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Pre-weaning growth traits of the Hereford breed in a multibreed composite beef cattle population

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Abstract

Data from a multibreed composite beef cattle population, managed under intensive irrigated grazing conditions, were used to estimate direct additive heritabilities (h^2_a), maternal heritabilities (h^2_m) and maternal permanent environmental effects (c^2) for birth weight (BW) and weaning weight (WW) of the calf and cow efficiency of the dam (CE: WW/dam weight$^{0.75}$ x 100). Calves born between 1968 and 1993 (n = 52628) had varying levels of Hereford genes, ranging from 0% to 100%, with an average of 19.3%. Direct heritabilities, fitting unitrait models, were 0.72, 0.54 and 0.19 for BW, WW and CE, respectively, with corresponding estimates of maternal heritabilities being 0.14, 0.21 and 0.42. Genetic correlations between direct and maternal effects (r_{am}) were negative for all three traits, varying from –0.40 to –0.65. Maternal permanent environmental effects were 0.06, 0.12 and 0.11 for BW, WW and CE, respectively. Direct breeding values and maternal breeding values for BW and WW decreased with increasing proportion of Hereford. Direct breeding value for CE increased, while maternal breeding value for CE reached a minimum value at 0.62 proportion of Hereford.

Keywords: Beef cattle, composite population, Hereford, pre-weaning traits

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Introduction

The wide variety of cattle types in the world offers the possibility of creating breed combinations, *e.g.* composite breeds, to increase and improve production. The practice of combining different breeds in order to create a "new breed" represents an opportunity to exploit breed complementarity (breed additive differences) and heterosis for a variety of traits. It also represents an opportunity to optimise additive genetic composition for composite superiority, incorporating climatic adaptability and performance traits into a "new breed" that is in harmony with the production environment and market requirements (Lin, 1996). Synthetic breeds are mostly intermediate to parental breeds for some individual contributing traits but superior for composite traits. In practice, complementarity is often used in combining the growth potential of rapidly growing breeds with the adaptive characteristics of another breed. The large number of composites or synthetic breeds, *e.g.* Bonsmara, Santa Gertrudis and Braford is the result of exploiting complementarity in practice (Schoeman, 1999). In addition to the production of large amounts of heterosis and the exploitation of breed complemetarity, the development of composites also offers breeders consistency of performance, an ability to produce their own replacements and ease of management once the composite population is stabilised and established (Newman & Coffey, 1999).

The aim of this study was to assess the contribution of the Hereford breed in a multibreed beef cattle herd in an intensive production system and to determine the optimum proportion of Hereford breeding for individual pre-weaning growth traits.

Material and Methods

Data were derived from the multibreed composite beef cattle population of the Johannesburg Metropolitan Council. The Johannesburg Municipal beef cattle operation consists of two farms; namely the Northern Farm and the Olifantsvlei farm. The multibreed beef herd is raised on a limited pasture intake system using irrigated annual and perennial rye grass (*Lolium* spp.) pastures supplemented with *Eragrostis curvula* hay, maize meal, distillers grain and silages (maize, sorghum and grass) when necessary.

Crossbreeding started in 1962 with the first crosses in a conventional crossbreeding programme, including two and three breed terminal and rotational systems. Ten base breeds were originally included in the crossbreeding programme (*viz*. Afrikaner, Bonsmara, Brahman, Brown Swiss, Charolais, Hereford, Holstein, S.A. Angus, Simmentaler and South Devon) and were mated to Bos Taurus crossbred cows of varying types (mostly Afrikaner, Angus and Bonsmara types), a large percentage of which were purchased from commercial herds. Hereford contribution varied from 7.8 to 100% in sires, and from 7.8 to 100% in the dams. Purebred Hereford sires were only used from 1968 to 1981. After the initial crossbreeding project was terminated in 1981, composite development started when all crossbred groups were pooled and selection was based on performance traits such as female reproduction, weaning weight, post-weaning gain and breeding soundness, without taking breed composition into account. The aim was to eventually reach an optimal breed composition through selection. However, since 1982 other breeds were also introduced to a limited degree. A few sires of Beefmaster, Gelbvieh, Limousin, Tauricus and Santa Gertrudis breeds were used. All matings were planned and artificial insemination (using the same sires across the two farms) was used throughout the cattle herd. Heifers were inseminated to calve for the first time at approximately two years of age. The majority of calves were born in winter (June to September), while the rest were born during December through to March. Season of birth was thus recorded as either "summer born" or "winter born". Calves were weighed after birth and at weaning at approximately 210 days of age. Paterson (1978, 1981), Paterson et al. (1980) and MacGregor (1997) described management, replacement and selection procedures of the herd in more detail.

The data consisted of 52 628 calf birth and weaning weight records collected from 1968 to 1993. The number of dam weight records was 6 239. This trait was only recorded between 1989 and 1993. The number of sires used was 362 with an average of 199 calves per sire, varying from 1 to 1 612 per sire. The number of dams with calf weaning weights recorded was 15 539, with an average of 3.4 calves per dam, varying from 1 to 14 calves per dam. The number of animals in the pedigree file was 57 078. Birth weight (BW) and weaning weight (WW) of the calf and dam weight at the time of weaning of her calf (DW) were recorded. Cow efficiency (CE) was calculated by dividing each individual WW of the calf by $DW^{0.75}$ ($WW/DW^{0.75}$ x 100). Dam ages ranged from 2 to 16 years. Due to the small number of cows older than 10 years, data from this category were pooled with the 10-year-old group. Average age of cows was 5.37 years before pooling and 5.23 years after pooling.

Breed composition, or proportion of different breeds in each animal was calculated from the original pedigrees. Data were classified as "remainder" in the case of females of unknown breed and when breeds were introduced at a later stage. The total number of genetic groups was 5741 when all breeds and breed combinations were taken into account. Genetic group was not fitted in the models due to the large number of genetic groups. It was also noted by Ahmad & Van der Werf (1999) that breed group models suffer from inaccuracy if some groups have few observations, as was the case in this analysis. Instead, proportion of Hereford, with the individual contribution of all other breeds ignored, was fitted in the model. Some groups with a small number of observations were pooled (*e.g.* $^{7}/_{16}$ to $^{9}/_{16}$ were pooled with ½ Hereford). The total number of genetic calf groups with varying proportions of Hereford then was 17. The total number of calves observed in relation to proportion of Hereford is presented in Table 1.

Table 1 Number of calves observed in relation to proportion of Hereford in a composite beef breed

Proportion of Hereford (%)																
1.6	3.1	6.3	9.4	12.5	15.6	18.8	21.9	25.0	31.3	37.5	50.0	56.3	62.5	75.0	87.5	100.0
349	1493	3660	1842	7210	1914	2027	1223	8605	3038	1943	3638	1107	1266	1233	458	459

Data were analysed using the VCE 4.2.5 package of Groeneveld (1994, 1997) and Groeneveld & Garcia-Cortés (1998) fitting the following model:

$$\mathbf{y} = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + Z_3\mathbf{p} + \mathbf{e}$$

where

y	=	a vector of observations
X	=	a known incidence matrix relating observations to the fixed effects
b	=	a vector of fixed effects
Z_1, Z_2 and Z_3	=	known incidence matrices relating elements of **a**, **m** and **p** to **y**
a	=	a random vector of direct additive genetic effects
m	=	a random vector of maternal additive genetic effects
p	=	a vector of random permanent environmental effects of the dam
e	=	a random vector of residual errors.

Only unitrait models were fitted to the data. These models accounted for direct additive heritability (h^2_a), maternal heritability (h^2_m), the genetic correlation between direct and maternal effects (r_{am}) and the maternal permanent environmental effect (c^2) and were subsequently used to predict individual breeding values of each animal for each trait. The model fitted to each trait and trait means are presented in Table 2.

Table 2 Statistical models for unitrait analyses of birth weight (BW) and weaning weight (WW) of calf and cow efficiency (CE) calculated as WW/cow weight$^{0.75}$ at calf weaning x 100

Effects	Type	Number of levels	Traits BW	WW	CE
Year	Fixed	26(6)	X	X	X
Farm	Fixed	2	X	X	X
Hereford proportion	Fixed	18(16)	X	X	X
Sex of calf	Fixed	3	X	X	X
Season of birth	Fixed	2	X	X	X
Dam age	Covariate	1	X	X	X
Weaning age of calf	Covariate	1		X	X
Maternal permanent environmental effect	Random	15539(2722)	X	X	X
Maternal	Animal	57078	X	X	X
Animal	Animal	57078	X	X	X
Means ± SD			35.5 ± 6.0	207.3 ± 38.5	212.0 ± 32.5

( ) number of levels for CE

Both individual direct and maternal breeding values were predicted and mean breeding values per group subsequently regressed on proportion of Hereford breeding. Similarly, Best Linear Unbiased Estimates (BLUE) for each trait were also estimated and regressed on proportion of Hereford breeding. Linear regressions were fitted, excluding those animals with no Hereford contribution.

Results and Discussion

Heritability estimates and the correlations between direct and maternal genetic effects for BW, WW and CE are presented in Table 3. In general, direct and maternal heritabilities tend to be higher than those reported in other studies. However, h^2_a estimates tend to be higher and h^2_m estimates tend to be lower for BW and WW, respectively, than those obtained by Schoeman *et al.* (2000b) on the same dataset when analysing the influence of Simmentaler contribution with the exclusion of c^2. The direct heritability for BW ($h^2_a = 0.72$) is considerably higher than the mean estimates of 0.39 obtained by Mostert *et al.* (1998) for five beef cattle breeds in South Africa, as well as those reported (0.30 and 0.31) by Mohiuddin (1993) and Koots *et al.* (1994a) in their respective reviews. The same trend was evident for WW, although to a smaller degree, in which case the direct heritability was 0.54. Mohiuddin (1993) and Koots *et al.* (1994a) obtained mean h^2_a values of 0.22 and 0.24, respectively, for the same trait, which corresponds closely to the mean value of 0.24 obtained by Mostert *et al.* (1998). The direct heritability for CE was considerably lower ($h^2_a = 0.19$). No comparable estimates were found in the literature for this trait.

Table 3 Direct additive (h^2_a), maternal heritability (h^2_m), genetic correlations between direct and maternal effects (r_{am}) and maternal permanent environmental effects (c^2) for birth weight (BW) and weaning weight (WW) of the calf and cow efficiency (CE) of the dam

	h^2_a	h^2_m	r_{am}	c^2
BW	0.720	0.143	-0.402	0.057
WW	0.538	0.214	-0.647	0.117
CE	0.188	0.415	-0.587	0.105

Direct heritabilities were larger than maternal estimates for calf weights. This is common in beef cattle for preweaning growth traits. For CE, maternal heritabilities were larger than direct heritabilities. The fairly high heritabilities, arising from large genetic variances due to the multibreed composition of the herd could have been expected, since the population consists of 15 breeds, and this effect was not accounted for by the model. Rodriguez-Almeida *et al.* (1995) reported quite variable estimates in different herd-line combinations. They suggested that the variable estimates might be due to the inclusion of non-additive genetic variances. Similarly in our study, a dominance effect was not fitted in the model. Being a crossbred population, dominance could be a possible contributor to the higher and possibly biased estimates. Bennett & Gregory (1996) and Tosh *et al.* (1999) also reported heritability estimates for early growth traits in composite populations, which were larger than literature means. When using a subset of the same data and including a sire genotype x dam genotype interaction, Schoeman *et al.* (2000a) obtained substantially reduced estimates of both direct and maternal heritabilities.

Correlations between direct and maternal genetic effects were negative for all three traits. The correlation for BW (r_{am} = -0.40) was the lowest and the highest for WW (r_{am} = -0.65). This resulted in a low total heritability (h^2_T = 0.24). These negative estimates are common in beef cattle for preweaning growth traits. In the review of Koots *et al.* (1994b) mean estimates of -0.27 and -0.30 were reported for BW and WW, respectively, while Meyer (1992a) reported estimates which varied from 0.55 to -0.51 for BW and from 0.25 to -0.72 for WW. The majority of estimates were, however, negative for both traits. For CE no comparable estimates were found in the literature. These large negative correlations reported in numerous studies (Baker, 1980; Cantet *et al.*, 1988; Meyer, 1992a) between direct and maternal effects, may according to Meyer (1992b), be due to management practices or environmentally induced negative dam-offspring covariances or selective reporting of data (Mallinckrodt *et al.*, 1995) or sire x year interactions (Robinson, 1996) and do not always reflect true adverse genetic relationships between growth and maternal performance. The latter may probably be a reason for the high covariance between direct and maternal effects for CE related to early calving of heifers.

Maternal environmental effects (c^2) ranged from 0.06 for BW to 0.12 for WW (Table 3). In general, c^2 estimates were smaller than h^2_m estimates which are in agreement with several other investigations (Meyer, 1992a; Mohiuddin, 1993; Schoeman & Jordaan, 1999). The permanent environment effect of the dam for CE (c^2 = 0.11) is relatively small in this study compared to Schoeman & Jordaan (1999) whom obtained a c^2 of 0.20 from a subset of the same dataset.

The breeds making the largest contribution to the population were the Angus, Bonsmara, Charolais, Hereford and Simmentaler. Individual contributions were reported in an earlier paper of Schoeman *et al.* (2000b). The Hereford made the second largest contribution (19.3 %) to the calves born between 1989 and 1993.

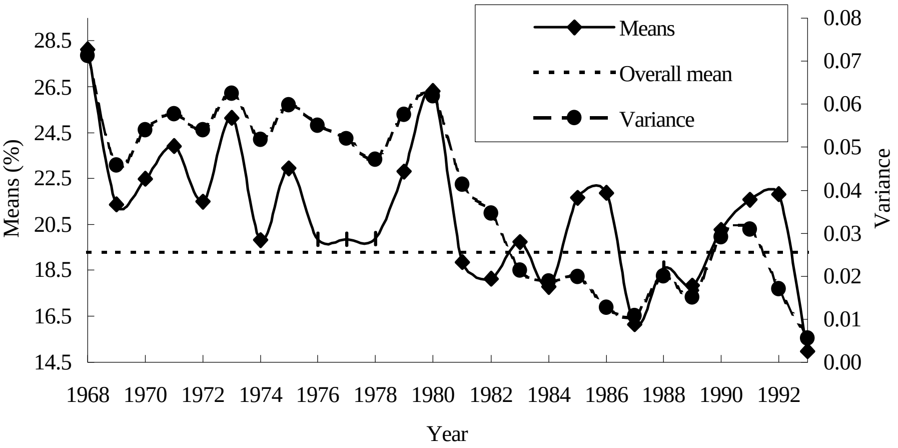

Figure 1 Changes in mean Hereford contribution (%) and variance in proportion of Hereford per year

The composition of individual calves born varied from 0-100% Hereford. The proportion of Hereford contribution per year of calves born and Hereford proportion variance is presented in Figure 1. The contribution of Hereford decreased from 1968 to 1993. There were increases in the contribution of the Hereford in 1980, 1985, 1986, 1991 and 1992. This was due to the re-use of some older sires with relatively high Hereford composition. The Hereford composition of sires used in these years was 50, 53.2, 56.3, 62.5 and 100% respectively. The breed proportion variance was relatively stable between 1968 and 1981, but declined rapidly thereafter as the herd became more uniform in composition for Hereford. The reasons for the sharp drop in 1982 were two-fold, firstly as a result of the termination of the conventional crossbreeding systems and the use of crossbred sires, and secondly due to the introduction of other breeds. Equilibrium was not reached at this point in time since equilibrium would only be attained when both parents and calf have the same proportion of Hereford genes. However, in 1993 the variance for Hereford contribution was low.

Regressions of BLUE and direct and maternal breeding values on proportion of Hereford for BW are presented in Figures 2a to 2c respectively. BW was influenced by proportion of Hereford (Figure 2a). It increased and reached a maximum value at 0.47 proportion of Hereford, after which it declined again. The maximum phenotypic value at an intermediate proportion of Hereford is surprising and may be partly explained by the heterotic effect, which is expected to be maximum at intermediate levels of Hereford contribution, since the non-additive genetic effect was not accounted for in the model. Relatively high contributions of Afrikaner, Angus and

Bonsmara at low Hereford proportions could also be a reason for the lower birth weights at low Hereford proportion. Mean direct breeding values (Fig. 2b) and maternal breeding values (Fig. 2c) for birth weight decreased linearly with increasing Hereford proportion. Reasons for the low average breeding values at 75 % Hereford versus the high average breeding values at 87.5 % Hereford contribution are not obvious. In total, 3% (1233) of calves were 75 % Hereford. Of those 1233 calves, 525 were 75 % Hereford combined with differing contributions of Brown Swiss, Charolais and Simmentaler, with the remaining 708 calves consisting of 5% Hereford and 25% contributions from smaller, earlier maturing breeds. In the case of 458 animals with 87.5 % Hereford breeding, 250 were 87.5 % Hereford combined with differing contributions of Brown Swiss, Charolais and Simmentaler, all of which are relatively large breeds. These large differences could therefore not be explained by differences in Hereford x British *vs.* Hereford x Continental breed contributions which one would have expected.

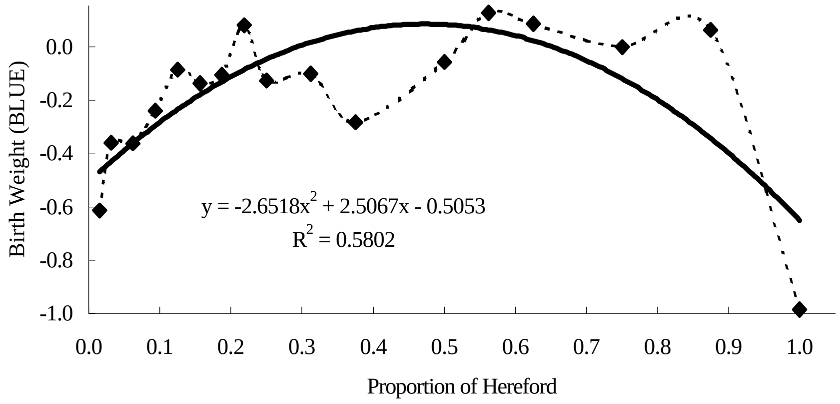

Figure 2a Regression of BLUE of birth weight on proportion of Hereford breeding

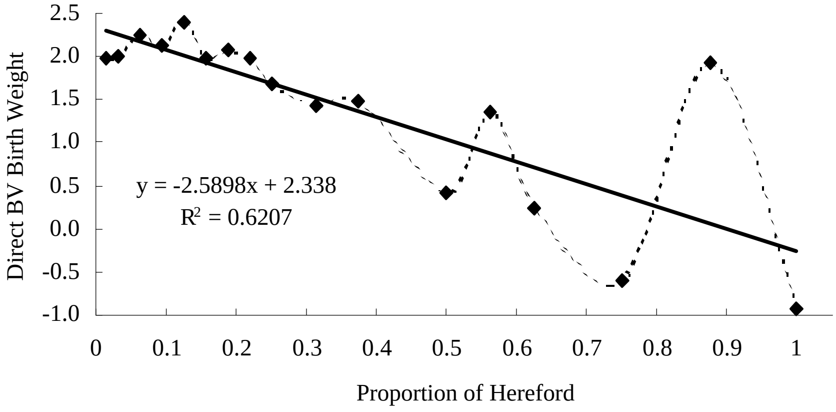

Figure 2b Regression of direct breeding value of birth weight on proportion of Hereford breeding

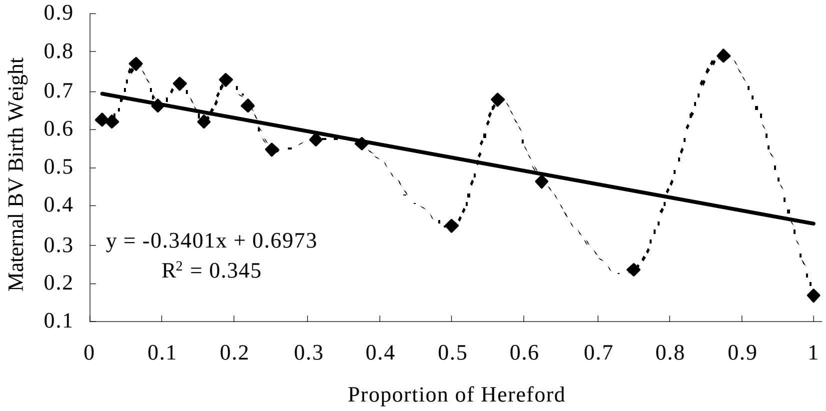

Figure 2c Regression of maternal breeding value of birth weight on proportion of Hereford breeding

In other studies, the direct additive effect for the Hereford for birth weight was positive in some (Gregory *et al*., 1978; Dillard *et al*., 1980; Roberson *et al*., 1986; Cunningham & Magee, 1988; Schoeman *et al*., 1993) and negative in others (Alenda *et al*., 1980; Franke, 1994) depending on the breeds with which it was compared. In analyzing part of the same data when comparing Hereford, Simmentaler and Afrikaner cattle, Skrypzeck *et al.* (2000) obtained a significant ($P \leq 0.01$) negative direct effect for Hereford. The direct breeding value of Hereford on BW is important because it can have a major influence on calving ease, indicating that in the case of a negative value, fewer calving difficulties would be expected with an increase in the proportion of Hereford. Van Zyl (1990) illustrated that BW declined at a faster rate with an increase in proportion of Afrikaner in Simmentaler x Afrikaner crossbreeding than in Hereford x Afrikaner crossbreeding. The maternal breeding value for birth weight reflects the potential of the dam or the bull's female progeny to limit the growth of the foetus within her uterus. Some investigations showed positive direct maternal effects for the Hereford (Alenda *et al.* 1980; Dillard *et al*., 1980; Cunningham & Magee, 1988; Schoeman *et al*., 1993; Arthur *et al*., 1994; Franke, 1994), while others showed negative direct maternal effects (Gregory *et al*., 1978; Skrypzeck *et al*., 2000), depending on the breeds against which it was compared. Higher levels of Hereford in crossbred or composite populations are recommended for the prevention of calving difficulties when dystocia is a problem.

Weaning weight

Regressions of BLUEs and direct and maternal breeding values on proportion of Hereford for WW are presented in Figures 3a to 3c, respectively. WW was influenced by proportion of Hereford (Figure 3a). It increased and reached a maximum value at 0.13 proportion of Hereford, after which it declined. Both mean direct breeding values (Figure 3b) and maternal breeding values (Figure 3c) decreased linearly with increasing Hereford proportion. The mean maternal direct breeding value for BW of 87.5 % Hereford was unexpectedly high. Although reasons for this are not obvious, it may also be related to the unbalanced nature of breed combinations in the dataset.

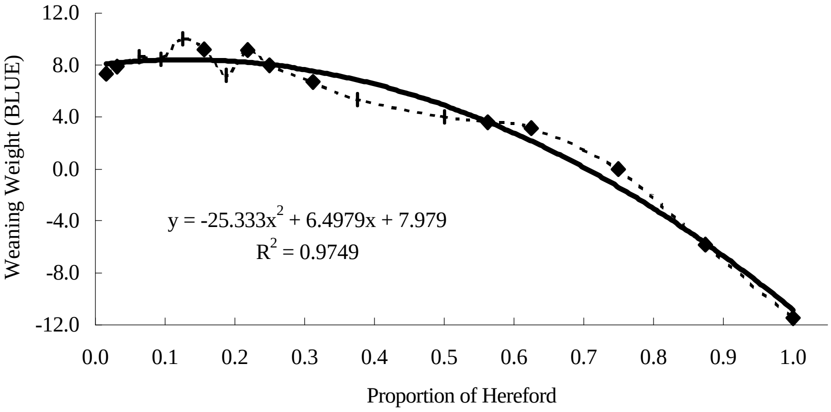

Figure 3a Regression of BLUE of weaning weight on proportion of Hereford breeding

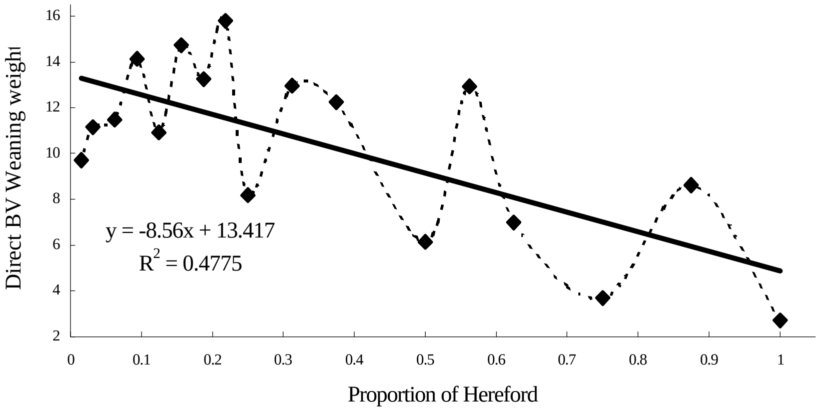

Figure 3b Regression of direct breeding value of weaning weight on proportion of Hereford breeding
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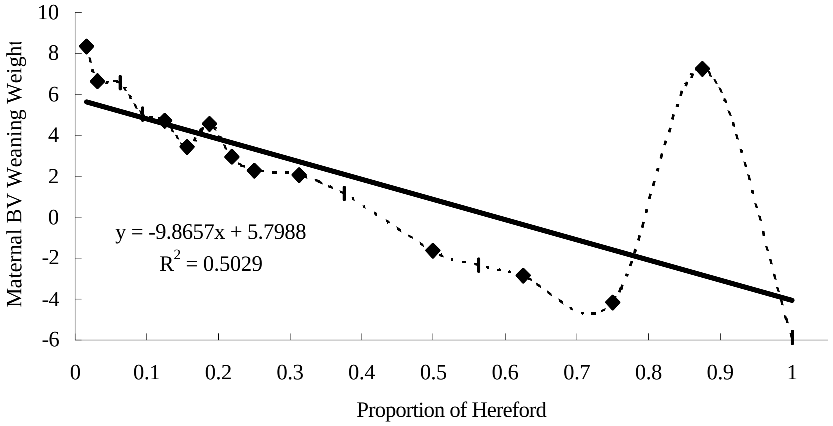

Figure 3c Regression of maternal breeding value of weaning weight on proportion of Hereford breeding

In other studies, the direct additive effect was positive in some investigations (Dillard *et al*., 1980; Cunningham & Magee, 1988; Franke, 1994), and negative in others (Gregory *et al*., 1978; Alenda *et al*., 1980; MacNeil *et al*., 1982; Franke, 1994; Skrypzeck *et al*., 2000). In this study, direct breeding value for WW was negatively associated with proportion of Hereford, most likely because of the large contribution of large frame-sized breeds such as the Simmentaler, Brown Swiss and Charolais to the composition of the herd (Schoeman *et al*., 2000b). In earlier reports (Schoeman *et al*., 1993) it was found that the large negative maternal effect overrides a positive direct effect, thus leading to the decreased WW with increasing proportion of Hereford, despite a positive direct effect in these studies. Schoeman *et al.* (2000b) and Skrypzeck *et al.* (2000), analysing part of the same dataset, both indicated a relatively unfavourable environment in which the herd is managed. Relative to the other breeds in the composite, increasing Hereford contribution decreased the genetic potential of the composite. The maternal breeding value of WW predicts the milk production of an animal and also reflects the milking ability of the animal's daughters (Bradfield & Erasmus, 1999). Figure 3c shows WW breeding values decreased with an increase in Hereford contribution. It is also known that the Hereford is a breed with low milk production (Jenkins & Ferrell, 1992). In some investigations the direct maternal effect for the Hereford was positive (Dillard *et al*., 1980; Koch *et al*., 1985; Cunningham & Magee, 1988; Arthur *et al*., 1994), while it was negative in others (Gregory *et al*., 1978; Alenda *et al*., 1980; Schoeman *et al*., 1993; Franke, 1994; Skrypzeck *et al*., 2000). Both Meyer (1992a) and Schoeman *et al.* (1993) associated the low WW in Hereford dams to the low milk production of the Hereford dam. The results in this study clearly illustrate a decrease in performance levels and breeding values with increasing Hereford contribution. No optimal Hereford proportion was evident in this multibreed beef cattle herd within this specific environment.

Regressions of BLUEs and direct and maternal breeding values on proportion of Hereford for CE are presented in Figures 4a to 4c, respectively. BLUEs for CE were influenced by proportion of Hereford (Figure 4a) which decreased linearly with increasing Hereford proportion. Contrary to this, mean direct breeding values (Figure 4b) increased almost linearly with increasing Hereford proportion. The increase in direct breeding values for CE, taking the decline in direct breeding values for WW into account, is also somewhat unexpected owing to the part-whole relationship between WW and CE. It should, however, be noted that the number of observations for CE was much less than for WW. Mean maternal breeding values (Figure 4c) decreased and reached minimum value at 0.62 proportion of Hereford, after which they increased again. The mean maternal direct breeding value for BW and WW of 87.5 % Hereford was unexpectedly high. Although reasons for this are not obvious, it may also be related to the unbalanced nature of breed combinations in the dataset and partly due to the high mean maternal breeding value for WW of the 87.5 % Hereford calves and the lower mean DW of the 75 % Hereford cows with differing contributions of medium-framed breeds such as Bonsmara, Angus, Afrikaner and South Devon.

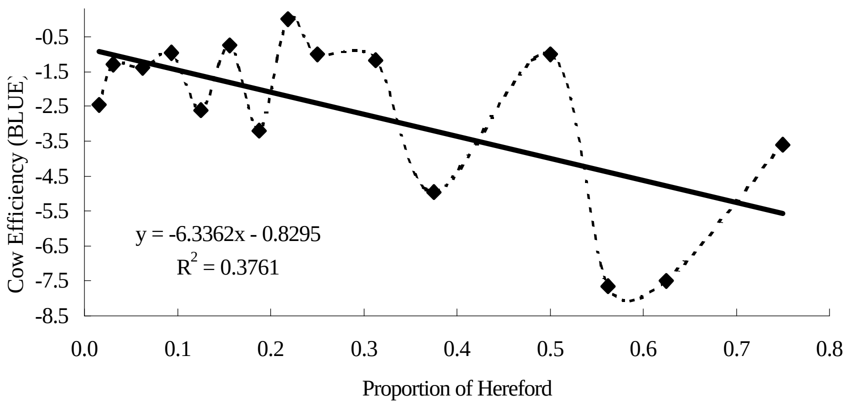

Figure 4a Regression of BLUE of cow efficiency on proportion of Hereford breeding

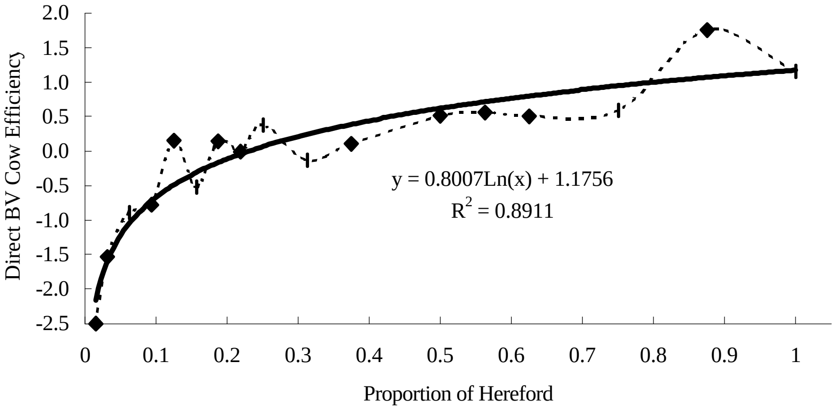

Figure 4b Regression of direct breeding value of cow efficiency on proportion of Hereford breeding

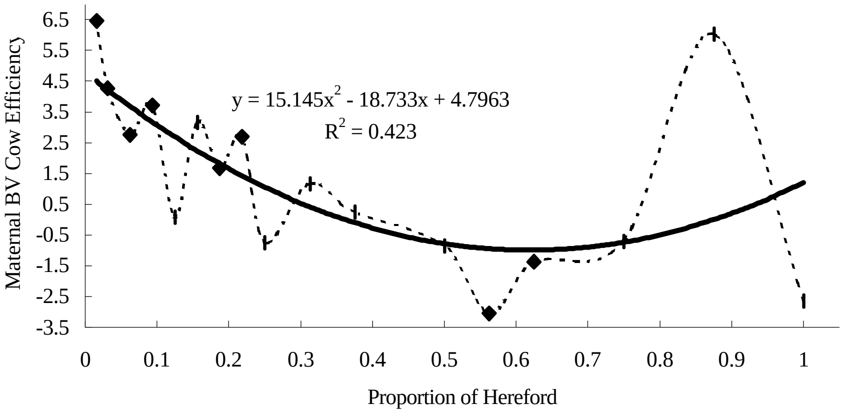

Figure 4c Regression of maternal breeding value of cow efficiency on proportion of Hereford breeding

Conclusion

Estimates of additive and maternal genetic variances may be biased and overestimated due to the inclusion of selected base animals from different breeds. This problem may be solved through genetic grouping or the inclusion of a sire genotype x dam genotype interaction. High negative genetic correlations between direct and maternal effects for BW and WW may be environmentally induced or may be due to problems with the model of analyses. These results clearly illustrate a decrease in direct breeding values for BW and WW but an increase for CE with increasing Hereford contribution. Maternal breeding values for BW and WW decreased with an increase in Hereford proportion. In general, high contributions of Hereford do not seem to be of any advantage in this composite. However, the maternal breeding value for CE reached a minimum value at 0.62 proportion of Hereford. Reasons for the large negative correlations between direct and maternal effects, together with the unexpected behaviour of the direct breeding value for WW with increased Hereford proportion, need further investigation. Other traits of importance such as carcass traits should also be investigated in further analyses.

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