# ESTIMATION OF VARIANCE COMPONENTS DUE TO DIRECT AND MATERNAL EFFECTS FOR GROWTH TRAITS OF YOUNG BEEF BULLS IN FOUR BREED GROUPS

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## SUMMARY

Records for birth weight (BW), 180-day weaning weight (WW), pre- and post-weaning ADG of young beef bulls in Hereford (HE), Beef Synthetic #1 (SY1), Dairy Synthetic (SD) and Double Muscled (DM) breed groups from 1970 to 1988 were used to estimate variance components and genetic parameters by derivative-free restricted maximum likelihood (DFREML) procedure using an univariate animal model with maternal effects. Heritability estimates for direct effects for BW and post-weaning ADG in all breed groups were consistently higher than heritability estimates for maternal effects, however, the pattern was reversed for WW and pre-weaning ADG. The heritability estimates were different among the breed groups. Heritability estimates for direct effects were moderate for BW (0.16-0.26) in DM and SD, and high in HE and SY1 (0.65-0.71), low for WW (0.07-0.15) and pre-weaning ADG (0.07-0.25), moderate for post-weaning ADG (0.27-0.39), except for HE (0.61). Heritability estimates for maternal effects were moderate for BW (0.17-0.36), low for post-weaning ADG (0.05-0.15) except for HE (0.59), moderate to high for WW (0.29-0.76), high for pre-weaning ADG (0.49-0.7) except for DM (0.09). The estimates of total heritability were high for BW (0.45-0.69) except for DM (0.04), low for WW (0.01-0.1) except for SY1 (0.32), moderate for pre-weaning ADG (0.18-0.35) except for DM (0.07), low for post-weaning ADG (0.07-0.15). The estimates of total heritability for all traits in DM were lower than other breed groups (0.01-0.07). The genetic correlation between direct and maternal effects were negative for all traits in the four breed groups, except for BW in SD and WW in SY1, indicating that it is important to utilize maternal genetic variation in a selection program for growth traits.

## INTRODUCTION

Early growth traits of an animal are determined not only by its own genetic potential but also by the maternal environment. Intrauterine environment, milk production and mothering ability of the dam may affect the offspring performance. Although maternal effects are strictly environmental with respect to offspring, these effects can have both environmental and genetic components with respect to the dam (Willham, 1972). The presence of maternal additive genetic effects may bias estimates of direct additive genetic effects. Baker (1980) has reviewed the influence of maternal effects on the efficiency of selection. During the last decade, most estimates of maternal heritabilities and direct-maternal genetic correlation have been obtained by equating variance component estimates from sire-maternal grandsire (Trus and Wilton, 1988) and sire-dam models analysis (Brown et al., 1990) to their expectations, while more recently estimates have been obtained using an animal model incorporating maternal effects (Mackinnon et al., 1991; Tawah et al., 1993).

Estimation of genetic parameters due to maternal effects in beef cattle has generally been restricted to pre-weaning traits. Mackinnon et al. (1991) showed that maternal effect also influences the post-weaning rate of growth. Meyer (1992) estimated genetic parameters due to direct and maternal effects for growth traits in Australian beef cattle fitting several animal models. Arthur et al. (1994) estimated additive and maternal heritabilities of growth and lifetime production traits in two breeds of beef cows. No published estimates of heritability for growth traits based on additive direct and maternal effects were available in the DM cattle. The objective of this study was to estimate variance components and heritabilities due to direct and maternal effects for growth traits of young bulls in four breed groups.

## MATERIALS AND METHODS

Records for birth weight, weaning weight adjusted to 180 days of age, pre-weaning average daily gain (ADG) and post-weaning ADG of young beef bulls were obtained from four genetically distinct breed groups from 1970 to 1988 at the University of Alberta ranch at Kinsella, Alberta, Canada. The purebred Hereford (HE) and the Beef Synthetic #1 (SY1) were established in 1960. In 1982, HE line was merged into a crossbred Hereford line. Dairy Synthetic (SD) line was started in 1967. The genetic composition of the synthetic lines has been described by Berg et al. (1990). Briefly, SY1 was composed of 33% each of Angus and Charolais, 20% Galloway, and small amount of other beef breeds. SD was composed of 60% dairy breeds (Holstein, Brown Swiss and Simmental) and 40% beef breeds. The Double Muscled (DM) breed group was used in studies on muscling and carcass leanness. The four breed groups have been maintained and managed similarly and have been subjected to the same selection program. The breeding herds were on the range year round and depended on natural grazing. Calves were weaned in the fall and following a 28-day adjustment period they were put on a performance test for 140 days. Bull calves were not castrated and full fed on a high energy feedlot diet. Selection of sires within each breed group was based on pre- and post-weaning gain. Females were selected with emphasis on reproductive performance, heifers and cows failing to wean a calf in any year were culled.

All analyses were conducted within breed group. Year of birth of bulls with 12 levels (1970-1981) for HE and SY1, 9 levels (1980-1988) for SD, and 16 levels (1973-1988) for DM, and age of dam with 5 levels (2, 3, 4, 5, ≥6 years) for the four breed groups were analyzed using GLM procedure of SAS (SAS, 1989). Year and age of dam effects for all traits studied in the four breed groups as the fixed effects in the model were all significant ($P<0.01$).

Estimates of variance and covariance components were obtained by derivative-free Restricted Maximum Likelihood (DFREML) procedure (Meyer, 1991), using an univariate animal model with direct and maternal additive effects as random effects. The covariances between direct and maternal effects were considered. The mixed linear model was as following: $y=X\beta+Z\mu_1+Z\mu_2+e$, with $E(Y)=X\beta$, and $Var(y)= Z_1\mathbf{A}Z_1'\sigma^2_A +Z_2\mathbf{A}Z_2'\sigma^2_M +(Z_1\mathbf{A}Z_2'+Z_2\mathbf{A}Z_1')\sigma_{AM} +I\sigma^2_e$, where, y= a vector of observations of a trait; $\beta$=a vector of fixed effects, consisting of effects for year and age of dam; $\mu_1$= a vector of random direct additive genetic effects; $\mu_2$=a vector of random maternal additive genetic effects; e=a vector of random residual errors; X, $Z_1$ and $Z_2$=design matrices relating elements of y to the fixed and random effects; **A**=the numerator relationship matrix between animals; I=the identity matrix; $\sigma^2_A$=the additive genetic variance; $\sigma^2_M$= the maternal genetic variance; $\sigma_{AM}$=the direct-maternal genetic covariance; and $\sigma^2_E$=the error variance. Estimates of direct ($h^2_A$) and maternal ($h^2_M$) heritabilities were obtained as ratios of the additive direct ($\sigma^2_A$) and additive maternal ($\sigma^2_M$) variances to the phenotypic variance, respectively. The genetic correlation between direct and maternal effects ($r_{AM}$) was estimated as the ratio of $\sigma_{AM}$ to the square root of the product of $\sigma^2_A$ and $\sigma^2_M$. The 'total' heritability ($h^2_T$) was estimated as (Willham, 1972): $h^2_T=(\sigma^2_A+0.5\sigma^2_M+1.5\sigma_{AM})/\sigma^2_P$. Sampling errors of heritability estimates were obtained from the cubic approximation of Meyer (1991).

## RESULTS AND DISCUSSION

The number of records, sires, dams and animals, and some statistics on the growth traits of bulls in the four breed groups are presented in table 1. The Dairy Synthetic and Beef Synthetic #1 were heavier and grew faster than Hereford and Double Muscled cattle.

**Table 1.** Number of records and some statistics for the growth traits (kg) of bulls in the four breed groups

| Trait[a] | Breed[b] | $N_R$[c] | $N_S$ | $N_D$ | $N_A$ | mean | s.d. | CV(%) | Max | Min |
|---|---|---|---|---|---|---|---|---|---|---|
| BW | HE | 702 | 144 | 459 | 1261 | 36.70 | 5.24 | 14.27 | 53 | 22 |
| | SY1 | 722 | 73 | 396 | 1191 | 38.26 | 5.60 | 14.63 | 59 | 20 |
| | SD | 180 | 23 | 142 | 345 | 39.93 | 6.37 | 15.94 | 54 | 28 |
| | DM | 150 | 29 | 100 | 279 | 35.19 | 4.25 | 12.09 | 44 | 28 |
| WW | HE | 702 | 144 | 459 | 1261 | 204.50 | 32.93 | 16.10 | 282 | 124 |
| | SY1 | 716 | 73 | 396 | 1185 | 223.24 | 28.83 | 12.92 | 292 | 119 |
| | SD | 180 | 23 | 143 | 338 | 237.44 | 25.14 | 10.59 | 292 | 181 |
| | DM | 155 | 30 | 101 | 286 | 202.74 | 28.33 | 13.97 | 254 | 143 |
| ADG1 | HE | 702 | 144 | 459 | 1261 | 0.93 | 0.18 | 18.79 | 1.43 | 0.37 |
| | SY1 | 722 | 73 | 396 | 1191 | 1.03 | 0.15 | 14.69 | 1.57 | 0.44 |
| | SD | 178 | 23 | 141 | 342 | 1.10 | 0.12 | 10.77 | 1.34 | 0.86 |
| | DM | 155 | 30 | 102 | 287 | 0.93 | 0.15 | 16.00 | 1.20 | 0.61 |
| ADG2 | HE | 702 | 144 | 459 | 1261 | 1.37 | 0.22 | 15.91 | 2.02 | 0.63 |
| | SY1 | 712 | 73 | 396 | 1181 | 1.47 | 0.22 | 15.22 | 2.01 | 0.62 |
| | SD | 179 | 23 | 144 | 346 | 1.63 | 0.18 | 10.89 | 1.93 | 1.19 |
| | DM | 155 | 28 | 102 | 285 | 1.42 | 0.22 | 15.59 | 1.86 | 0.71 |

[a] BW, birth weight; WW, weaning weight adjusted to 180 days of age; ADG1, pre-weaning ADG; ADG2, post-weaning ADG.
[b] HE, Hereford; SY1, Beef Synthetic #1; SD, Dairy Synthetic; DM, Double Muscled breed group.
[c] $N_R$, No. of records; $N_S$, No. of sires; $N_D$, No. of dams; $N_A$, No. of animals.

**Table 2.** Estimates of variance-covariance components ($kg^2$) and genetic parameters for growth traits of bulls in the our breed groups

| Trait | Breed | $\sigma^2_A$ | $\sigma^2_M$ | $\sigma_{AM}$ | $\sigma^2_E$ | $\sigma^2_P$ | $h^2_A$ | $h^2_M$ | $c_{AM}$ | $r_{AM}$ | $h^2_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BW | HE | 13.88 | 4.00 | -.86 | 4.91 | 21.08 | .65±.34 | .19±.02 | -.04 | -.11 | .69 |
| | SY1 | 12.80 | 6.57 | -4.99 | 8.57 | 17.95 | .71±.01 | .36±.01 | -.28 | -.54 | .48 |
| | SD | 5.96 | 5.24 | 1.10 | 9.33 | 22.73 | .26±.11 | .23±.02 | .05 | .20 | .45 |
| | DM | 2.23 | 2.41 | -2.32 | 14.14 | 14.14 | .16±.02 | .17±.01 | -.16 | -.99 | .04 |
| WW | HE | 45.4 | 468.6 | -145.8 | 395.9 | 618.2 | .07±.01 | .76±.01 | -.24 | -1.0 | .10 |
| | SY1 | 87.20 | 164.3 | 6.45 | 300.4 | 564.8 | .15±.01 | .29±.06 | .01 | .05 | .32 |
| | SD | 32.36 | 122.8 | -44.51 | 276.1 | 432.3 | .09±.01 | .36±.01 | -.13 | -.71 | .08 |
| | DM | 51.48 | 229.1 | -108.6 | 417.6 | 480.9 | .11±.01 | .48±.01 | -.23 | -.99 | .01 |
| ADG1 | HE | .02 | .15 | -.01 | .08 | .21 | .07±.01 | .70±.01 | -.06 | -.27 | .33 |
| | SY1 | .02 | .06 | -.02 | .09 | .13 | .14±.03 | .49±.07 | -.14 | -.53 | .18 |
| | SD | .02 | .04 | -.01 | .07 | .08 | .20±.01 | .53±.01 | -.10 | -.28 | .35 |
| | DM | .04 | .01 | -.02 | .15 | .16 | .25±.01 | .09±.01 | -.15 | -.98 | .07 |
| ADG2 | HE | .15 | .14 | -.12 | .19 | .24 | .61±.09 | .59±.02 | -.50 | -.83 | .15 |
| | SY1 | .12 | .02 | -.05 | .38 | .42 | .30±.01 | .05±.02 | -.12 | -1.0 | .13 |
| | SD | .09 | .03 | -.05 | .21 | .22 | .39±.01 | .15±.01 | -.24 | -.99 | .14 |
| | DM | .08 | .03 | -.05 | .30 | .31 | .27±.01 | .11±.01 | -.17 | -.95 | .07 |

[a] $\sigma^2_A$, additive direct variance; $\sigma^2_M$, additive maternal variance; $\sigma_{AM}$, direct-maternal genetic covariance; $\sigma^2_E$, error variance; $\sigma^2_P$, phenotypic variance; $h^2_A$, direct heritability; $h^2_M$, maternal heritability; $c_{AM}=\sigma_{AM}/\sigma^2_P$; $r_{AM}$, direct-maternal genetic correlation; $h^2_T$, total heritability.
[b] See table 1 for abbreviations.

Variance-covariance components and genetic parameter estimates for growth traits of young bulls in four breed groups are presented in Table 2. The estimates of heritabilities were different among the breed groups. Heritability estimates for direct effects were moderate for BW (0.16-0.26) in DM and SD, and high in HE and SY1 (0.65-0.71), low for WW (0.07-0.15) and pre-weaning ADG (0.07-0.25), moderate for post-weaning ADG (0.27-0.39), except for HE (0.61). Heritability estimates for maternal effects were moderate for BW (0.17-0.36), low for post-weaning ADG (0.05-0.15) except for HE (0.59), moderate to high for WW (0.29-0.76), high for pre-weaning ADG (0.49-0.7) except for DM (0.09). The estimates of total heritability were high for BW (0.45-0.69) except for DM (0.04), low for WW (0.01-0.1) except for SY1 (0.32), moderate for pre-weaning ADG (0.18-0.35) except for DM (0.07), low for post-weaning ADG (0.07-0.15). The estimates of total heritability for all traits in DM were lower than other breed groups (0.01-0.07). The estimates of heritabilities were generally within the range of published estimates summarized by Baker (1980) and Mohiuddin (1993).

Direct variances and $h^2_A$ for BW and post-weaning ADG in all breed groups were consistently higher than maternal variances and $h^2_M$, but for WW and pre-weaning ADG the pattern was reversed. It indicated that weaning weight and pre-weaning ADG were more influenced by maternal additive effects of the dam, but birth weight and post-weaning ADG were more determined by the direct additive effects of the animal, implying that genetic change in BW and post-weaning ADG would be more rapid if effort were more concentrated on direct effects. The genetic covariance and genetic correlation between direct and maternal effects were consistently negative for all traits in the four breed groups, except for BW in SD and WW in SY1. This genetic antagonism indicates that generally the traits which are less affected by direct effect are more influenced by maternal additive effect, and that the probable reduction in maternal performance due to intensive selection for individual growth may be substantial. Therefore in selection for growth traits in beef cattle, maternal additive effect should not be ignored.

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