Across-Breed EPD Tables for the Year 2005 Adjusted to Breed Differences for Birth Year of 2003

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Introduction

This report is the year 2005 update of estimates of sire breed means from data of the Germplasm Evaluation (GPE) project at the U.S. Meat Animal Research Center (MARC) adjusted to a year 2003 base using EPD from the most recent national cattle evaluations. Factors to adjust EPD of 16 breeds to a common birth year of 2003 were calculated and are reported in Tables 1-3 for birth weight (BWT), weaning weight (WWT), and yearling weight (YWT) and in Table 4 for the MILK component of maternal weaning weight (MWWT).

Some changes from the 2004 update (Van Vleck and Cundiff, 2004) are as follows:

Records from USMARC for birth, weaning, and yearling weight were the same as last year. The EPDs from the Maine-Anjou national cattle evaluations were computed with a new base which causes major changes in the across-breed adjustment factors for Maine-Anjou weights and maternal milk.

A considerable number of maternal records (weaning weights of grandprogeny) were added again this year, ranging from about 190 for Hereford and Angus to about 75 for Simmental, Limousin, Charolais, Gelbvieh, and Red Angus. For the first time, maternal records for Brangus (62) and Beefmaster (71) were included.

1) For BWT, the MARC records were the same as last year so any changes from the analysis done last year will be due to EPDs reported by the breed associations. The new Maine-Anjou base resulted in a change in the across-breed adjustment factor from 6.7 to 6.3 lb. The base year for Angus was changed from 1979 to 1982. Their model also was changed to include maternal genetic effects.

2) For WWT, the MARC records were also the same as last year. The new Maine-Anjou base changed that adjustment factor from 17.6 to -5.3 lb.

3) For YWT, the same animals had records at MARC as last year. The new Maine-Anjou base changed the across-breed adjustment factor from 5.5 to -41.7 lb.

4) a) About 190 maternal weaning weights for both Hereford and Angus grandsires and about 75 for Simmental, Limousin, Charolais, Gelbvieh and Red Angus grandsires were added to the maternal analysis. Changes in the across-breed adjustments were not large except for that due to the Maine-Anjou base change (from 7.6 to -9.4 lb).

   b) The second crop of Brangus and Beefmaster sired heifers had calves with weaning weights available this year and so for the first time are included in the maternal milk analyses (62 and 71 grandprogeny, respectively).

The across-breed table adjustments apply **only** to EPDs for most recent (in most cases; spring, 2005) national cattle evaluations. Serious biases can occur if the table adjustments are used with earlier EPDs which may have been calculated with a different within-breed base.

Materials and Methods

Adjustment for heterosis

The philosophy underlying the calculations has been that bulls compared using the across-breed adjustment factors will be used in a crossbreeding situation. Thus, calves and cows would generally exhibit 100% of both direct and maternal heterosis for the MILK analysis and 100% of direct heterosis for the BWT, WWT, and YWT analyses. The use of the MARC III composite (1/4 each of Pinzgauer, Red Poll, Hereford, and Angus) as a dam breed for Angus, Brangus, Hereford and Red Angus sires requires a small adjustment for level of heterozygosity for analyses of calves for BWT, WWT, and YWT and for cows for maternal weaning weight. Some sires (all multiple sire pasture mated) mated to the F1 cows are also crossbred so that adjustment for direct heterosis for the maternal analysis is required. Two approaches for accounting for differences in breed heterozygosity have been tried which resulted in similar final table adjustments. One approach was to include level of heterozygosity in the statistical models which essentially adjusts to a basis of no heterozygosity. The other approach was based on the original logic that bulls will be mated to another breed or line of dam so that progeny will exhibit 100% heterozygosity. Most of the lack of heterozygosity in the data results from homozygosity of Hereford or Angus genes from pure Hereford or Angus matings and also from Red Angus by Angus and from Hereford, Angus or Red Angus sires mated with MARC III composite dams. Consequently, the second approach was followed with estimates of heterosis obtained from analyses of BWT, WWT, YWT, and MWWT using only records from the imbedded diallel experiments with Hereford and Angus. Red Angus by Angus matings were assumed not to result in heterosis. With Brangus representing 5/8 and 3/8 inheritance from Angus and Brahman genes, records of Brangus sired calves were also adjusted to a full F1 basis when dams were Angus cows and MARC III cows (1/4 Angus). The adjustment for calves with Beefmaster (1/2 Brahman, 1/4 Shorthorn, 1/4 Hereford) sires was only when dams were MARC III cows (1/4 Hereford) as Beefmaster sires were not mated to Hereford cows.

The steps were:

1) Analyze records from Hereford-Angus (H-A) diallel experiments to estimate direct heterosis effects for BWT, WWT, YWT (1,326, 1,279, and 1,249 records for BWT, WWT, and YWT, respectively, representing 152 sires). The H-A diallel experiments were conducted as part of Cycle I (1970-1972 calf crops), Cycle II (1973-1974), Cycle IV (1986-1990) and Cycle VII (1999-2001) of the GPE program at MARC.
2) Adjust maternal weaning weight (MWWT) records of calves of the Hereford and Angus cows from the diallel for estimates of direct heterosis from Step 1) and then estimate maternal heterosis effects from 3,404 weaning weight records of 795 daughters representing 174 Hereford and Angus maternal grandsires.
3) Adjust all records used for analyses of BWT, WWT, and YWT for lack of direct heterozygosity using estimates from Step 1), and
4) Adjust all records used for analysis of MWWT for lack of both direct and maternal heterozygosity using estimates from Steps 1) and 2).

Models for the analyses to estimate heterosis were the same as for the across-breed analyses with the obvious changes in breed of sire and breed of dam effects. Estimates of direct heterosis were 3.01, 14.70, and 30.39 lb for BWT, WWT, and YWT, respectively. The estimate of maternal heterosis was 23.20 lb for MWWT. As an example of step 3), birth weight of a Hereford by Hereford calf would have 3.01 added. A Red Angus by MARC III calf would have (1/4) (3.01) added to its birth weight. A Red Poll sired calf of an Angus by MARC III dam would have (1/8) (14.70) plus (1/4) (23.20) added to its weaning weight record to adjust to 100% heterozygosity for both direct and maternal components of weaning weight.

After these adjustments, all calculations were as outlined in the 1996 BIF Guidelines. The basic steps were given by Notter and Cundiff (1991) with refinements by Núñez-Dominguez et al. (1993), Cundiff (1993, 1994), Barkhouse et al. (1994, 1995), and Van Vleck and Cundiff (1997–2004). All calculations were done with programs written in Fortran language with estimates of variance components, regression coefficients, and breed effects obtained using the MTDFREML package (Boldman et al., 1995). All breed solutions are reported as differences from Angus. The table values of adjustment factors to add to within-breed EPD are relative to Angus.

Models for Analysis of MARC Records

Fixed effects in the models for BWT, WWT (205-d), and YWT (365-d) were: breed of sire (17 including Pinzgauer); dam line (Hereford, Angus, selection lines of Herefords, MARC III composite) by sex (female, male) by age of dam (2, 3, 4, 5-9, ≥10 yr) combination (49), year of birth (21) of dam (1970-76, 86-90, 92-94, 97-99, and 2000-02) by damline combination (101) and a separate covariate for day of year at birth of calf for each of the three breeds of dam. Cows from the Hereford selection lines were used in Cycle IV of GPE. To account for differences from the original Hereford cows, Hereford dams were subdivided into the selection lines and others. That refinement of the model had little effect on breed of sire solutions. Dam of calf was included as a random effect to account for correlated maternal effects for cows with more than one calf (4,630 dams for BWT, 4,395 for WWT, 4,243 for YWT). For estimation of variance components and to estimate breed of sire effects, sire of calf was also used as a random effect (650).

Variance components were estimated with a derivative-free REML algorithm. At convergence, the breed of sire solutions were obtained as were the sampling variances of the estimates to use in constructing prediction error variances for pairs of bulls of different breeds.

For estimation of coefficients of regression of progeny performance on EPD of sire the random sire effect was dropped from the model. Pooled regression coefficients, and regression coefficients by sire breed, by dam line, and by sex of calf were obtained. These regression coefficients are monitored as accuracy checks and for possible genetic by environment interactions. The pooled regression coefficients were used as described later to adjust for genetic trend and bulls used at MARC.

The fixed effects for the analysis of maternal effects included breed of maternal grandsire (17 including Pinzgauer), maternal grandam line (Hereford, Angus, MARC III), breed of natural service mating sire (17), sex of calf (2), birth year-GPE cycle-age of dam subclass (84), and mating sire breed by GPE cycle by age of dam subclass (45) with a covariate for day of year of birth. The subclasses are used to account for confounding of years, mating sire breeds, and age of dams. Age of dam classes were 2, 3, 4, 5-9, ≥10 yr. For estimation of variance components and estimation of breed of maternal grandsire effects, random effects were maternal grandsire (618) and dam (3,196 daughters of the maternal grandsires). Mating sires were unknown within breed. For estimation of regression coefficients of grandprogeny weaning weight on maternal grandsire EPD for weaning weight and milk, random effects of both maternal grandsire and dam (daughter of MGS) were dropped from the model.

Adjustment of MARC Solutions

The calculations of across-breed adjustment factors rely on solutions for breed of sire or breed of maternal grandsire from records at MARC and on averages of within-breed EPD from the breed associations. The records from MARC are not used in calculation of within-breed EPD by the breed associations. The basic calculations for BWT, WWT, and YWT are as follows:

MARC breed of sire solution for breed i (MARC (i)) adjusted for genetic trend (as if bulls born in the base year had been used rather than the bulls actually used):

$$M_i = MARC(i) + b[EPD(i)_{YY} - EPD(i)_{MARC}].$$

Breed Table Factor (A_i) to add to the EPD for a bull of breed i:

$$A_i = (M_i - M_x) - (EPD(i)_{YY} - EPD(x)_{YY})$$

where,

MARC(i) is solution from mixed model equations with MARC data for sire breed i,

$EPD(i)_{YY}$ is the average within-breed EPD for breed i for animals born in the base year (YY, which is two years before the update; e.g., YY = 2003 for the 2005 update),

$EPD(i)_{MARC}$ is the weighted (by number of progeny at MARC) average of EPD of bulls of breed i having progeny with records at MARC,

b is the pooled coefficient of regression of progeny performance at MARC on EPD of sire (for 2005: 1.03, 0.85, and 1.13 for BWT, WWT, YWT),

i denotes sire breed i, and

x denotes the base breed, which is Angus in this report.

The calculations to arrive at the Breed Table Factor for MILK are more complicated because of the need to separate the direct effect of the maternal grandsire breed from the maternal effect of the breed.

MARC breed of maternal grandsire solution for WWT adjusted for genetic trend:

$$MWWT(i) = MARC(i)_{MGS} + b_{wwt}[EPD(i)_{YYWWT} - EPD(i)_{MARCWWT}] + b_{MLK}[EPD(i)_{YYMLK} - EPD(i)_{MARCMLK}]$$

MARC breed of maternal grandsire solution (MWWT(i)) adjusted for genetic trend and direct genetic effect:

$$MILK(i) = [MWWT(i) - 0.5\,M(i)] - [\overline{MWWT} - 0.5\,\overline{M}]$$

Breed Table Factor to add to EPD for MILK for bull of breed i:

$$A_i = [MILK(i) - MILK(x)] - [EPD(i)_{YYMLK} - EPD(i)_{MARCMLK}]$$

where,

$MARC(i)_{MGS}$ is solution from mixed model equations with MARC data for MGS breed i for WWT,

$EPD(i)_{YYWWT}$ is the average within-breed EPD for WWT for breed i for animals born in base year (YY),

$EPD(i)_{MARCWWT}$ is the weighted (by number of grandprogeny at MARC) average of EPD for WWT of MGS of breed i having grandprogeny with records at MARC,

$EPD(i)_{YYMLK}$ is the average within-breed EPD for MILK for breed i for animals born in base year (YY),

$EPD(i)_{MARCMLK}$ is the weighted (by number of grandprogeny at MARC) average of EPD for MILK of MGS of breed i having grandprogeny with records at MARC,

b_{WWT}, b_{MLK} are the coefficients of regression of performance of MARC grandprogeny on MGS EPD for WWT and MILK (for 2005: 0.58 and 1.14),

$M(i) = M_i$ is the MARC breed of sire solution from the first analysis of direct breed of sire effects for WWT adjusted for genetic trend,

$\overline{MWWT}$ and $\overline{M}$ are unneeded constants corresponding to unweighted averages of MWWT(i) and M(i) for i = 1,..., n, the number of sire (maternal grandsire) breeds included in the analysis.

Results

Tables 1, 2, and 3 (for BWT, WWT, and YWT) summarize the data from, and results of, MARC analyses to estimate breed of sire differences and the adjustments to the breed of sire effects to a year 2003 base. The last column of each table corresponds to the Breed Table Factor for that trait.

The general result shown in Tables 1-4 is that many breeds are continuing to become more similar to the arbitrary base breed, Angus. Most of the other breeds have not changed much relative to each other. Column 7 of Tables 1-3 and column 10 of Table 4 represent the best estimates of breed differences for calves born in 2003. These pairs of differences minus the corresponding differences in average EPD for animals born in 2003 result in the last column of the tables to be used as adjustment factors for pairs of sires with within-breed EPD.

Birth Weight

The range in estimated breed of sire differences for BWT relative to Angus is large: from 1.1 lb for Red Angus to 9.0 lb for Charolais and 11.9 lb for Brahman. The relatively heavy birth weights of Brahman sired progeny would be expected to be completely offset by favorable maternal effects reducing birth weight if progeny were from Brahman or Brahman cross dams which would be an important consideration in crossbreeding programs involving Brahman cross females. Differences from Angus were only slightly changed from the 2004 update (Van Vleck and Cundiff, 2004) but most of the changes continue generally a trend to slightly smaller differences from Angus.

Suppose the EPD for birth weight for a Charolais bull is +2.0 (which is above the year 2003 average of 1.4 for Charolais) and for a Hereford bull is also +2.0 (which is below the year 2003 average of 3.7 for Herefords). The across-breed adjustment factors in the last column of Table 1 are 2.9 for Hereford and 10.0 for Charolais. Then the adjusted EPD for the Charolais bull is 10.0 + 2.0 = 12.0 and for the Hereford bull is 2.9 + 2.0 = 4.9. The expected birth weight difference when both are mated to another breed of cow, e.g., Angus, would be 12.0 - 4.9 = 7.1 lb.

Weaning Weight

Weaning weights also seem to be becoming more similar for the breeds when used as sire breeds. Most of the changes between the year 2004 and 2005 updates were less than 2 lb. All except three sire breed means for WWT adjusted to year of birth of 2003 are within about 10 lb of the Angus mean.

Yearling Weight

Changes in adjusted differences from Angus from the 2004 update were generally to become more similar to Angus. Adjusted to a base year of 2003, Angus have heavier yearling weights than 10 breeds (10.4 to 50.0 lb), lighter yearling weights than 2 breeds (11.1 and 18.2 lb), and slightly heavier than 3 breeds (1.1 to 3.1 lb).

MILK

The changes from last year for MILK compared to Angus for the current base year were generally small. Comparison of Hereford and Angus changed somewhat. The greatest changes in the across-breed adjustment factors were for Maine-Anjou which changed its base.

Table 5 summarizes the average Beef Improvement Federation (BIF) accuracy for bulls with progeny at MARC weighted appropriately by number of progeny or grandprogeny. South Devon bulls had relatively small accuracy for all traits as did Hereford, Brahman, and Maine-Anjou bulls. Braunvieh bulls had low accuracy for milk. The accuracy values for Brangus are relatively high. Table 6 reports the estimates of variance components from the records that were used in the mixed model equations to obtain breed of sire and breed of MGS solutions. Neither

Table 5 nor Table 6 changed much from the 2004 report.

Regression Coefficients

Table 7 updates the coefficients of regression of records of MARC progeny on sire EPDs for BWT, WWT, and YWT which have theoretical expected values of 1.00. The standard errors of the specific breed regression coefficients are large relative to the regression coefficients. Large differences from the theoretical regressions, however, may indicate problems with genetic evaluations, identification, or sampling. The pooled (overall) regression coefficients of 1.03 for BWT, 0.85 for WWT, and 1.13 for YWT were used to adjust breed of sire solutions to the base year of 2003. These regression coefficients are reasonably close to expected values of 1.0. Deviations from 1.00 are believed to be due to scaling differences between performance of progeny in the MARC herd and of progeny in herds contributing to the national genetic evaluations of the 16 breeds. The regression coefficient for Angus birth weight EPDs changed from 1.02 last year to 0.86 this year. The reason is that the American Angus Association has now added maternal effects to the model they use for calculating EPD for birth weight.

The regression coefficient for female progeny on sire EPDs for YWT was 0.98 compared to 1.26 for steers. These differences are probably expected because postweaning average daily gains for heifers have been significantly less than those for steers. The heifers were fed relatively high roughage diets to support average daily gains of 1.6 lb per day while the steers were fed relatively high energy growing and finishing diets supporting average daily gains of about 3.4 lb per day. For reasons that have never been clear, the regressions for sex used to fluctuate widely from year to year, but for the past few years the pattern has been fairly consistent (female estimates have ranged from 0.93 to 1.02; while male estimates have ranged from 1.26 to 1.32).

The coefficients of regression of records of grandprogeny on MGS EPDs for WWT and MILK are shown in Table 8. Several sire (MGS) breeds have regression coefficients considerably different from the theoretical expected values of 0.50 for WWT and 1.00 for MILK. The standard errors for the regression coefficients by breed are large except for Angus and Hereford. The standard errors for regression coefficients over all breeds of grandsires associated with heifers and steers overlap for MILK EPDs. Again, the pooled regression coefficients of 0.58 for MWWT and 1.14 for MILK are reasonably close to the expected regression coefficients of 0.50 and 1.00, respectively.

Prediction Error Variances of Across-Breed EPD

The standard errors of differences in the solutions for breed of sire and breed of MGS differences from the MARC records can be adjusted by theoretical approximations to obtain variances of adjusted breed differences (Van Vleck, 1994; Van Vleck and Cundiff, 1994). These variances of estimated breed differences can be added to prediction error variances of within-breed EPDs to obtain prediction error variances (PEV) or equivalently standard errors of prediction (SEP) for across-breed EPDs (Van Vleck and Cundiff, 1994, 1995). The variances of adjusted breed differences are given in the upper triangular part of Table 9 for BWT, lower triangular part of Table 9 for YWT, upper triangular part of Table 10 for direct WWT, and lower triangular part of Table 10 for MILK. Use of these tables to calculate standard errors of prediction for expected progeny differences of pairs of bulls of the same or different breeds was discussed in the 1995 BIF proceedings (Van Vleck and Cundiff, 1995).

Even though the variances of estimates of adjusted breed differences look large, especially for YWT and MILK, they generally contribute a relatively small amount to standard errors of predicted differences. For example, suppose for WWT, a Salers bull has an EPD of 15.0 with prediction error variance of 75 (SEP = 8.7) and a Hereford bull has an EPD of 30.0 with PEV of 50 (SEP = 7.1). The difference in predicted progeny performance is (Salers adjustment + Salers bull's EPD) - (Hereford adjustment + Hereford bull's EPD):

$$(29.0 + 15.0) - (-1.8 + 30.0) = 44.0 - 28.2 = 15.8.$$

The prediction error variance for this difference is (use the 18.0 in the upper part of Table 10 at intersection of row for HE and column for SA):
V(Salers breed - Hereford breed) + PEV(Salers bull) + PEV(Hereford bull):

$$18 + 75 + 50 = 143$$

with

standard error of prediction, SEP $= \sqrt{143} = 12$.

If the difference between the Salers and Hereford breeds in the year 2003 could be estimated perfectly, the variance of the estimate of the breed difference would be 0 and the standard error of prediction between the two bulls would be:

SEP(difference) $= \sqrt{0 + 75 + 50} = 11.2$ which is only slightly smaller than 12.0.

Implications

Bulls of different breeds can be compared on a common EPD scale by adding the appropriate table factor to EPDs produced in the most recent genetic evaluations for each of the 16 breeds. The across-breed EPDs are most useful to commercial producers purchasing bulls of two or more breeds to use in systematic crossbreeding programs. Uniformity in across-breed EPDs should be emphasized for rotational crossing. Divergence in across-breed EPDs for direct weaning weight and yearling weight should be emphasized in selection of bulls for terminal crossing. Divergence favoring lighter birth weight may be helpful in selection of bulls for use on first calf heifers. Accuracy of across-breed EPDs depends primarily upon the accuracy of the within-breed EPDs of individual bulls being compared.

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Table 1. Breed of sire solutions from MARC, mean breed and MARC EPD used to adjust for genetic trend to the year 2003 base and factors to adjust within breed EPD to an Angus equivalent – BIRTH WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2003 (2)	Ave. Base EPD MARC Bulls (3)	Breed Soln at MARC + Ang (4)	Breed Soln at MARC vs Ang (5)	Adjust to 2003 Base + Ang (6)	Adjust to 2003 Base vs Ang (7)	Factor to adjust EPD To Angus (8)
Hereford	113	1817	87	3.7	2.5	88	3.6	89	4.2	2.9
Angus	105	1421	84	2.4	1.7	84	0.0	85	0.0	0.0
Shorthorn	25	181	87	1.8	0.8	90	6.4	91	6.7	7.3
South Devon	15	153	80	0.1	-0.2	88	4.3	89	3.9	6.2
Brahman	40	589	98	1.8	0.7	96	11.6	97	11.9	12.5
Simmental	48	623	87	1.8	2.7	91	7.0	90	5.3	5.9
Limousin	40	589	83	2.2	0.7	87	3.0	89	3.8	4.0
Charolais	75	675	89	1.4	0.4	93	8.8	94	9.0	10.0
Maine-Anjou	18	218	94	2.6	5.8	95	10.6	91	6.5	6.3
Gelbvieh	48	595	89	1.8	1.1	88	4.1	89	4.1	4.7
Tarentaise	7	199	80	2.2	1.8	87	3.2	88	2.9	3.1
Salers	27	189	85	1.2	1.8	88	4.4	88	3.0	4.2
Red Angus	21	206	85	0.4	-0.8	85	0.6	86	1.1	3.1
Braunvieh	7	188	88	1.1	0.8	89	5.1	89	4.7	6.0
Brangus	21	215	91	2.1	2.5	90	5.9	90	4.8	5.1
Beefmaster	21	214	96	0.4	0.8	92	8.3	92	7.2	9.2

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) – (3)] with b = 1.03
(7) = (6) – (6, Angus)
(8) = (7) – (7, Angus) – [(2) – (2, Angus)]

Table 2. Breed of sire solutions from MARC, mean breed and MARC EPD used to adjust for genetic trend to the year 2003 base and factors to adjust within breed EPD to an Angus equivalent – WEANING WEIGHT (lb)

	Number		Raw MARC Mean	Ave. Base EPD		Breed Soln at MARC		Adjust to 2003 Base		Factor to adjust EPD To Angus
				Breed 2003	MARC Bulls	+ Ang vs Ang		+ Ang vs Ang		
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hereford	112	1712	503	36.0	22.6	501	-2.7	513	-2.8	-1.8
Angus	106	1315	504	37.0	23.5	504	0.0	516	0.0	0.0
Shorthorn	25	170	521	13.2	6.6	518	14.1	524	8.2	32.0
South Devon	15	134	443	19.2	0.1	503	-0.6	520	4.1	21.9
Brahman	40	509	532	14.2	4.5	520	16.1	528	12.8	35.6
Simmental	47	564	505	33.4	23.6	526	22.4	535	19.2	22.8
Limousin	40	533	477	35.5	20.7	503	-0.8	516	0.3	1.8
Charolais	74	600	514	19.2	8.4	527	23.3	537	21.0	38.8
Maine-Anjou	18	197	459	38.8	47.0	519	15.1	512	-3.5	-5.3
Gelbvieh	48	559	507	40.0	32.3	518	14.3	525	9.3	6.3
Tarentaise	7	191	476	12.0	-4.8	507	2.7	521	5.6	30.6
Salers	27	176	525	15.2	7.0	516	11.7	523	7.2	29.0
Red Angus	21	199	535	29.0	27.2	505	1.0	507	-9.0	-1.0
Braunvieh	7	183	451	7.0	7.3	516	12.0	516	0.2	30.2
Brangus	21	208	550	23.1	26.7	524	20.3	521	5.7	19.6
Beefmaster	22	215	563	6.0	13.3	530	26.3	524	8.5	39.5

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) – (3)] with b = 0.85
(7) = (6) – (6, Angus)
(8) = (7) – (7, Angus) – [(2) – (2, Angus)]

Table 3. Breed of sire solutions from MARC, mean breed and MARC EPD used to adjust for genetic trend to the year 2003 base and factors to adjust within breed EPD to an Angus equivalent – YEARLING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2003 (2)	Ave. Base EPD MARC Bulls (3)	Breed Soln at MARC + Ang vs Ang (4)	Breed Soln at MARC + Ang vs Ang (5)	Adjust to 2003 Base + Ang vs Ang (6)	Adjust to 2003 Base + Ang vs Ang (7)	Factor to adjust EPD To Angus (8)
Hereford	112	1627	852	61.0	38.6	852	-20.0	877	-21.7	-14.2
Angus	106	1257	872	68.5	44.6	872	0.0	899	0.0	0.0
Shorthorn	25	168	918	20.7	12.9	887	15.0	896	-3.1	44.7
South Devon	15	134	744	26.1	0.1	868	-3.7	898	-1.4	41.0
Brahman	40	438	838	23.4	8.2	832	-40.1	849	-50.0	-4.9
Simmental	47	528	852	57.8	38.9	889	16.7	910	11.1	21.8
Limousin	40	527	797	66.7	42.1	849	-23.3	876	-22.6	-20.8
Charolais	74	566	882	33.5	15.7	897	25.1	917	18.2	53.2
Maine-Anjou	18	196	787	77.4	93.4	884	12.3	866	-32.8	-41.7
Gelbvieh	48	555	849	73.0	58.0	864	-7.8	881	-17.8	-22.3
Tarentaise	7	189	807	23.0	-3.4	837	-35.2	867	-32.4	13.1
Salers	27	173	899	25.1	9.1	880	7.8	898	-1.1	42.3
Red Angus	21	194	916	52.0	46.9	877	5.4	883	-15.8	0.7
Braunvieh	7	182	737	8.0	11.8	856	-16.4	851	-47.7	12.8
Brangus	21	152	977	38.2	44.9	896	24.1	889	-10.4	19.9
Beefmaster	22	157	991	10.5	23.3	893	20.9	878	-20.5	37.5

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) – (3)] with b = 1.13
(7) = (6) – (6, Angus)
(8) = (7) – (7, Angus) – [(2) – (2, Angus)]

Table 4. Breed of maternal grandsire solutions from MARC, mean breed and MARC EPD used to adjust for genetic trend to the year 2003 base and factors to adjust within-breed EPD to an Angus equivalent – MILK (lb)

Breed	MGS	Number Gpr	Number Daughters	Raw MARC Mean (1)	Mean EPD Breed WWT (2)	Mean EPD Breed MILK (3)	Mean EPD MARC WWT (4)	Mean EPD MARC MILK (5)	Breed Soln at MARC MWWT Ang (6)	Breed Soln at MARC MWWT vs Ang (7)	Adjust to 2003 Base MWWT Ang (8)	Adjust to 2003 Base MWWT vs Ang (9)	MILK (10)	Factor to Adjust MILK EPD to Angus (11)
Hereford	108	2758	709	479	36.0	14.0	20.8	6.8	478	-20.5	495	-25.2	-17.1	-18.8
Angus	104	2013	530	498	37.0	19.0	19.3	8.9	498	0.0	520	0.0	6.8	0.0
Shorthorn	22	251	69	527	13.2	2.4	6.5	6.8	521	23.3	520	0.4	3.1	12.9
South Devon	14	347	69	488	19.2	7.1	0.0	5.5	501	3.5	514	-5.4	-0.7	4.5
Brahman	40	880	216	522	14.2	6.3	4.7	2.9	529	31.0	538	18.7	19.0	24.9
Simmental	47	1058	239	515	33.4	5.5	21.4	8.1	522	24.0	526	6.3	3.4	10.1
Limousin	40	1033	240	482	35.5	18.8	18.5	16.0	490	-7.6	504	-16.3	-9.6	-16.2
Charolais	68	966	235	504	19.2	6.1	6.5	3.2	509	10.5	519	-0.6	-4.3	1.8
Maine-Anjou	17	485	86	533	38.8	19.2	46.3	22.0	516	18.4	509	-10.9	-2.4	-9.4
Gelbvieh	46	916	232	530	40.0	18.0	32.1	17.3	520	22.4	526	6.1	8.2	2.4
Tarentaise	6	341	78	513	12.0	1.5	-6.0	4.7	517	18.6	523	3.6	7.6	18.3
Salers	25	351	87	534	15.2	8.4	5.5	11.9	521	23.0	523	2.9	6.1	9.9
Red Angus	21	261	89	489	29.0	16.0	27.2	13.9	502	4.0	505	-14.3	-3.0	-6.8
Braunvieh	7	502	92	542	7.0	0.0	7.9	-0.4	523	25.4	523	3.5	10.2	22.4
Brangus	18	62	42	502	23.1	9.7	25.9	4.3	505	7.2	510	-10.0	-6.1	-3.6
Beefmaster	20	71	50	509	6.0	2.0	14.8	-1.2	504	5.9	502	-17.3	-14.8	-4.6

Calculations:
(6) = (7) + (1, Angus); (8) = (6) + b_{WWT}[(2) – (4)] + b_{MLK} [(3) – (5)] with $b_{WWT} = 0.58$ and $b_{MLK} = 1.14$; (9) = (8) – (8, Angus);
(10) = [(9) – Average (9)] – 0.5[(7, Table 2) – Average (7, Table 2)]; (11) = [(10) – (10, Angus)] – [(3) – (3, Angus)].

Table 5. Mean weighted[a] accuracies for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), maternal weaning weight (MWWT) and milk (MILK) for bulls used at MARC

Breed	BWT	WWT	YWT	MWWT	MILK
Hereford	0.57	0.54	0.49	0.51	0.49
Angus	0.72	0.75	0.69	0.71	0.62
Shorthorn	0.82	0.80	0.74	0.82	0.79
South Devon	0.37	0.39	0.38	0.41	0.41
Brahman	0.50	0.55	0.37	0.55	0.42
Simmental	0.94	0.93	0.93	0.94	0.93
Limousin	0.92	0.89	0.82	0.90	0.84
Charolais	0.71	0.65	0.56	0.64	0.55
Maine-Anjou	0.72	0.71	0.71	0.71	0.71
Gelbvieh	0.72	0.66	0.50	0.70	0.57
Tarentaise	0.95	0.95	0.94	0.95	0.95
Salers	0.83	0.83	0.77	0.82	0.83
Red Angus	0.87	0.85	0.84	0.84	0.81
Braunvieh	0.84	0.85	0.83	0.85	0.77
Brangus	0.80	0.78	0.64	0.81	0.63
Beefmaster	0.63	0.72	0.57	0.75	0.58

[a]Weighted by number of progeny at MARC for BWT, WWT, and YWT and by number of grandprogeny for MWWT and MILK.

Table 6. REML estimates of variance components (lb^2) for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), and maternal weaning weight (MWWT) from mixed model analyses

	Direct			Maternal
Analysis[a]	BWT	WWT	YWT	MWWT
Direct				
Sires (650) within breed (17)	11.4	152	631	
Dams (4395) within breed (3)	26.6	876	1233	
Residual	68.2	1535	4037	
Maternal				
MGS (618) within MGS breed (17)				197
Daughters within MGS (3196)				937
Residual				1342

[a]Numbers for weaning weight.

Table 7. Pooled regression coefficients (lb/lb) for weights at birth (BWT), 205 days (WWT), and 365 days (YWT) of F_1 progeny on sire expected progeny difference and by sire breed, dam breed, and sex of calf

	BWT	WWT	YWT
Pooled	1.03 ± 0.05	0.85 ± 0.05	1.13 ± 0.05
Sire breed			
Hereford	1.18 ± 0.08	0.79 ± 0.07	1.12 ± 0.07
Angus	0.86 ± 0.10	0.79 ± 0.10	1.16 ± 0.08
Shorthorn	0.68 ± 0.48	0.77 ± 0.43	1.18 ± 0.34
South Devon	0.91 ± 0.57	-0.15 ± 0.36	-0.05 ± 0.40
Brahman	1.82 ± 0.26	1.11 ± 0.26	0.69 ± 0.24
Simmental	1.05 ± 0.22	1.24 ± 0.17	1.29 ± 0.15
Limousin	0.68 ± 0.17	0.55 ± 0.16	1.17 ± 0.15
Charolais	1.03 ± 0.14	0.95 ± 0.13	0.91 ± 0.12
Maine-Anjou	1.07 ± 0.37	0.51 ± 0.48	0.17 ± 0.49
Gelbvieh	1.01 ± 0.16	1.24 ± 0.27	1.34 ± 0.22
Tarentaise	0.67 ± 0.89	0.76 ± 0.55	1.38 ± 0.61
Salers	1.19 ± 0.38	0.98 ± 0.45	0.77 ± 0.45
Red Angus	0.54 ± 0.19	0.56 ± 0.34	0.75 ± 0.30
Braunvieh	0.47 ± 0.37	0.86 ± 0.82	2.05 ± 0.54
Brangus	1.44 ± 0.34	0.80 ± 0.44	0.47 ± 0.40
Beefmaster	1.61 ± 0.57	1.47 ± 0.38	1.60 ± 0.43
Dam breed			
Hereford	0.92 ± 0.08	0.79 ± 0.08	0.99 ± 0.07
Angus	1.12 ± 0.06	0.89 ± 0.06	1.17 ± 0.06
MARC III	0.98 ± 0.08	0.86 ± 0.09	1.20 ± 0.09
Sex of calf			
Heifers	1.01 ± 0.06	0.95 ± 0.06	0.98 ± 0.06
Steers	1.05 ± 0.06	0.76 ± 0.06	1.26 ±.0 06

Table 8. Pooled regression coefficients (lb/lb) for progeny performance on maternal grandsire EPD for weaning weight (MWWT) and milk (MILK) and by breed of maternal grandsire, breed of maternal grandam, and sex of calf

Type of regression	MWWT	MILK
Pooled	0.58 ± 0.04	1.14 ± 0.06
Breed of maternal grandsire		
Hereford	0.55 ± 0.06	1.12 ± 0.11
Angus	0.57 ± 0.09	1.06 ± 0.12
Shorthorn	0.33 ± 0.37	0.93 ± 0.49
South Devon	0.30 ± 0.24	-1.22 ± 0.85
Brahman	0.46 ± 0.20	0.53 ± 0.33
Simmental	0.78 ± 0.17	1.15 ± 0.41
Limousin	1.20 ± 0.13	1.97 ± 0.24
Charolais	0.44 ± 0.11	1.38 ± 0.20
Maine-Anjou	0.13 ± 0.34	0.48 ± 0.38
Gelbvieh	0.87 ± 0.23	1.50 ± 0.33
Tarentaise	0.20 ± 0.68	0.76 ± 0.82
Salers	0.90 ± 0.32	2.26 ± 0.36
Red Angus	0.95 ± 0.30	1.68 ± 0.34
Braunvieh	– ± –	3.13 ± 0.71
Brangus	0.59 ± 0.91	0.88 ± 0.82
Beefmaster	0.95 ± 0.76	3.50 ± 0.76
Breed of maternal grandma		
Hereford	0.55 ± 0.06	1.58 ± 0.10
Angus	0.61 ± 0.05	1.03 ± 0.09
MARC III	0.56 ± 0.08	0.88 ± 0.10
Sex of calf		
Heifers	0.58 ± 0.05	1.13 ± 0.08
Steers	0.58 ± 0.05	1.14 ± 0.08

Table 9. Variances (lb^2) of adjusted breed differences to add to sum of within breed prediction error variances to obtain variance of differences of across breed EPD for bulls of two different breeds[a]. Birth weight above the diagonal and yearling weight below the diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	TA	SA	RA	BV	BS	BM
HE	0.0	0.2	0.8	1.4	0.5	0.5	0.5	0.4	1.0	0.4	2.6	0.8	0.8	1.2	0.9	1.0
AN	14	0.0	0.9	1.4	0.5	0.5	0.5	0.4	1.1	0.5	2.6	0.8	0.8	1.2	0.9	1.0
SH	53	55	0.0	2.0	1.2	1.1	1.2	1.0	1.6	1.0	3.1	1.1	1.4	1.7	1.7	1.7
SD	82	83	122	0.0	1.7	1.3	1.4	1.3	2.1	1.6	3.7	1.9	1.8	2.3	2.2	2.3
BR	36	37	78	110	0.0	0.9	0.9	0.8	1.3	0.8	2.6	1.1	1.2	1.5	1.3	1.4
SI	28	29	69	79	56	0.0	0.5	0.5	1.3	0.6	2.8	1.1	0.8	1.4	1.3	1.3
LI	31	32	72	82	58	30	0.0	0.5	1.3	0.7	2.9	1.1	0.8	1.5	1.3	1.4
CJ	24	25	61	81	52	29	31	0.0	1.2	0.5	2.7	0.9	0.8	1.3	1.2	1.3
MA	62	64	97	127	86	75	78	71	0.0	1.0	3.2	1.5	1.6	1.1	1.9	1.9
GE	28	30	63	95	54	37	39	34	62	0.0	2.8	0.9	0.8	1.2	1.2	1.3
TA	151	154	188	219	158	167	170	163	191	164	0.0	3.1	3.2	3.4	3.4	3.5
SA	49	51	70	118	74	66	68	57	93	60	184	0.0	1.4	1.7	1.6	1.7
RA	46	46	88	110	75	49	51	48	95	52	188	84	0.0	1.7	1.5	1.6
BV	69	72	105	135	93	83	85	79	67	69	198	101	102	0.0	2.0	2.1
BS	65	65	113	141	96	85	87	82	122	85	212	109	99	129	0.0	1.0
BM	66	66	115	142	97	86	89	83	123	87	213	111	102	131	77	0.0

[a]For example, a Hereford bull has within breed PEV of 300 for YWT and that for a Shorthorn bull is 200. Then the PEV for the difference in EPDs for the two bulls is 53 + 300 + 200 = 553 with SEP $= \sqrt{553}$ = 23.5.

Table 10. Variances (lb^2) of adjusted breed differences to add to sum of within breed prediction error variances to obtain variance of difference of across breed EPDs for bulls of two different breeds. Weaning weight direct above the diagonal and MILK below the diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	TA	SA	RA	BV	BS	BM
HE	0	4	19	28	11	9	10	8	22	9	42	18	17	24	20	20
AN	13	0	20	28	11	10	10	8	23	9	43	18	17	25	20	20
SH	50	52	0	43	27	25	26	22	36	23	56	26	33	38	38	38
SD	58	59	98	0	36	27	28	27	45	32	66	42	39	47	46	46
BR	25	26	66	75	0	18	18	16	29	16	43	25	26	31	29	29
SI	25	26	65	60	42	0	10	9	27	12	48	24	18	29	27	27
LI	27	28	67	62	44	31	0	10	28	13	48	25	18	29	28	28
CJ	21	22	58	59	38	27	29	0	26	11	46	21	18	27	26	26
MA	55	57	93	101	70	69	70	64	0	22	58	35	35	24	41	41
GE	23	24	59	68	39	34	35	29	58	0	46	21	19	23	27	27
TA	123	126	161	171	127	139	140	134	164	135	0	55	56	59	60	60
SA	41	44	70	89	58	57	58	50	84	50	153	0	31	37	36	37
RA	45	46	85	88	62	51	52	48	89	51	159	77	0	37	34	34
BV	81	83	119	127	97	95	96	90	95	84	190	110	115	0	42	42
BS	85	85	129	135	103	102	104	98	133	100	202	120	121	160	0	21
BM	75	75	119	125	93	92	94	88	123	90	192	110	111	150	115	0