.36	.51	.51	2.3	3.0	2.8	3.6	5.3	5.2	1.6	3.3	3.3
Charolais	.29	.40	.40	2.0	2.4	2.2	3.0	4.1	4.0	1.4	2.6	2.7
Maine-Anjou	.44	.62	.58	2.9	3.5	3.3	4.5	6.2	6.0	1.9	3.6	3.8
Gelbvieh	.33	.47	.47	2.2	2.8	2.6	3.4	4.9	4.8	1.5	3.0	3.0
Pinzgauer	.33	.51	.51	2.0	2.8	2.6	3.3	5.3	5.1	1.7	3.4	3.3
Tarentaise	.40	.69	.69	2.5	3.8	3.6	4.0	7.2	7.0	1.9	4.7	4.4
Salers	.36	.51	.47	2.5	2.9	2.7	3.8	5.0	4.9	1.6	3.0	3.1

Standard errors were not as affected by the change of model for these contrasts. Apparent standard errors of AOD and BOD contrasts increased as sources of variation were removed. Neither sire nor dam variance was expected to contribute significantly to these contrasts because AOD and SEX are cross-classified with sires and dams. As a result, apparent standard errors were primarily affected by residual variance, which increased when sires and dams were removed from the models.

Implications

Models that ignored random effects of sires or of sires and dams resulted in standard errors of sire breed differences that were underestimated relative to standard errors with the complete model. Standard errors of fixed effects cross-classified with random effects were generally unchanged. Estimates of breed of sire solutions and contrasts of fixed effects changed only slightly and with no apparent pattern when random effects of sires and dams were ignored. Generally, rankings of effects did not change significantly. Underestimation of standard errors of breed of sire comparisons will result in underestimation of prediction error variances associated with across-breed EPD. As a result, breed of sire comparisons and standard errors resulting from a model including random effects of sires and dams (or maternal grandsires and daughters of maternal grandsires) should be used to calculate adjustment factors for across-breed EPD and prediction error variances.

Table 10. Ranges for birth weight, weaning weight, and yearling weight in apparent standard errors (kg) of fixed effect contrasts for models ignoring random effects (R), including random sire effects (RS), and including random dam effects (RSD)

Item	R	RS	RSD
Sex[a]			
Birth weight	.14	.14	.14
Weaning weight	.7	.7	.7
Yearling weight	1.2	1.1	1.1
Age of dam[b]			
Birth weight	.23–.41	.23–.36	.23–.36
Weaning weight	1.3–2.2	1.3–2.1	1.2–2.0
Yearling weight	2.0–3.5	2.0–3.3	1.9–3.3
Breed of dam[c]			
Birth weight	.18–.36	.36–.36	.18–.36
Weaning weight	.9–2.0	.9–2.0	1.0–2.0
Yearling weight	1.4–3.2	1.4–3.1	1.5–3.2

[a]Contrast vs heifer.
[b]Contrast vs age of 2 yr.
[c]Contrast vs Angus.

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