ACROSS-BREED EPD TABLES FOR THE YEAR 2003 ADJUSTED TO BREED DIFFERENCES FOR BIRTH YEAR OF 2001

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Introduction

This report is the year 2003 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 2001 base using EPDs from the most recent national cattle evaluations. Factors to adjust EPD of 17 breeds to a common birth year of 2001 were calculated and reported in Tables 1-3 for birth weight, weaning weight, and yearling weight and in Table 4 for 15 breeds for the MILK component of maternal weaning weight.

Changes from the 2002 update (Van Vleck and Cundiff, 2002) are as follows:

1) Records were added for the first time for 21 Brangus sires with 215 calves and for 20 Beefmaster sires with 205 calves at USMARC. Maternal information will not be available for two more years.
2) Braunvieh was added last year but two more (total of seven) sires with 52 calves (total now 188) were included this year. Those two sires also added about 50% more maternal records for the MILK analysis.
3) The EPDs of seven Hereford sires used in Cycles I and II of GPE which had not been reported last year were reported this year which added several hundred Hereford calves to the total compared with the year 2002 analyses.
4) Maternal data for Red Angus tripled from last year when maternal granddaughter performance first became available.
5) New data on maternal performance of females with Hereford, Angus, Simmental, Limousin, Charolais, and Gelbvieh sires added about 80 records of grandprogeny for each breed.

The across-breed table adjustments apply **only** to EPDs for most recent (in most cases; spring, 2003) 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 direct and maternal heterozygosity for MILK analysis and 100% of direct heterozygosity for 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 heterozygosity for the maternal analysis is required. Two approaches for accounting for differences in breed heterozygosity were tried which resulted in similar final table adjustments. One approach is to include level of heterozygosity in the statistical models which essentially adjusts to a basis of no heterozygosity. The other approach is 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 (1/4 each, Pinzgauer, Red Poll, Hereford, and Angus). 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 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 H-A cows from the diallel for estimates of direct heterosis from 1) and then estimate maternal heterosis effects from 3,116 weaning weight records of 750 daughters representing 166 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 1), and
4) Adjust all records used for analysis of MWWT for lack of both direct and maternal heterozygosity using estimates from 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 30.54 lb for BWT, WWT and YWT, respectively. The estimate of maternal heterosis was 23.44 lb for MWWT. As an example of step 3), birth weight of an H by H 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) (23.44) 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, 1998, 1999, 2000, 2001, 2002). All calculations were done with programs written in Fortran language with estimates of variance components, regression coefficients, and breed effects obtained with the MTDFREML package (Boldman et al., 1995). All breed solutions are reported as differences from Angus. The table values to add to within-breed EPDs are relative to Angus.

For completeness, the basic steps in the calculations will be repeated.

Models for Analysis of MARC Records

Fixed effects in the models for birth weight, weaning weight (205-d) and yearling weight (365-d) were: breed of sire (17), dam line (Hereford, Angus, 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 and 97-99, 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 have been used in 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, 4,248 for YWT). For estimation of variance components and to estimate breed of sire effects, sire of calf was also used as a random effect (591).

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 variance 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 analyses of maternal effects included breed of maternal grandsire (15), maternal granddam line (Hereford, Angus, MARC III), breed of natural service mating sire (16), sex of calf (2), birth year-GPE cycle-age of dam subclass (75), and mating sire breed by GPE cycle by age of dam subclass (40) with a covariate for day of year of birth. The subclasses are used to account for confounding of years, mating sire breeds, and ages of dams. Ages of dams 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 (556) and dam (2,892 daughters of the maternal grandsires). 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 EPDs. The records from MARC are not included in calculation of within-breed EPD.
The basic calculations for BWT, WWT, and YWT are as follows:

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

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

Breed table factor 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 = 2001 for 2003 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 2003: 1.05, 0.83, 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 (milk) 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 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 2003: 0.57 and 1.19),

$M(i) = M_i$ 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 2001 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 2001. These pairs of differences minus the corresponding differences in average EPD for animals born in 2001 result in the last column of the tables to be used as adjustments for pairs of within-breed EPD.

Birth Weight

The range in estimated breed of sire difference for BWT relative to Angus is large: from 1.5 lb for Red Angus to 9.5 lb for Charolais and 12.3 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. The trend seen in past years of the differences from Angus becoming smaller seems to have stopped. Differences from Angus were only slightly changed from the 2002 update but most of the changes were to slightly larger differences from Angus. The adjustments for heterosis were slightly smaller than last year for straightbred Angus calves and Angus sired calves from MARC III cows. Adjusted breed of sire effects for Brangus and Beefmaster were similar to the averages for their founder breeds and were intermediate between Angus and Brahman.

Suppose the EPD for birth weight for a Charolais bull is +2.0 (which is above the year 2001 average of 1.5 for Charolais) and for a Hereford bull is also +2.0 (which is below the year 2001 average of 3.8 for Herefords). Then the adjusted EPD for the Charolais bull is 10.5 + 2.0 = 12.5 and for the Hereford bull is 3.3 + 2.0 = 5.3. The expected birth weight difference when both are mated to another breed of cow, e.g., Angus, would be 12.5 - 5.3 = 7.2 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 2002 and 2003 updates were about 2 lb or less except for Hereford (+3.0 partly due to the seven bulls not reported in 2002) and Braunvieh (+4.2) due to the weaning weights of the two _new_ Braunvieh sires when compared with Angus sired calves. Brangus and Beefmaster sire breed effects adjusted to a 2001 base were almost exactly the weighted averages of their founder breeds. All except three sire breed means for WWT adjusted to year of birth of 2001 are within about 10 lb of the Angus mean.

Yearling Weight

Changes in adjusted differences from Angus from the 2002 update were relatively small. The major exception was for Braunvieh. Progeny of two _new_ Braunvieh sires closed the difference from Angus from -56.5 to -42.5. The difference between Hereford and Angus was also smaller, probably due to including again this year the seven sires missing last year. These seven sires were reference sires that produced a relatively larger number of progeny in cycles I (1970-1972), II (1973-1974), III (1975-1976), and cycle IV (1986-1990) of the Germplasm Evaluation Program at MARC. Changes from last year of 4 to 5 lb for Pinzgauer and Tarentaise seem due primarily to the head-to-head comparison with Angus at MARC. Brangus and Beefmaster adjusted means for YWT, as with BWT and WWT, are close to the weighted average for their founder breeds and reflect the adverse effect of cold weather on postweaning growth rate of progeny with Brahman sires. Adjusted to a base year of 2001, Angus have heavier yearling weights than 10 breeds (1.3 to 43.4 lb) and lighter yearling weights than 3 breeds (2.0 to 19.6 lb).

MILK

As with previous updates, changes relative to Angus are somewhat volatile. Most of the larger changes from the 2002 update seem associated with more maternal records. Gelbvieh decreased relative to Angus but both had more maternal performance records. The largest change was for Red Angus but nearly three times more Red Angus grandprogeny had records in the 2003 analysis than in the 2002 analysis. The change for Red Angus is due almost entirely to the change in breed of sire solution for Red Angus vs Angus with the added grandprogeny at MARC. The large change for Salers is due to the inexplicable change in MILK EPD of bulls which produced calves at MARC. The average MILK EPD for the MARC bulls increased from 4.4 to 9.7. The same bulls were included in both the 2002 and 2003 analyses. The breed average for EPD for MILK, however, was 8.0 lb for both the 2000 and 2001 years of birth.

Table 5 summarizes the average 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 2002 report.

Table 7 updates the coefficients of regression of records of MARC progeny on sire EPD 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 1.05 for BWT, 0.83 for

WWT, and 1.13 for YWT were used to adjust breed of sire solutions to the base year of 2001. These regression coefficients are reasonably close to expected values of 1.0. Deviations from 1.0 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 17 breeds.

The regression coefficient for female progeny on sire EPD was 0.97 compared to 1.26 for steers. These differences are probably expected since postweaning average daily gains for heifers have been significantly less than those for steers. The females 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 five years the pattern has been fairly consistent (female estimates have ranged from .94 to 1.02; while male estimates have ranged from 1.26 to 1.32).

The coefficients of regression of records of grandprogeny on MGS EPD 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 EPD. Again, the pooled regression coefficients of 0.57 for MWWT and 1.19 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. How to use these 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 and a Hereford bull has an EPD of 30.0 with PEV of 50. The difference in predicted progeny performance is (Salers adjustment + Salers bull's EPD) - (Hereford adjustment + Hereford bull's EPD):

$$(28.4 + 15.0) - (-2.4 + 30.0) = 43.4 – 27.6 = 15.8.$$

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, $\sqrt{143} = 12$.

If the difference between the Salers and Hereford breeds in the year 2001 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:

$\sqrt{0 + 75 + 50} = 11.2$ 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 expected progeny differences (EPDs) produced in the most recent genetic evaluations for each of the 17 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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Van Vleck, L. D., and L. V. Cundiff. 2002. Across-breed EPD tables for 2002 adjusted to breed differences for birth year of 2000. Proc. Beef Improvement Federation Research and Annual Meeting, Omaha, NE. July 10-13, 2002. pp 139-159Table 1. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2001 base and factors to adjust within breed EPDs to Angus equivalent - BIRTH WEIGHT (lb)

	Number		Raw MARC Mean	Ave. Base EPD Breed 2001	MARC Bulls	Breed Soln at MARC + Ang vs Ang		Adjust to 2001 Base + Ang vs Ang		Factor to adjust EPD to Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hereford	113	1817	87	3.8	2.5	88	3.6	89	4.5	3.3
Angus	105	1421	84	2.6	2.2	84	0.0	84	0.0	0.0
Shorthorn	25	181	87	1.8	0.9	90	6.4	91	7.0	7.8
South Devon	15	153	80	0.0	-0.2	88	4.3	89	4.1	6.7
Brahman	40	589	98	1.9	0.7	96	11.6	97	12.3	13.0
Simmental	48	623	87	3.1	2.8	91	7.0	91	6.9	6.4
Limousin	40	589	83	1.3	-0.5	87	3.0	89	4.5	5.8
Charolais	75	675	89	1.5	0.5	93	8.8	94	9.4	10.5
Maine-Anjou	18	218	94	3.2	6.0	95	10.6	92	7.2	6.6
Gelbvieh	48	595	89	1.4	1.0	88	4.2	89	4.1	5.3
Pinzgauer	16	435	84	-0.1	-0.4	89	5.2	89	5.0	7.7
Tarentaise	7	199	80	2.2	1.8	87	3.2	88	3.2	3.6
Salers	27	189	85	1.3	1.5	88	4.4	88	3.8	5.1
Red Angus	21	206	85	0.5	-0.7	85	0.6	86	1.5	3.6
Braunvieh	7	188	88	1.1	0.7	89	5.2	90	5.1	6.6
Brangus	21	215	91	2.0	2.4	90	5.9	90	5.1	5.7
Beefmaster	20	205	96	0.5	0.8	93	8.5	92	7.8	9.9

Calculations:

(4) = (5) + (1, Angus)
(6) = (4) + b[(2) - (3)] with b = 1.05
(7) = (6) - (6, Angus)
(8) = (7) - (7, Angus) - [(2) - (2, Angus)]

Table 2. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2001 base and factors to adjust within breed EPDs to Angus equivalent - WEANING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2001 (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 2001 Base + Ang vs Ang (6)	Adjust to 2001 Base + Ang vs Ang (7)	Factor to adjust EPD to Angus (8)
Hereford	112	1712	503	34.0	22.8	501	-2.7	511	-2.4	-2.4
Angus	106	1315	504	34.0	23.2	504	0.0	513	0.0	0.0
Shorthorn	25	170	521	13.1	6.9	518	14.1	523	10.3	31.2
South Devon	15	134	443	16.2	0.2	503	-0.6	517	3.7	21.5
Brahman	40	509	532	15.1	4.7	520	16.1	529	15.8	34.7
Simmental	47	564	505	35.1	23.9	526	22.4	536	22.7	21.6
Limousin	40	533	477	12.4	-1.6	503	-0.8	515	1.9	23.5
Charolais	74	600	514	14.6	5.7	527	23.3	535	21.7	41.1
Maine-Anjou	18	197	459	16.2	23.4	519	15.1	513	0.1	17.9
Gelbvieh	48	559	507	36.0	30.5	518	14.3	523	9.9	7.9
Pinzgauer	16	415	478	0.6	-4.1	504	-0.1	508	-5.2	28.2
Tarentaise	7	191	476	12.0	-4.8	507	2.7	521	7.8	29.8
Salers	27	176	525	13.2	7.4	516	11.7	521	7.6	28.4
Red Angus	21	199	535	27.0	27.2	505	1.0	505	-8.2	-1.2
Braunvieh	7	183	451	6.3	6.7	516	12.0	516	2.6	30.3
Brangus	21	208	550	20.9	26.1	524	20.3	520	7.0	20.1
Beefmaster	22	215	563	6.1	14.2	530	26.3	524	10.6	38.5

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) - (3)] with b = 0.83
(7) = (6) - (6, Angus)
(8) = (7) - (7, Angus) - [(2) - (2, Angus)]

Table 3. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2001 base and factors to adjust within breed EPDs to Angus equivalent - YEARLING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2001 (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 2001 Base + Ang vs Ang (6)	Adjust to 2001 Base + Ang vs Ang (7)	Factor to adjust EPD to Angus (8)
Hereford	112	1627	851	58.0	38.9	851	-20.8	873	-20.1	-15.1
Angus	106	1259	872	63.0	44.5	872	0.0	893	0.0	0.0
Shorthorn	25	168	918	20.5	13.4	887	14.8	895	2.0	44.5
South Devon	15	134	744	22.5	0.2	868	-4.3	893	0.0	40.5
Brahman	40	438	838	25.1	8.5	831	-41.3	849	-43.4	-5.5
Simmental	47	528	852	58.4	39.3	888	15.9	909	16.5	21.1
Limousin	40	527	797	23.4	0.4	848	-24.2	874	-19.1	20.5
Charolais	74	566	882	24.8	10.7	897	24.5	912	19.6	57.8
Maine-Anjou	18	196	787	31.3	46.2	884	11.7	867	-25.9	5.8
Gelbvieh	48	555	849	66.0	55.1	863	-8.7	876	-17.3	-20.3
Pinzgauer	16	347	838	0.7	-8.0	846	-26.3	855	-37.4	24.9
Tarentaise	7	189	807	23.0	-3.4	836	-36.1	866	-27.2	12.8
Salers	27	173	899	21.1	10.5	880	7.6	892	-1.3	40.6
Red Angus	21	194	916	46.0	47.0	877	4.8	876	-17.1	-0.1
Braunvieh	7	182	737	7.0	10.9	855	-17.2	850	-42.5	13.5
Brangus	21	155	957	33.5	44.0	886	14.2	874	-18.4	11.1
Beefmaster	22	159	972	11.1	24.6	886	13.9	871	-22.2	29.7

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 EPDs used to adjust for genetic trend to 2001 base and factors to adjust within-breed EPDs to Angus equivalent - MILK (lb)

Breed	Sr	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 2001 Base MWWT + Ang (8)	Adjust to 2001 Base MWWT vs Ang (9)	MILK (10)	Factor to Adjust MILK EPD to Angus (11)
Hereford	96	2400	621	472	34.0	12.0	18.5	5.6	472	-16.9	488	-22.4	-17.9	-16.2
Angus	92	1669	446	489	34.0	17.0	16.4	7.0	489	0.0	511	0.0	3.3	0.0
Shorthorn	22	251	69	527	13.1	2.3	6.9	6.8	515	26.2	513	2.4	0.6	12.0
South Devon	14	347	69	488	16.2	6.3	0.1	5.6	494	5.1	504	-6.8	-5.4	2.1
Brahman	40	880	216	522	15.1	7.7	4.8	2.7	524	34.8	536	24.7	20.1	26.1
Simmental	47	909	233	509	35.1	7.6	19.0	8.3	514	24.5	522	11.0	2.9	9.0
Limousin	40	879	233	474	12.4	5.1	-7.9	0.0	482	-6.5	500	-10.7	-8.4	0.2
Charolais	68	820	224	498	14.6	9.0	1.6	3.7	502	13.1	516	4.9	-2.7	2.0
Maine-Anjou	17	485	86	533	16.2	4.0	22.8	4.8	511	21.6	506	-5.0	-1.7	8.0
Gelbvieh	46	765	222	528	36.0	18.0	29.6	17.6	516	27.5	521	9.7	8.1	3.8
Pinzgauer	15	545	133	504	0.6	-1.0	-1.7	6.4	504	14.8	496	-14.6	-8.7	6.0
Tarentaise	6	341	78	513	12.0	1.5	-6.0	4.7	511	21.8	517	6.2	5.6	17.8
Salers	25	351	87	534	13.2	8.0	5.8	9.7	515	25.8	517	6.1	5.6	11.3
Red Angus	21	112	83	450	27.0	14.0	26.7	14.7	494	4.8	493	-17.8	-10.4	-10.7
Braunvieh	7	502	92	542	6.3	-0.3	7.3	-1.1	518	28.6	518	7.1	9.1	23.1

Calculations:

(6) = (7) + (1, Angus)

(8) = (6) + b_{WWT} [(2) - (4)] + b_{MLK} [(3) - (5)] with b_{WWT} = 0.57 and b_{MLK} = 1.19

(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	0.56	0.53	0.48	0.48	0.46
Angus	0.88	0.87	0.84	0.83	0.81
Shorthorn	0.81	0.80	0.74	0.81	0.78
South Devon	0.37	0.39	0.37	0.41	0.42
Brahman	0.50	0.54	0.37	0.55	0.41
Simmental	0.94	0.93	0.92	0.95	0.94
Limousin	0.95	0.93	0.89	0.94	0.90
Charolais	0.81	0.79	0.69	0.77	0.68
Maine-Anjou	0.72	0.71	0.71	0.71	0.71
Gelbvieh	0.72	0.65	0.51	0.67	0.55
Pinzgauer	0.85	0.68	0.62	0.70	0.64
Tarentaise	0.95	0.95	0.94	0.95	0.95
Salers	0.81	0.81	0.75	0.80	0.81
Red Angus	0.87	0.84	0.83	0.83	0.79
Braunvieh	0.77	0.70	0.69	0.70	0.48
Brangus	0.76	0.75	0.61	–	–
Beefmaster	0.57	0.66	0.47	–	–

[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	639	
Dams (4395) within breed (3)	26.8	876	1231	
Residual	68.0	1535	4125	
Maternal				
MGS (556) within MGS breed (15)				185
Daughters within MGS (2892)				899
Residual				1272

[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	1.05 ± 0.05	0.83 ± 0.05	1.13 ± 0.05
Sire breed			
Hereford	1.17 ± 0.08	0.76 ± 0.07	1.11 ± 0.07
Angus	1.01 ± 0.11	0.79 ± 0.10	1.18 ± 0.08
Shorthorn	0.63 ± 0.47	0.72 ± 0.41	1.11 ± 0.34
South Devon	0.88 ± 0.58	-0.18 ± 0.37	-0.09 ± 0.42
Brahman	1.80 ± 0.26	1.11 ± 0.27	0.69 ± 0.24
Simmental	1.04 ± 0.22	1.20 ± 0.17	1.25 ± 0.15
Limousin	0.66 ± 0.16	0.49 ± 0.15	1.07 ± 0.14
Charolais	0.99 ± 0.14	0.95 ± 0.14	0.99 ± 0.13
Maine-Anjou	1.11 ± 0.38	0.59 ± 0.48	0.26 ± 0.49
Gelbvieh	1.01 ± 0.16	1.24 ± 0.27	1.34 ± 0.23
Pinzgauer	1.26 ± 0.17	1.49 ± 0.21	1.66 ± 0.16
Tarentaise	0.67 ± 0.89	0.76 ± 0.55	1.38 ± 0.61
Salers	1.26 ± 0.40	0.68 ± 0.38	0.68 ± 0.41
Red Angus	0.55 ± 0.19	0.53 ± 0.33	0.75 ± 0.30
Braunvieh	0.46 ± 0.36	0.78 ± 0.79	1.95 ± 0.54

Brangus	1.25 ± 0.32	0.81 ± 0.46	0.17 ± 0.41
Beefmaster	1.95 ± 0.69	1.46 ± 0.37	1.68 ± 0.43
Dam breed			
Hereford	0.98 ± 0.08	0.73 ± 0.08	0.99 ± 0.07
Angus	1.11 ± 0.06	0.84 ± 0.06	1.17 ± 0.06
MARC III	1.00 ± 0.08	0.92 ± 0.09	1.20 ± 0.08
Sex of calf			
Heifers	1.03 ± 0.06	0.94 ± 0.06	0.97 ± 0.06
Steers	1.06 ± 0.06	0.73 ± 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	0.57 ± 0.04	1.19 ± 0.07
Breed of maternal grandsire		
Hereford	0.58 ± 0.06	1.17 ± 0.12
Angus	0.57 ± 0.09	1.03 ± 0.14
Shorthorn	0.30 ± 0.35	0.83 ± 0.49
South Devon	0.32 ± 0.24	-1.21 ± 0.81
Brahman	0.42 ± 0.21	0.66 ± 0.35
Simmental	0.67 ± 0.19	1.21 ± 0.48
Limousin	0.74 ± 0.14	2.19 ± 0.26
Charolais	0.36 ± 0.14	1.33 ± 0.20
Maine-Anjou	0.09 ± 0.33	0.43 ± 0.37
Gelbvieh	0.98 ± 0.26	1.80 ± 0.35
Pinzgauer	0.70 ± 0.19	0.31 ± 0.58
Tarentaise	0.20 ± 0.66	0.77 ± 0.80
Salers	0.94 ± 0.26	2.35 ± 0.34
Red Angus	0.40 ± 0.43	1.14 ± 0.52
Braunvieh	0.00 ± –	2.76 ± 0.65

Breed of maternal grandam		
Hereford	0.52 ± 0.06	1.51 ± 0.11
Angus	0.63 ± 0.05	1.18 ± 0.10
MARC III	0.46 ± 0.09	0.80 ± 0.13
Sex of calf		
Heifers	0.57± 0.05	1.18 ± 0.09
Steers	0.57± 0.05	1.21 ± 0.09

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 EPDs for bulls of two different breeds[a]. Birth weight above diagonal and yearling weight below diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	PI	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	0.8	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	0.9	2.6	0.8	0.8	1.2	0.9	1.0
SH	54	55	0.0	2.0	1.2	1.1	1.2	1.0	1.6	1.0	1.3	3.1	1.1	1.4	1.8	1.7	1.8
SD	84	84	124	0.0	1.7	1.3	1.4	1.3	2.1	1.6	2.0	3.7	1.9	1.8	2.3	2.2	2.3
BR	37	37	80	112	0.0	0.9	0.9	0.7	1.3	0.8	0.9	2.6	1.1	1.2	1.5	1.3	1.5
SI	29	29	71	81	57	0.0	0.5	0.5	1.3	0.6	1.1	2.8	1.1	0.8	1.5	1.3	1.4
LI	31	31	73	84	59	31	0.0	0.5	1.3	0.6	1.1	2.9	1.1	0.8	1.5	1.3	1.4
CJ	24	25	61	82	52	28	31	0.0	1.2	0.5	1.0	2.7	0.9	0.8	1.4	1.2	1.3
MA	63	65	99	130	87	77	79	72	0.0	1.0	1.5	3.2	1.5	1.6	1.1	1.9	2.0
GE	28	30	65	97	55	38	40	34	64	0.0	1.0	2.8	0.9	0.8	1.2	1.2	1.4
PI	54	56	87	125	66	70	73	64	96	65	0.0	2.6	1.3	1.4	1.7	1.7	1.8
TA	153	156	191	223	160	170	172	165	194	166	158	0.0	3.1	3.2	3.4	3.4	3.5
SA	50	51	72	121	76	67	69	57	95	61	84	187	0.0	1.4	1.7	1.6	1.8
RA	47	47	90	113	76	50	51	48	97	53	91	191	86	0.0	1.8	1.5	1.6
BV	76	78	113	143	100	90	92	85	75	77	109	207	109	110	0.0	2.1	2.2
BS	66	66	115	144	98	87	89	83	124	87	116	215	112	102	138	0.0	1.0
BM	70	70	119	148	101	91	93	87	128	91	119	219	116	106	142	82	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 54 + 300 + 200 = 554 with SEP $= \sqrt{554}$ = 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 diagonal and MILK below the diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	PI	TA	SA	RA	BV	BS	BM
HE	0	4	19	28	11	9	10	8	22	9	15	42	18	17	25	20	20
AN	15	0	20	28	11	10	10	8	23	9	16	43	18	17	26	20	20
SH	49	52	0	43	27	25	26	22	36	23	29	56	27	33	40	38	38
SD	57	59	96	0	36	27	28	27	45	32	40	66	42	39	48	46	46
BR	25	27	65	73	0	18	18	16	29	17	18	43	26	26	32	29	29
SI	27	29	66	60	43	0	10	9	27	12	21	48	24	18	30	27	27
LI	29	31	68	62	45	33	0	10	28	13	22	48	25	18	31	28	28
CJ	22	24	58	59	38	29	31	0	26	11	19	46	21	17	29	26	26
MA	54	57	90	99	69	69	71	64	0	22	31	58	35	35	26	41	41
GE	24	27	59	68	40	37	38	31	58	0	19	46	21	19	25	27	27
PI	50	53	84	96	57	66	68	60	81	61	0	41	27	29	35	34	34
TA	121	124	158	167	125	138	140	132	151	121	132	0	55	56	61	61	61
SA	41	44	68	87	56	57	59	50	81	50	69	146	0	31	38	37	37
RA	52	54	91	93	68	59	60	55	100	66	95	149	88	0	38	34	34
BV	78	80	114	122	92	93	95	87	94	80	111	182	96	116	0	44	44
BS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	22
BM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0