ACROSS-BREED EPD TABLES FOR THE YEAR 2007 ADJUSTED TO BREED DIFFERENCES FOR BIRTH YEAR OF 2005

L. A. Kuehn, L. D. Van Vleck, R. M. Thallman and L. V. Cundiff
Roman L. Hruska U.S. Meat Animal Research Center, USDA-ARS, Lincoln and Clay Center, NE 68933

Introduction

This report is the year 2007 update of estimates of sire breed means from data of the Germplasm Evaluation (GPE) project at the U.S. Meat Animal Research Center (USMARC) adjusted to a year 2005 base using EPD from the most recent national cattle evaluations. Factors to adjust EPD of 16 breeds to a common birth year of 2005 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 maternal milk (MILK) component of maternal weaning weight (MWWT).

There were a few data changes and one important procedural change from the 2006 update (Van Vleck and Cundiff, 2006):

Records from USMARC for birth, weaning, and yearling weight were added for seven breeds (Hereford, Angus, Simmental, Limousin, Charolais, Gelbvieh, and Red Angus) from repeated use of sires from GPE Cycle VII in 2006. These additional records caused some small changes in the breed of sire solutions for these breeds relative to the other breeds in the analysis. Maine-Anjou EPD were derived in a multi-breed analysis with Simmental causing the EPD of the sires used at USMARC to shift slightly.

Maternal records continued to be added this year for Hereford and Angus (about 135 records); Simmental, Limousin, Charolais, Gelbvieh, and Red Angus (about 80 records); and for Brangus and Beefmaster (about 40 records). Numbers for Brangus and Beefmaster reflect an increase in records of about 40%.

One procedural change was incorporated into the adjustment factor derivation this year. In past across breed analyses for growth traits, the breed of sire solution (M_i) adjusted for base year has been calculated by scaling the difference between the average EPD of sires used at USMARC ($EPD(i)_{USMARC}$) and the breed average EPD for the base year ($EPD(i)_{YY}$) by the regression coefficient of progeny performance on EPD of sire (b) and then adding the USMARC breed of sire solution (USMARC(i)):

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

This solution can be thought of as the breed of sire solution adjusted to year YY *on a USMARC scale*. In the past, it had been added to a function of the breed average EPD to derive the across breed adjustment factor. However, these breed average EPD are *on an industry scale*. Therefore, this year, the breed of sire solution was divided by the regression coefficient (b) to put it on an industry, rather than a USMARC scale. By dividing the equation by b, the breed of sire solution (M_i) is now:

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

This methodology change does cause all of the adjustment factors and breed of sire solutions adjusted for year to change more this year than they have in the past from year to year. However, we feel this procedure more closely represents the breed differences on an industry basis. A similar change was also made for deriving the MILK adjustment factors. These scaling adjustments are similar to those used to adjust USMARC carcass differences to a common base in Van Vleck et al. (2007).

The across-breed table adjustments apply **only** to EPDs for most recent (in most cases; spring, 2007) 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 USMARC.
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 2,448 weaning weight records of 532 daughters representing 128 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 23.37 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) (23.37) 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 (1997–2006). 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 USMARC 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 by GPE cycle (25), year of dam by damline combination (109), 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 (Koch et al., 1994) 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 (4,902 dams for BWT, 4,656 for WWT, 4,488 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 in the next section to adjust for genetic trend and bulls used at USMARC.

The fixed effects for the analysis of maternal effects included breed of maternal grandsire (17 including Pinzgauer), maternal grand dam line (Hereford, Angus, MARC III), breed of natural service mating sire (28), sex of calf (2), birth year-GPE cycle-age of dam subclass (93), and mating sire breed by GPE cycle by age of dam subclass (80) 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. 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 (620) and dam (3,257 daughters of the maternal grandsires). Due to multiple sire pastures, mating sires were unknown within breed. For estimation of regression coefficients of grand progeny 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 USMARC Solutions

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

USMARC breed of sire solution for breed i (USMARC (i)) converted to an industry scale (divided by b—new this year) and adjusted for genetic trend (as if bulls born in the base year had been used rather than the bulls actually used):

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

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

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

For weaning weight, the breed of sire solution for breed i adjusted for genetic trend on a USMARC scale is also calculated for use in MILK factor derivation:

$M_{USMARCi}$ = USMARC (i) + b[EPD(i)$_{YY}$ - EPD(i)$_{USMARC}$].

where,

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

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 = 2005 for the 2007 update),

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

b is the pooled coefficient of regression of progeny performance at USMARC on EPD of sire (for 2007: 1.04, 0.87, and 1.14 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.

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

MWWT(i) = USMARC(i)$_{MGS}$ +

b_{WWT}[EPD(i)$_{YYWWT}$ - EPD(i)$_{USMARCWWT}$]

+ b_{MLK}[EPD(i)$_{YYMLK}$ - EPD(i)$_{USMARCMLK}$]

USMARC breed of maternal grandsire solution (MWWT(i)) adjusted for genetic trend and direct genetic effect and converted to an industry scale for milk EPD (divided by b_{MLK}—new this year):

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

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

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

where,

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

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

$EPD(i)_{USMARCWWT}$ is the weighted (by number of grand progeny at USMARC) average of EPD for WWT of MGS of breed i having grand progeny with records at USMARC,

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

$EPD(i)_{USMARCMLK}$ is the weighted (by number of grand progeny at USMARC) average of EPD for MILK of MGS of breed i having grand progeny with records at USMARC,

b_{WWT}, b_{MLK} are the coefficients of regression of performance of USMARC grand progeny on MGS EPD for WWT and MILK (for 2007: 0.58 and 1.09),

$M(i) = M_{USMARCi}$ is the USMARC breed of sire solution from the first analysis of direct breed of sire effects for WWT adjusted for genetic trend and to a USMARC scale,

$\overline{MWWT}$ and $\overline{M}$ are constants corresponding to un-weighted 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, USMARC analyses to estimate breed of sire differences and the adjustments to the breed of sire effects to a year 2005 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 for weaning weight many breeds are continuing to become more similar to the arbitrary base breed, Angus. For yearling weight, however, Angus is becoming heavier in comparison to differences in the 2005 report. Most of the other breeds have not changed much relative to each other. Column 7 of Tables 1 and 3, column 8 of Table 2, and column 10 of Table 4 represent the best estimates of breed differences for calves born in 2005 on an industry scale. These pairs of differences minus the corresponding differences in average EPD for animals born in 2005 result in the last column of the tables to be used as adjustment factors for pairs of sires having within-breed EPD.

Birth Weight

The range in estimated breed of sire differences for BWT relative to Angus is large: from 0.6 lb for Red Angus to 8.6 lb for Charolais and 11.6 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. Even after adjusting to put breed of sire differences on an industry scale, breed differences from Angus were only slightly changed from the 2006 update (Van Vleck and Cundiff, 2006). The most noticeable changes occurred in Maine-Anjou and Braunvieh differences from Angus due to EPD changes in both of these breeds.

Suppose the EPD for birth weight for a Charolais bull is +2.0 (which is above the year 2005 average of 1.3 for Charolais) and for a Hereford bull is also +2.0 (which is below the year 2005 average of 3.7 for Herefords). The across-breed adjustment factors in the last column of Table 1 are 2.7 for Hereford and 9.6 for Charolais. Then the adjusted EPD for the Charolais bull is 9.6 + 2.0 = 11.6 and for the Hereford bull is 2.7 + 2.0 = 4.7. The expected birth weight difference when both are mated to another breed of cow, e.g., Angus, would be 11.6 – 4.7 = 6.9 lb.

Weaning Weight

Weaning weights remained fairly similar to Angus for most breeds—12 of the 15 sire breed differences were less than a 10 lb deviation from Angus. With new data added and the new adjustment to put sire breed differences on an EPD scale, these breed differences changed slightly more than usual, but they were still within 4 lb of the estimates reported in 2006 (Van Vleck and Cundiff, 2006) for all but one breed (Braunvieh).

Yearling Weight

Yearling weight was the trait most affected by the addition of new weight records for 7 breeds and the new adjustment for breed of sire differences to year 2005. However, most changes were within 5 lb of last year's estimated difference relative to Angus (adjusted to year 2004). Angus-sired calves were predicted to have heavier yearling weights than 13 other breeds.

Maternal Milk

The changes from last year for milk for the current base year (Table 4, column 10) were generally small. The largest changes were for Brangus (-4.5 lb) and Limousin (+3.1 lb), both of which had new maternal records this year. Changes for other breeds were all less than 2 lb.

Accuracies and Variance Components

Table 5 summarizes the average Beef Improvement Federation (BIF) accuracy for bulls with progeny at USMARC weighted appropriately by number of progeny or grand progeny. South Devon bulls had relatively small accuracy for all traits as did Hereford, Brahman, and Shorthorn bulls. Charolais bulls had low accuracy for yearling weight and milk. 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 USMARC 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 1.04 for BWT, 0.87 for WWT, and 1.14 for YWT were used to adjust breed of sire solutions to the base year of 2005. 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 USMARC herd and of progeny in herds contributing to the national genetic evaluations of the 16 breeds.

The regression coefficient for female progeny on sire EPDs for YWT was 1.00 compared to 1.28 for steers. These differences might be expected because post weaning average daily gains for heifers at USMARC 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. This result may imply that heifers at USMARC are treated in a similar fashion to bulls and heifers in herds contributing to the national genetic evaluations.

The coefficients of regression of records of grand progeny 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. Standard errors, however, for the regression coefficients by breed are large except for Angus and Hereford. The pooled regression coefficients of 0.58 for MWWT and 1.09 for MILK are reasonably close to the expected regression coefficients of 0.50 and 1.00.

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 USMARC 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):

(30.7+ 15.0) - (-3.1 + 30.0) = 45.7 – 26.9 = 18.8.

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 2005 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.

References

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1994. Breed comparisons for growth and maternal traits adjusted to a 1992 base. Proc. BIF Research Symposium, Des Moines, IA, May, 1994. pp 197-209.

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1995. Mixed model methods to estimate breed comparisons for growth and maternal traits adjusted to a 1993 base. Proc. BIF Research Symposium, Sheridan, WY. May 31-June 3, 1995. pp 218-239.

Boldman, K. G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. *A Manual for Use of MTDFREML* (DRAFT). A set of programs to obtain estimates of variances and covariances. USDA-ARS, Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. (120 pp).

Cundiff, L. V. 1993. Breed comparisons adjusted to a 1991 basis using current EPD's. Proc. BIF Research Symposium, Asheville, NC, May 26-29, 1993. pp 114-123.

Cundiff, L. V. 1994. Procedures for across breed EPD's. Proc. Fourth Genetic Prediction Workshop, Beef Improvement Federation, Kansas City, MO, Jan. 1994.

Koch, R. M., L. V. Cundiff, and K. E. Gregory. 1994. Cumulative selection and genetic change for weaning or yearling weight or for yearling weight plus muscle score in Hereford cattle. J. Anim. Sci. 72:864-885.

Notter, D. R., and L. V. Cundiff. 1991. Across-breed expected progeny differences: Use of within-breed expected progeny differences to adjust breed evaluations for sire sampling and genetic trend. J. Anim. Sci. 69:4763-4776.

Núñez-Dominguez, R., L. D. Van Vleck, and L. V. Cundiff. 1993. Breed comparisons for growth traits adjusted for within-breed genetic trend using expected progeny differences. J. Anim. Sci. 71:1419-1428.

Van Vleck, L. D. 1994. Prediction error variances for inter-breed EPD's. Proc. Fourth Genetic Predication Workshop, Beef Improvement Federation, Kansas City, MO, Jan. 1994.

Van Vleck, L. D., and L. V. Cundiff. 1994. Prediction error variances for inter-breed genetic evaluations. J. Anim. Sci. 71:1971-1977.

Van Vleck, L. D., and L. V. Cundiff. 1995. Assignment of risk to across-breed EPDs with tables of variances of estimates of breed differences. Proc. BIF Research Symposium, Sheridan, WY. May 31-June 3, 1995. pp 240-245.

Van Vleck, L. D., and L. V. Cundiff. 1997. Differences in breed of sire differences for weights of male and female calves. Proc. BIF Research Symposium, Dickinson, ND. May 14-17, 1997. pp 131-137.

Van Vleck, L. D., and L. V. Cundiff. 1997. The across-breed EPD tables adjusted to a

1995 base. Proc. BIF Research Symposium, Dickinson, ND. May 14-17, 1997. pp 102-117.

Van Vleck, L. D., and L. V. Cundiff. 1998. Across-breed EPD tables for 1998 adjusted to a 1996 base. Proc. Beef Improvement Federation Research Symposium and Annual Meeting. Calgary, Alberta, Canada. July 2, 1998. pp 196-212.

Van Vleck, L. D., and L. V. Cundiff. 1998. Influence of breed of dam on across-breed adjustment factors. Midwestern Section ASAS and Midwest Branch ADSA 1998 Meeting, Des Moines, IA. Abstract # 10. p 31.

Van Vleck, L. D., and L. V. Cundiff. 1999. Across-breed EPD tables for 1999 adjusted to a 1997 base. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Roanoke, VA. June 15-19, 1999. pp 155-171.

Van Vleck, L. D., and L. V. Cundiff. 2000. Across-breed EPD tables for 2000 adjusted to a 1998 base. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Wichita, KS. July 12-15, 2000. pp 98-116.

Van Vleck, L. D., and L. V. Cundiff. 2001. Across-breed EPD tables for 2001 adjusted to breed differences for birth year 1999. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, San Antonio, TX. July 11-14, 2001. pp 44-63

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 139-159.

Van Vleck, L. D., and L. V. Cundiff. 2003. Across-breed EPD tables for the year 2003 adjusted to breed differences for birth year of 2001. Beef Improvement Federation Research and Annual Meeting, Lexington, KY. May 28-31, 2003. pp 55-63.

Van Vleck, L. D., and L. V. Cundiff. 2004. Across-breed EPD tables for the year 2004 adjusted to breed differences for birth year of 2002. Beef Improvement Federation Research and Annual Meeting, Sioux Falls, SD. May 25-28, 2004. pp 46-61.

Van Vleck, L. D., and L. V. Cundiff. 2005. Across-breed EPD tables for the year 2005 adjusted to breed differences for birth year of 2003. Beef Improvement Federation Research and Annual Meeting, Billings, MT. July 6-9, 2005. pp 126-142.

Van Vleck, L. D., and L. V. Cundiff. 2006. Across-breed EPD tables for the year 2006 adjusted to breed differences for birth year of 2004. Beef Improvement Federation Research and Annual Meeting, Choctaw, MS. April 18-21, 2006. Available online at: http://www.beefimprovement.org/proceedings/06proceedings/2006-bif-vanvleck-cundiff.pdf

Van Vleck, L. D., L. V. Cundiff, T. L. Wheeler, S. D. Shackelford, and M. Koohmaraie. 2007. Across-breed adjustment factors for expected progeny differences for carcass traits. J. Anim. Sci. jas.2006-658v1. Available online at: http://jas.fass.org/cgi/reprint/jas.2006-658v1.

Table 1. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2005 base and factors to adjust within breed EPD to an Angus equivalent – BIRTH WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw USMARC Mean (1)	Ave. Base EPD Breed 2005 (2)	Ave. Base EPD USMARC Bulls (3)	Breed Soln at USMARC + Ang (4)	Breed Soln at USMARC vs Ang (5)	Adjust to 2005 Base + Ang (6)	Adjust to 2005 Base vs Ang (7)	Factor to adjust EPD To Angus (8)
Hereford	113	1903	87	3.7	2.5	88	3.6	86	4.1	2.7
Angus	105	1453	84	2.3	1.7	84	0.0	82	0.0	0.0
Shorthorn	25	181	87	1.8	0.9	90	6.4	88	6.5	7.0
South Devon	15	153	80	0.0	0.0	88	4.2	85	3.5	5.8
Brahman	40	589	98	1.8	0.7	95	11.5	93	11.6	12.1
Simmental	48	718	88	1.7	2.3	91	6.6	87	5.1	5.7
Limousin	40	671	84	1.9	0.5	87	3.0	85	3.6	4.0
Charolais	75	731	89	1.3	0.3	92	8.5	90	8.6	9.6
Maine-Anjou	18	218	94	2.4	4.8	95	10.6	89	7.2	7.1
Gelbvieh	48	662	89	1.7	1.3	88	4.2	86	3.8	4.4
Tarentaise	7	199	80	1.5	1.7	87	3.2	84	2.2	3.0
Salers	27	189	85	1.1	1.8	88	4.5	85	3.0	4.2
Red Angus	21	253	84	0.4	-1.0	84	-0.3	82	0.6	2.5
Braunvieh	7	188	88	-0.2	0.3	89	5.1	85	3.8	6.3
Brangus	21	215	91	2.2	2.6	90	6.1	87	4.9	5.0
Beefmaster	21	214	96	0.4	0.8	92	8.5	89	7.1	9.0

Calculations:

(4) = (5) + (1, Angus)

(6) = (4) / b + [(2) – (3)] with b = 1.04

(7) = (6) – (6, Angus)

(8) = (7) – (7, Angus) – [(2) – (2, Angus)]

Table 2. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2005 base and factors to adjust within breed EPD to an Angus equivalent – WEANING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw USMARC Mean (1)	Ave. Base EPD Breed 2005 (2)	Ave. Base EPD USMARC Bulls (3)	Breed Soln at USMARC + Ang (4)	Breed Soln at USMARC vs Ang (5)	USMARC Scale (6)	Adjust to 2005 Base + Ang (7)	Adjust to 2005 Base vs Ang (8)	Factor to adjust EPD To Angus (9)
Hereford	112	1795	508	39.0	24.7	504	-2.1	516.4	597	-4.1	-3.1
Angus	106	1344	506	40.0	24.0	506	0.0	519.9	601	0.0	0.0
Shorthorn	25	170	521	14.0	7.8	520	14.2	525.5	607	6.5	32.5
South Devon	15	134	443	19.6	-0.3	505	-1.0	522.3	603	2.7	23.1
Brahman	40	509	532	14.0	4.1	522	16.1	530.7	613	12.5	38.5
Simmental	47	650	520	32.9	24.5	528	21.6	534.9	618	17.3	24.4
Limousin	40	608	491	37.6	22.3	503	-2.5	516.7	597	-3.7	-1.3
Charolais	74	650	521	20.9	9.2	529	22.6	538.8	623	21.8	40.9
Maine-Anjou	18	197	459	39.1	44.1	521	14.9	516.6	597	-3.8	-2.9
Gelbvieh	48	623	517	41.0	32.8	520	13.7	526.8	609	8.0	7.0
Tarentaise	7	191	476	4.0	-4.7	509	2.8	509.9	597	-4.1	31.9
Salers	27	176	525	16.3	7.0	518	11.9	516.4	608	7.0	30.7
Red Angus	21	246	538	30.1	26.7	504	-1.6	526.0	586	-14.6	-4.7
Braunvieh	7	183	451	3.3	7.2	518	11.7	507.3	594	-6.4	30.3
Brangus	21	208	550	23.6	25.6	528	22.4	514.4	609	7.9	24.3
Beefmaster	22	215	563	7.0	13.9	534	27.9	526.7	610	9.2	42.2

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) – (3)] with b = 0.87 (used in MILK calculation; Table 4)
(7) = (4) / b + [(2) – (3)] with b = 0.87
(8) = (7) – (7, Angus)
(9) = (8) – (8, Angus) – [(2) – (2, Angus)]

Table 3. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2005 base and factors to adjust within breed EPD to an Angus equivalent – YEARLING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw USMARC Mean (1)	Ave. Base EPD Breed 2005 (2)	Ave. Base EPD USMARC Bulls (3)	Breed Soln at USMARC + Ang (4)	Breed Soln at USMARC vs Ang (5)	Adjust to 2005 Base + Ang (6)	Adjust to 2005 Base vs Ang (7)	Factor to adjust EPD To Angus (8)
Hereford	112	1708	860	65.0	41.2	856	-19.1	775	-21.7	-12.7
Angus	106	1286	875	74.0	45.2	875	0.0	796	0.0	0.0
Shorthorn	25	168	918	22.0	12.2	890	14.9	791	-5.9	46.1
South Devon	15	134	744	26.7	-0.6	870	-4.6	791	-5.6	41.7
Brahman	40	438	838	23.2	7.7	835	-39.9	748	-48.2	2.6
Simmental	47	601	870	57.5	42.0	891	15.7	797	0.5	17.0
Limousin	40	591	813	71.2	46.1	849	-26.4	770	-26.8	-24.0
Charolais	74	616	892	37.6	17.3	899	23.7	809	12.3	48.7
Maine-Anjou	18	196	787	77.6	87.7	887	12.0	768	-28.3	-31.9
Gelbvieh	48	617	863	74.0	58.9	867	-8.5	775	-21.2	-21.2
Tarentaise	7	189	807	11.0	-3.9	840	-35.1	752	-44.7	18.3
Salers	27	173	898	27.4	8.8	883	8.0	793	-3.1	43.5
Red Angus	21	240	924	52.4	46.1	875	0.2	774	-22.3	-0.7
Braunvieh	7	182	737	5.9	13.0	858	-16.8	746	-50.7	17.4
Brangus	21	152	977	39.1	42.6	902	27.2	788	-8.4	26.5
Beefmaster	22	157	991	12.0	22.4	899	23.7	778	-18.3	43.7

Calculations:
(4) = (5) + (1, Angus)
(6) = (4)/b + [(2) – (3)] with b = 1.14
(7) = (6) – (6, Angus)
(8) = (7) – (7, Angus) – [(2) – (2, Angus)]

Table 4. Breed of maternal grandsire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2005 base and factors to adjust within-breed EPD to an Angus equivalent – MILK (lb)

Breed	MGS	Gpr	Number Daughters	Raw USMARC Mean (1)	Mean EPD Breed WWT (2)	Mean EPD Breed MILK (3)	Mean EPD USMARC WWT (4)	Mean EPD USMARC MILK (5)	Breed Soln at USMARC MWWT Ang (6)	Breed Soln at USMARC MWWT vs Ang (7)	Adjust to 2005 Base MWWT Ang (8)	Adjust to 2005 Base MWWT vs Ang (9)	MILK (10)	Factor to Adjust MILK EPD to Angus (11)
Hereford	108	3024	721	487	39.0	15.0	23.3	7.9	488	-19.9	505	-24.4	-15.3	-15.7
Angus	104	2307	550	508	40.0	20.0	21.4	10.3	508	0.0	529	0.0	5.4	0.0
Shorthorn	22	251	69	527	14.0	2.0	7.7	6.1	532	23.5	531	1.3	4.0	16.6
South Devon	14	347	69	488	19.6	7.5	-0.5	5.5	512	3.9	526	-3.7	0.9	8.0
Brahman	40	880	216	522	14.0	6.3	4.3	2.6	539	31.3	549	19.6	18.4	26.7
Simmental	47	1217	244	528	32.9	4.9	23.1	8.6	534	25.6	535	5.9	3.9	13.7
Limousin	40	1193	242	496	37.6	19.4	20.6	16.8	501	-7.4	513	-16.1	-7.8	-12.6
Charolais	68	1108	239	515	20.9	6.3	8.3	4.2	518	10.0	528	-1.7	-4.8	3.5
Maine-Anjou	17	485	86	533	39.1	19.3	43.2	23.2	527	18.8	520	-9.2	-1.5	-6.2
Gelbvieh	47	1086	240	542	41.0	18.0	32.4	17.0	531	23.3	537	8.0	9.6	6.2
Tarentaise	6	341	78	513	4.0	1.0	-5.9	4.6	527	18.9	529	-0.7	6.4	20.0
Salers	25	351	87	534	16.3	8.4	5.5	11.9	531	23.2	534	4.3	6.6	12.8
Red Angus	21	423	97	519	30.1	15.5	27.3	13.5	509	0.7	513	-16.8	-4.2	-5.1
Braunvieh	7	502	92	542	3.3	0.0	8.0	-0.4	534	25.7	531	2.2	9.9	24.5
Brangus	19	136	43	549	23.6	7.7	24.3	2.6	511	2.7	516	-13.4	-10.0	-3.1
Beefmaster	20	152	51	551	7.0	2.0	15.8	-1.7	510	2.1	509	-20.2	-16.7	-4.1

Calculations:
(6) = (7) + (1, Angus); (8) = (6) + b_{WWT}[(2) – (4)] + b_{MLK} [(3) – (5)] with b_{WWT} = 0.58 and b_{MLK} = 1.09; (9) = (8) – (8, Angus); (10)= {[(9) – Average (9)] – 0.5[(6, Table 2) – Average (6, Table 2)]}/b_{MLK}; (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 USMARC

Breed	BWT	WWT	YWT	MWWT	MILK
Hereford	0.59	0.56	0.55	0.53	0.48
Angus	0.73	0.75	0.70	0.73	0.66
Shorthorn	0.65	0.59	0.58	0.61	0.48
South Devon	0.37	0.39	0.37	0.41	0.42
Brahman	0.50	0.55	0.38	0.55	0.42
Simmental	0.94	0.94	0.94	0.94	0.93
Limousin	0.92	0.89	0.83	0.89	0.84
Charolais	0.73	0.67	0.58	0.66	0.57
Maine-Anjou	0.72	0.71	0.71	0.71	0.71
Gelbvieh	0.74	0.68	0.54	0.72	0.59
Tarentaise	0.95	0.95	0.95	0.95	0.95
Salers	0.83	0.83	0.77	0.82	0.83
Red Angus	0.89	0.87	0.87	0.85	0.82
Braunvieh	0.85	0.86	0.84	0.86	0.79
Brangus	0.81	0.79	0.67	0.82	0.68
Beefmaster	0.72	0.78	0.64	0.79	0.68

[a]Weighted by number of progeny at USMARC for BWT, WWT, and YWT and by number of grand progeny 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	BWT	WWT	YWT	MWWT
Direct[a]				
Sires (650) within breed (17)	11.67	155.16	632.39	
Dams (4656) within breed (3)	26.19	880.58	1242.62	
Residual	68.62	1550.32	4070.35	
Maternal				
MGS (620) within MGS breed (17)				215.56
Daughters within MGS (3257)				967.54
Residual				1407.36

[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	1.04 ± 0.05	0.87 ± 0.05	1.14 ± 0.05
Sire breed			
Hereford	1.20 ± 0.08	0.82 ± 0.07	1.16 ± 0.07
Angus	0.85 ± 0.10	0.80 ± 0.09	1.16 ± 0.08
Shorthorn	0.51 ± 0.52	0.66 ± 0.46	1.28 ± 0.37
South Devon	0.97 ± 0.56	-0.17 ± 0.35	-0.07 ± 0.40
Brahman	1.79 ± 0.27	1.13 ± 0.27	0.70 ± 0.24
Simmental	1.05 ± 0.19	1.35 ± 0.17	1.33 ± 0.15
Limousin	0.72 ± 0.14	0.54 ± 0.15	0.98 ± 0.14
Charolais	1.09 ± 0.13	0.98 ± 0.13	0.93 ± 0.12
Maine-Anjou	0.81 ± 0.38	0.32 ± 0.49	0.08 ± 0.50
Gelbvieh	1.01 ± 0.15	1.13 ± 0.25	1.27 ± 0.20
Tarentaise	0.59 ± 0.85	0.74 ± 0.56	1.32 ± 0.59
Salers	1.20 ± 0.38	1.04 ± 0.45	0.81 ± 0.45
Red Angus	0.69 ± 0.19	0.76 ± 0.33	0.89 ± 0.30
Braunvieh	0.53 ± 0.39	0.67 ± 0.65	1.94 ± 0.53
Brangus	1.62 ± 0.35	0.63 ± 0.43	0.45 ± 0.40
Beefmaster	1.18 ± 0.53	1.59 ± 0.38	1.49 ± 0.42
Dam breed			
Hereford	0.95 ± 0.08	0.84 ± 0.08	1.02 ± 0.07
Angus	1.12 ± 0.06	0.85 ± 0.06	1.17 ± 0.06
MARC III	0.99 ± 0.08	0.92 ± 0.09	1.22 ± 0.08
Sex of calf			
Heifers	1.01 ± 0.06	0.95 ± 0.06	1.00 ± 0.06
Steers	1.06 ± 0.06	0.78 ± 0.06	1.27 ±.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 grand dam, and sex of calf

Type of regression	MWWT	MILK
Pooled	0.58 ± 0.04	1.09 ± 0.06
Breed of maternal grandsire		
Hereford	0.50 ± 0.06	1.20 ± 0.12
Angus	0.53 ± 0.08	1.02 ± 0.12
Shorthorn	0.72 ± 0.39	0.14 ± 0.60
South Devon	0.31 ± 0.24	-1.21 ± 0.86
Brahman	0.40 ± 0.22	0.49 ± 0.35
Simmental	0.91 ± 0.17	0.82 ± 0.37
Limousin	1.19 ± 0.12	1.83 ± 0.21
Charolais	0.41 ± 0.10	1.08 ± 0.19
Maine-Anjou	0.04 ± 0.35	0.39 ± 0.47
Gelbvieh	0.97 ± 0.21	1.50 ± 0.33
Tarentaise	0.27 ± 0.71	0.88 ± 0.86
Salers	0.89 ± 0.33	2.26 ± 0.37
Red Angus	0.88 ± 0.25	1.80 ± 0.28
Braunvieh	3.24 ± 0.98	-2.08 ± 1.67
Brangus	0.07 ± 0.61	0.81 ± 0.57
Beefmaster	1.22 ± 0.46	3.74 ± 0.46
Breed of maternal grand dam		
Hereford	0.54 ± 0.06	1.44 ± 0.10
Angus	0.56 ± 0.05	1.03 ± 0.09
MARC III	0.63 ± 0.07	0.91 ± 0.10
Sex of calf		
Heifers	0.56 ± 0.05	1.09 ± 0.08
Steers	0.59 ± 0.05	1.10 ± 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	0.9	1.4	0.5	0.5	0.5	0.4	1.0	0.4	2.6	0.8	0.8	1.2	0.9	0.9
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	0.9
SH	55	58	0.0	2.1	1.2	1.2	1.2	1.0	1.6	1.0	3.2	1.2	1.5	1.8	1.7	1.7
SD	83	84	126	0.0	1.8	1.3	1.4	1.4	2.1	1.6	3.7	2.0	1.9	2.3	2.2	2.2
BR	36	37	82	111	0.0	0.8	0.9	0.8	1.3	0.8	2.7	1.1	1.2	1.5	1.3	1.3
SI	27	28	72	80	55	0.0	0.5	0.5	1.3	0.6	2.9	1.1	0.8	1.4	1.2	1.2
LI	28	29	73	82	56	28	0.0	0.5	1.3	0.7	2.9	1.1	0.8	1.4	1.2	1.2
CH	24	25	64	82	52	28	30	0.0	1.2	0.5	2.8	0.9	0.8	1.3	1.1	1.2
MA	62	64	101	129	86	75	76	72	0.0	1.0	3.2	1.5	1.6	1.1	1.8	1.9
GE	26	28	65	94	53	35	36	33	62	0.0	2.8	0.9	0.8	1.1	1.2	1.2
TA	152	155	191	221	158	167	169	163	192	163	0.0	3.1	3.2	3.4	3.4	3.4
SA	49	51	74	119	75	65	67	57	94	59	185	0.0	1.4	1.7	1.6	1.6
RA	45	45	90	111	74	48	49	48	95	50	188	84	0.0	1.7	1.4	1.5
BV	69	72	108	136	93	82	83	79	68	69	199	101	102	0.0	2.0	2.0
BS	63	64	114	139	95	81	82	79	120	82	211	108	96	127	0.0	0.9
BM	63	64	115	139	94	81	82	79	120	81	211	108	97	127	75	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 55 + 300 + 200 = 555 with SEP = $\sqrt{555}$ = 23.6.

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	20	28	11	9	9	8	22	8	42	18	16	24	19	19
AN	13	0	21	28	11	9	10	8	23	9	43	19	16	25	20	19
SH	51	53	0	44	28	26	26	23	37	23	58	28	33	39	38	38
SD	60	61	100	0	36	27	28	27	45	32	67	42	38	47	46	45
BR	26	27	67	77	0	17	18	16	29	16	43	26	25	31	29	29
SI	25	26	65	62	43	0	9	9	27	11	48	23	17	29	26	26
LI	26	27	67	64	44	30	0	9	27	12	48	24	17	29	26	26
CH	21	22	59	61	38	27	29	0	26	10	47	21	16	27	25	25
MA	56	58	94	104	72	70	71	65	0	22	58	35	34	24	40	40
GE	22	24	59	69	40	33	34	29	59	0	46	21	17	23	26	25
TA	128	130	166	177	132	143	144	138	169	139	0	56	55	60	61	60
SA	42	45	71	92	59	57	59	51	86	51	158	0	31	37	36	36
RA	43	43	83	87	61	49	50	46	88	48	162	75	0	36	32	32
BV	84	86	122	131	100	97	98	92	98	86	197	114	115	0	42	42
BS	72	72	116	124	91	88	89	84	121	86	193	108	105	148	0	21
BM	64	65	109	116	83	81	82	77	114	79	186	101	97	141	99	0