

## The influence of proportion of Simmentaler breeding in a multibreed synthetic beef cattle population on preweaning growth traits

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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 ( $h^2_a$ ) and maternal heritabilities ( $h^2_m$ ) for birth weight (BW) and weaning weight (WW) of the calf and cow efficiency of the dam (CE; WW/dam weight<sup>0.75</sup>). Calves born between 1968 and 1993 ( $n = 52\ 628$ ) had varying levels of Simmentaler genes, ranging from 0% to 97%, with an average of 33.4%. Direct heritabilities fitting unitrait models were 0.66, 0.53 and 0.21 for BW, WW and CE respectively, with corresponding estimates of  $h^2_m$  being 0.22, 0.36 and 0.59. Genetic correlations between direct and maternal effects ( $r_{am}$ ) were negative for all three traits, varying from -0.32 to -0.63. Direct breeding values for BW and WW decreased and maternal breeding values increased with increasing proportion of Simmentaler. Cow efficiency was unaffected by an increase in the proportion of Simmentaler.

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**Keywords:** Beef cattle, herd composition, Simmentaler, synthetic population

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### Introduction

Composite breed development is a topic of major importance for the genetic improvement of beef cattle. It provides a simple way to use both breed additive differences (direct and maternal) and heterosis for a variety of traits. The main objective of creating a composite or synthetic population is to combine desirable and sometimes divergent characteristics from different breeds into one population. It eliminates some of the major constraints in conventional crossbreeding and is relatively simple to manage (Schoeman, 1999). In order to be able to create an optimal combination between a number of breeds, genetic effects (e.g. breed direct additive, maternal additive and heterotic) have to be estimated from various crosses among a number of breeds. Procedures describing ways of separating these genetic effects using linear functions of cross means or multiple regression approaches were applied by Alenda *et al.* (1980), Dillard *et al.* (1980), Robison *et al.* (1981) and Schoeman *et al.* (1993). These can subsequently be used to predict the performance of a series of potential crosses.

The optimal breed composition of a synthetic population for a single trait was determined empirically by Kinghorn (1980, 1982) and Alenda & Martin (1981). These methods involve testing a number of crossbred combinations to find the best possible one. Lin (1996) described equations to optimise breed composition for net merit based on genetic parameters and index selection weights. These equations were used by Newman *et al.* (1998) and Hayes *et al.* (1999) for the prediction of an optimal Charolais-Brahman composite in a tropical environment using a "mate selection index" approach (Kinghorn & Shepherd, 1999). However, these approaches become very complicated as the number of breeds and crossbred groups increases.

The objective of this study was to assess the contribution of the Simmentaler breed in a multibreed beef cattle herd in an intensive production system and to obtain the desired proportion of Simmentaler breeding for individual pre-weaning growth-related traits therein. The Simmentaler made the greatest contribution to the creation of this synthetic population.

### Material and methods

Data were obtained from the multibreed synthetic beef cattle population of the Johannesburg Metropolitan Council. The herd, comprising approximately 2 500 breeding females, was kept on two different farms in an intensive management system (Patterson *et al.*, 1980). Initial crossbreeding started in 1962 with the first crosses in a conventional crossbreeding programme, including two and three breed terminal and rotational systems. Ten foundation breeds were included in the initial 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. After the original 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 objective was to eventually reach optimal or desired breed composition through selection. Other breeds were, however, also introduced to a limited degree since 1982. A few sires of Beefmaster, Gelbvieh, Limousin, Tauricus and Santa Gertrudis breeds were used. Sire selection was based on weaning weight and post-weaning gain (Schoeman & Jordaan, 1998). Mating occurred at random without taking breed composition into account. Close inbreeding was, however, deliberately avoided using a relationship matrix between all sires and all dams.

Females were artificially inseminated using the same sires across the two farms. Heifer calves were inseminated to calve for the first time at approximately two years of age. Although cows calved throughout the year, the majority of calves were born in winter (June to September), while the rest were born during December to March. Season of birth was thus recorded as either "summer born" or "winter born". Out-of-season calves were excluded from the analysis.

Date of birth was recorded and calves were weighed within two days after birth and again at weaning at approximately 210 days of age. Dam weight at weaning was also recorded from 1988. 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. The number of sires used was 362 with an average of 145 calves per sire which varied from 10 to 1 612 per sire. Sires with less than 10 calves were removed from the dataset during editing of the data. The number of dams with recorded calf weaning weights was 15 539, with an average of 3.4 calves per dam that varied from one to 14 calves. 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 indices (CE) ( $WW/DW^{0.75} \times 100$ ) were also calculated. Dam ages ranged from 2 to 16 years. Owing to the small number of cows older than 10 years, data from these were pooled with the 10 year old group. The average age of cows before pooling was 5.37 years, and 5.23 years after pooling.

Breed composition, or proportion of different breeds in each animal was calculated from the original pedigrees. Females of unknown breed and breeds that were introduced at a later stage were designated "remainder". The total number of genetic groups, taking all breeds and breed combinations into account was 5 741. Genetic group was not fitted in the models owing to the large number of 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. Proportion of Simmentaler was fitted in the model and the individual contribution of all other breeds was ignored. Some groups were pooled due to a small number of observations e.g.  $7/16$  to  $9/16$  were pooled with  $1/2$  Simmentaler. There were 16 genetic groups with varying proportions of Simmentaler.

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

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z}_1\mathbf{a} + \mathbf{Z}_2\mathbf{m} + \mathbf{e}$$

where

$\mathbf{y}$	=	a vector of observations
$\mathbf{X}$	=	a known incidence matrix relating observations to the fixed effects
$\mathbf{b}$	=	a vector of fixed effects
$\mathbf{Z}_1$ and $\mathbf{Z}_2$	=	known incidence matrices relating elements of $\mathbf{a}$ and $\mathbf{m}$ to $\mathbf{y}$
$\mathbf{a}$	=	a random vector of direct additive genetic effects
$\mathbf{m}$	=	a random vector of maternal additive genetic effects
$\mathbf{e}$	=	a random vector of residual errors.

Only univariate models were fitted to the data. These models accounted for direct additive heritability ( $h^2_a$ ), maternal heritability ( $h^2_m$ ) and the genetic correlation between direct and maternal effects ( $r_{am}$ ), and were subsequently used to predict individual breeding values of each animal for each trait. The models fitted to each trait and trait means are presented in Table 1.

**Table 1** Statistical models for univariate analyses of birth weight (BW) and weaning weight (WW) for calf and cow efficiency (WW/cow weight<sup>0.75</sup> at calf weaning x 100)

Effects	Type	Number of levels	Traits		
			BW	WW	CE
Year	Fixed	25	X	x	x
Farm	Fixed	2	x	x	x
Simmentaler proportion	Fixed	16	x	x	x
Sex of calf	Fixed	2	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	Animal	57 078	x	x	x
Animal	Animal	57 078	x	x	x
Means ± s.d.			34.5 ± 5.92	207.3 ± 38.00	212.0 ± 32.51

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

## Results and discussion

Heritability estimates and the correlations between direct and maternal genetic effects for BW, WW and CE are presented in Table 2. In general, direct heritabilities tend to be higher than those reported in other studies. The direct heritability for BW ( $h^2_a = 0.66$ ) is considerably higher than the mean estimates of (0.30 and 0.31) reported by Mohiuddin (1993) and Koots *et al.* (1994a) in their respective reviews, as well as those obtained by Mostert *et al.* (1998) for five beef cattle breeds in South Africa. A similar disparity was observed for WW, for which the direct heritability was 0.53. Mostert *et al.* (1998) obtained a mean  $h^2_a$  estimated of 0.24 for the same trait which corresponds closely to the mean values of 0.22 and 0.24 reported by Mohiuddin (1993) and Koots *et al.* (1994a), respectively. The direct heritability for CE was considerably lower ( $h^2_a = 0.21$ ). No comparable estimates were found in the literature for this trait.

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

Traits	Estimates		
	$h^2_a$	$h^2_m$	$r_{am}$
BW	0.663	0.219	-0.322
WW	0.527	0.359	-0.529
CE	0.206	0.593	-0.629

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. Comparatively high heritabilities, arising from large genetic variances due to the multibreed composition of the herd could have been expected, since the population consists of several breeds, and this effect was not accounted for by the model. Quite variable estimates in different herd-line combinations were also reported by Rodriguez-Almeida *et al.* (1995). They suggested that the variable estimates may be due to the inclusion of non-additive genetic variance. Similarly, a dominance effect was not included in our models and, being a crossbred population, dominance could be a possible contributor to the higher and possibly biased estimates. Likewise, heritability estimates for early growth traits, which were larger than literature means, were also reported by Tosh *et al.* (1999) in a multibreed population.

Correlations between direct and maternal genetic effects were negative for all three traits. As expected, it was lowest for BW ( $r_{am} = -0.32$ ) and highest for CE ( $r_{am} = -0.63$ ) indicating that it would be difficult to improve CE through selection. This resulted in a low total heritability ( $h^2_T = 0.14$ ). These negative estimates are common in beef cattle for preweaning traits. Mean estimates of  $-0.27$  and  $-0.30$  were reported for BW and WW, respectively in the review of Koots *et al.* (1994b). No comparable estimates were found in the literature for CE. Large negative estimates reported in several studies (Baker, 1980; Cantet *et al.* 1988; Meyer, 1992a) may, according to Meyer (1992b), be due to management practices or environmentally-induced negative dam-offspring covariances 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.

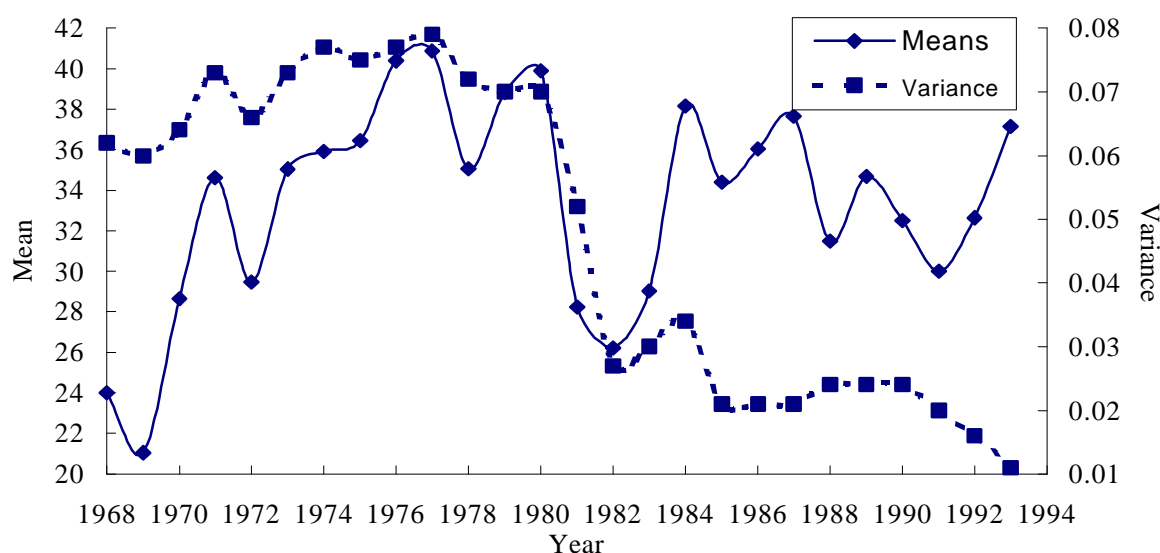
In total, 15 breeds contributed to the composition of the herd. The contributions of individual breeds for all calves born between 1989 and 1993 are presented in Table 3. Of the individual breeds, Simmentaler made the greatest contribution (33.4%), followed by Hereford (19.3%), while the contributions of other breeds were relatively small, with only the Angus, Bonsmara and Charolais having contributions of more than 8%.

**Table 3** Breed composition of herd and composition variance of calves born between 1989 and 1993

	Breed									
	Afrikaner	Angus	Bonsmara	Brown Swiss	Charolais	Holstein	Hereford	Simmentaler	South Devon	"Remainder"
Contribution (%)	4.30	8.37	8.14	1.47	8.05	0.95	19.30	33.40	3.42	12.60
Variance ( $\times 10^{-3}$ )	1.4	4.5	13.8	0.6	6.9	0.3	19.5	19.0	4.0	25.7

The proportion of Simmentaler contribution per year of calves born and Simmentaler proportion variance is presented in Figure 1. The contribution of Simmentaler increased from 1968 to 1980, but was relatively stable during the rest of the period. The composition of individual animals varied from 0 to 96.9% (or  $^{31}/_{32}$ ) Simmentaler. In earlier years (1968-1971), the maximum percentage of Simmentaler was 75%, which resulted from backcrossing Simmentaler with  $1/2$  Simmentaler crossbred cows in the three-breed rotational crossbreeding systems. The breed proportion variance was relatively stable between 1968 and 1984, but declined rapidly thereafter as the herd became more uniform in composition for Simmentaler.

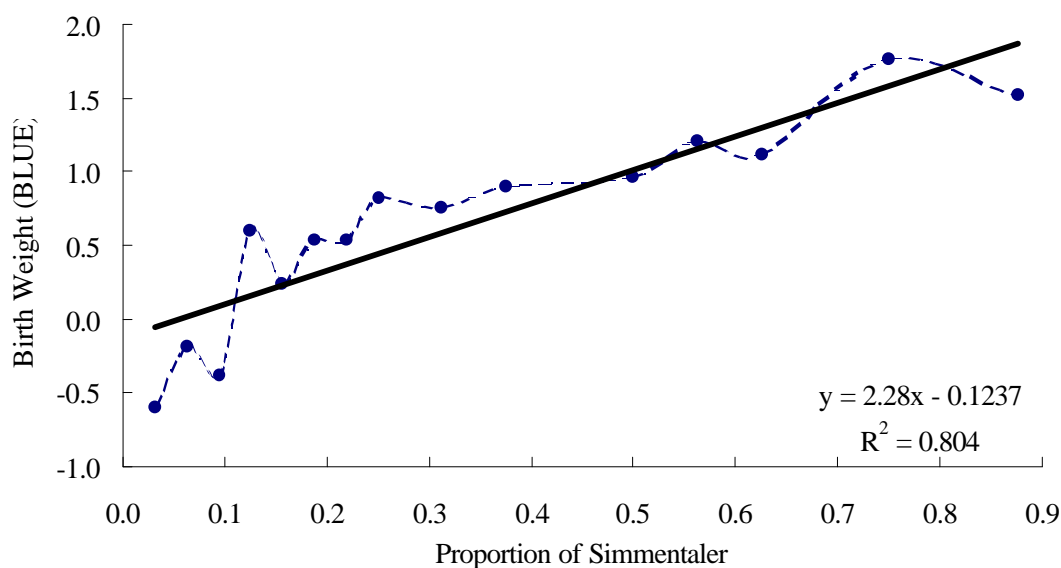
**Figure 1** Changes in mean Simmentaler contribution (%) and variance in proportion of Simmentaler per year.



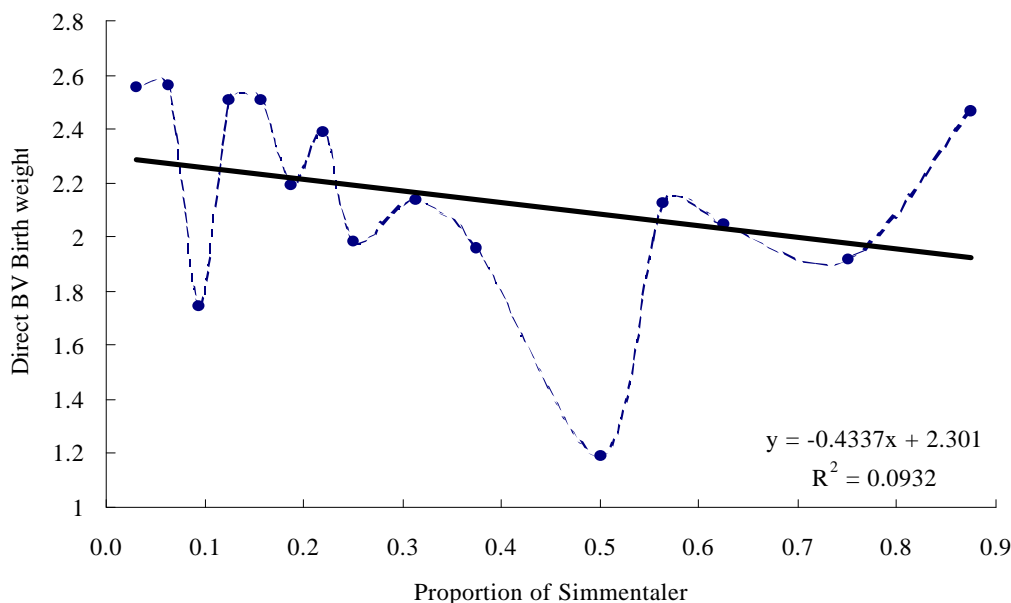
The reasons for the sharp drop in 1982 were twofold: firstly, as a result of the termination of the conventional crossbreeding systems and the use of crossbred sires, and secondly owing to the introduction of other breeds. However, it should be noted that equilibrium can only be attained when both parents and calf have the same proportion of Simmentaler genes. This point has not yet been reached.

Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for BW are presented in Figures 2a to 2c. BW was influenced by proportion of Simmentaler and increased with increasing Simmentaler contribution (Figure 2a). Likewise, maternal breeding values increased almost linearly with increasing Simmentaler proportions (Figure 2c), while mean direct breeding values decreased with increasing Simmentaler proportion (Figure 2b). Although the reasons for this unexpected decline are not obvious, it may be related to the contribution of other breeds such as the Charolais and Limousin at low Simmentaler proportion levels. The low average breeding value at ½ Simmentaler contribution is also not obvious. In total 20.6% (10 851) of calves born were ½ Simmentaler. Of those, 7 286 (67.2%) were ½ Simmentaler combined with differing contributions of Afrikaner, Angus, Bonsmara, Hereford and Devon, all of which are relatively small breeds compared to the Simmentaler, thus leading to low direct breeding values for the ½ Simmentaler. This may partly explain the low average breeding value at ½ Simmentaler proportion.

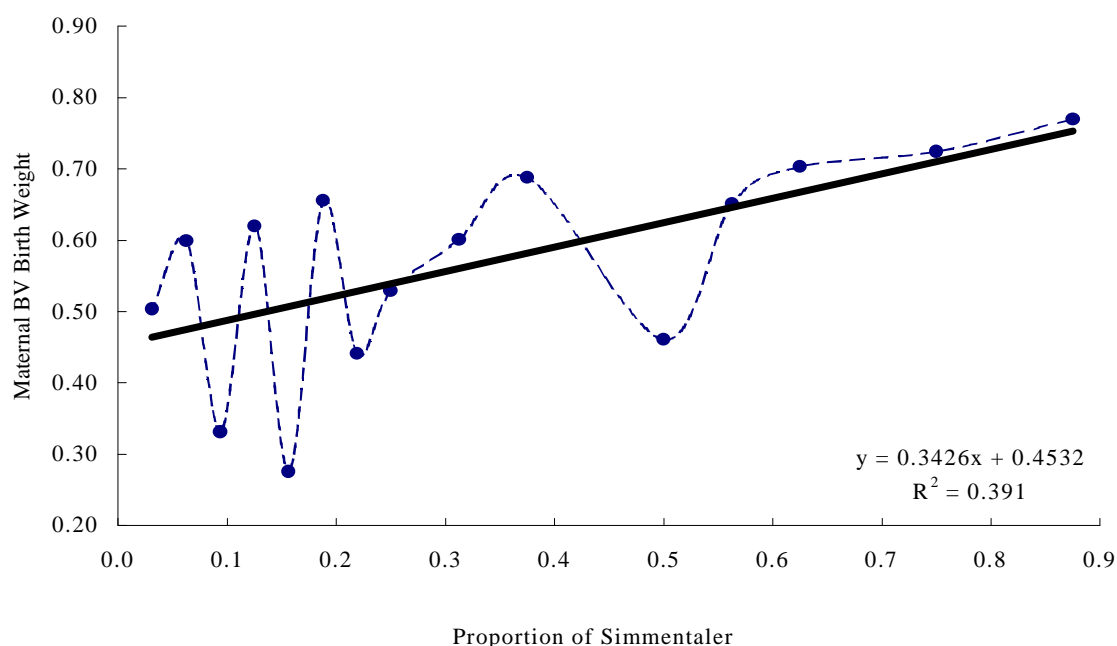
**Figure 2(a)** Regression of BLUE for birth weight on proportion of Simmentaler breeding.



**Figure 2(b)** Regression of direct breeding value for birth weight on proportion of Simmentaler breeding.



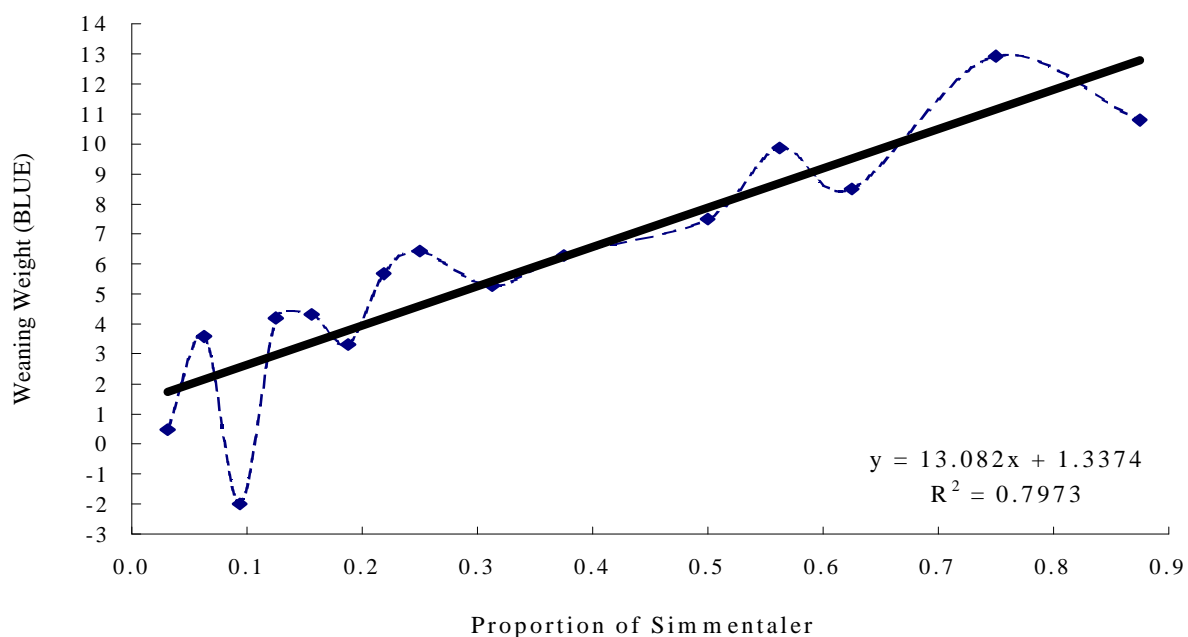
**Figure 2(c)** Regression of maternal BV for birth weight on proportion of Simmentaler breeding.



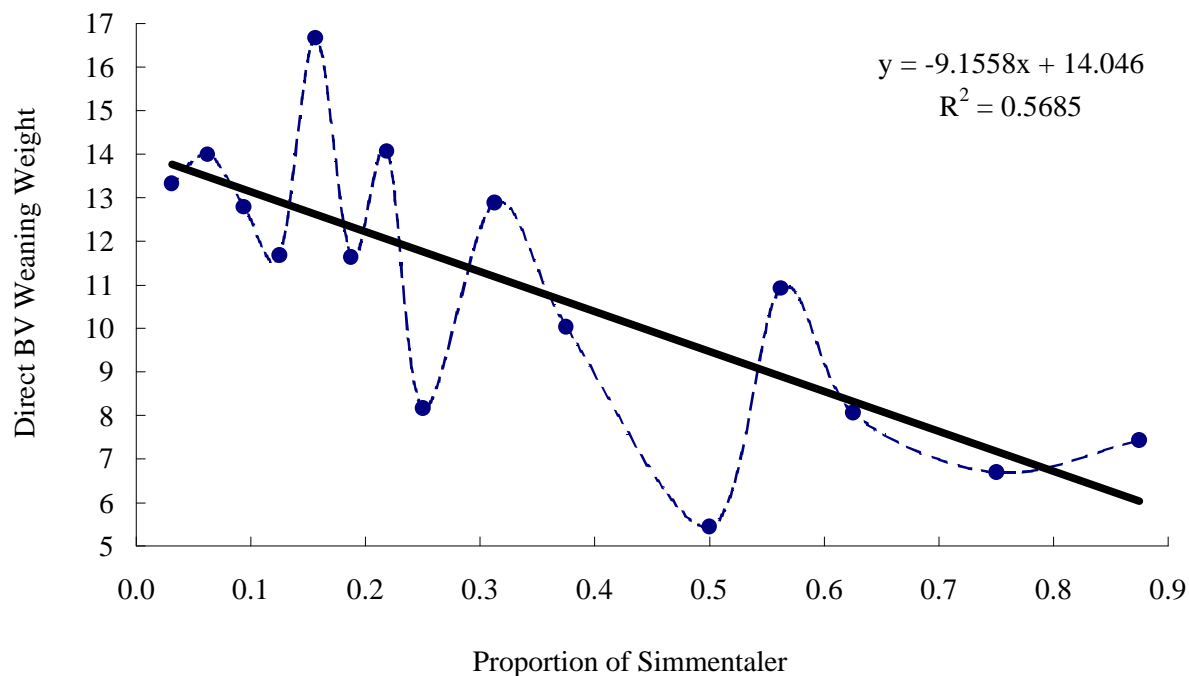
In several crossbreeding studies, positive direct effects were reported for Simmentaler (Cunningham & Magee, 1988; Schoeman *et al.*, 1993). In analysing part of the same dataset when comparing Simmentaler, Hereford and Afrikaner cattle a significant ( $P \leq 0.01$ ) positive direct effect was also observed for the Simmentaler. In other studies, an increase in Simmentaler contribution also resulted in an increased BW (Aaron & Thrift, 1982; Lawlor *et al.*, 1984), which in turn was associated with an increase in calving difficulties and a decrease in calf survival rate (Lawlor *et al.*, 1984). Also, in straight breeding operations the Simmentaler is known for high mortality rates, especially in early breeding systems (Van der Merwe & Schoeman, 1995). Van Zyl (1990) found 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. Analysing the data from the same crossbreeding project, Schoeman *et al.* (1993) obtained negative direct maternal effects for the Simmentaler, but large positive direct additive effects. High levels of Simmentaler in crossbreeding or synthetic populations are therefore not recommended.

Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for WW are presented in Figures 3a-c. WW increased linearly with an increase in Simmentaler proportion (Figure 3a). This is in contrast with the general decrease in direct breeding values (Figure 3b), but in accordance with the increase in maternal (Figure 3c) breeding values. This contradiction may also be the result of the fairly high, possibly environmentally induced, negative correlation between direct and maternal effects (Table 2) so that maternal breeding values increased where direct breeding values decreased or *vice versa*. Mean direct breeding values of  $\frac{1}{2}$  Simmentaler for BW were unexpectedly low. Although the reason for this is not obvious, this may be related to the imbalanced nature of breed combinations in the data set, especially the contribution of late maturing large-frame breeds such as the Charolais, as discussed previously.

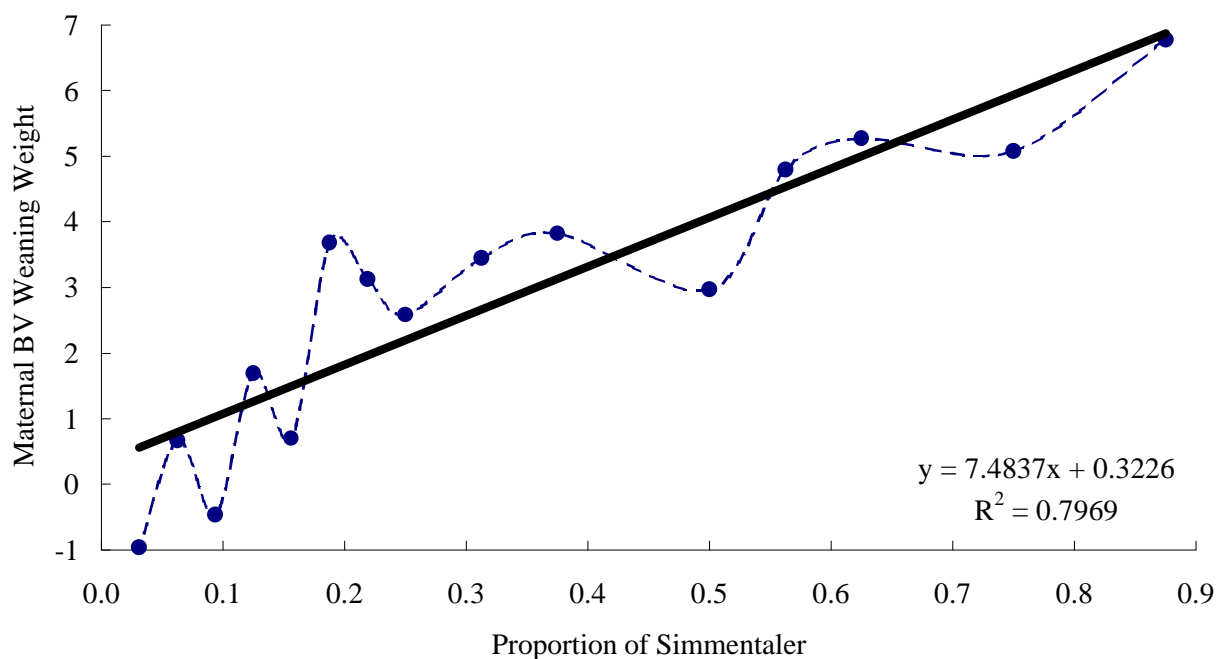
**Figure 3(a)** Regression of BLUE for weaning weight on proportion of Simmentaler breeding



**Figure 3(b)** Regression of direct breeding value for weaning weight on proportion of Simmentaler breeding



**Figure 3(c)** Regression of maternal breeding value for weaning weight on proportion of Simmentaler breeding

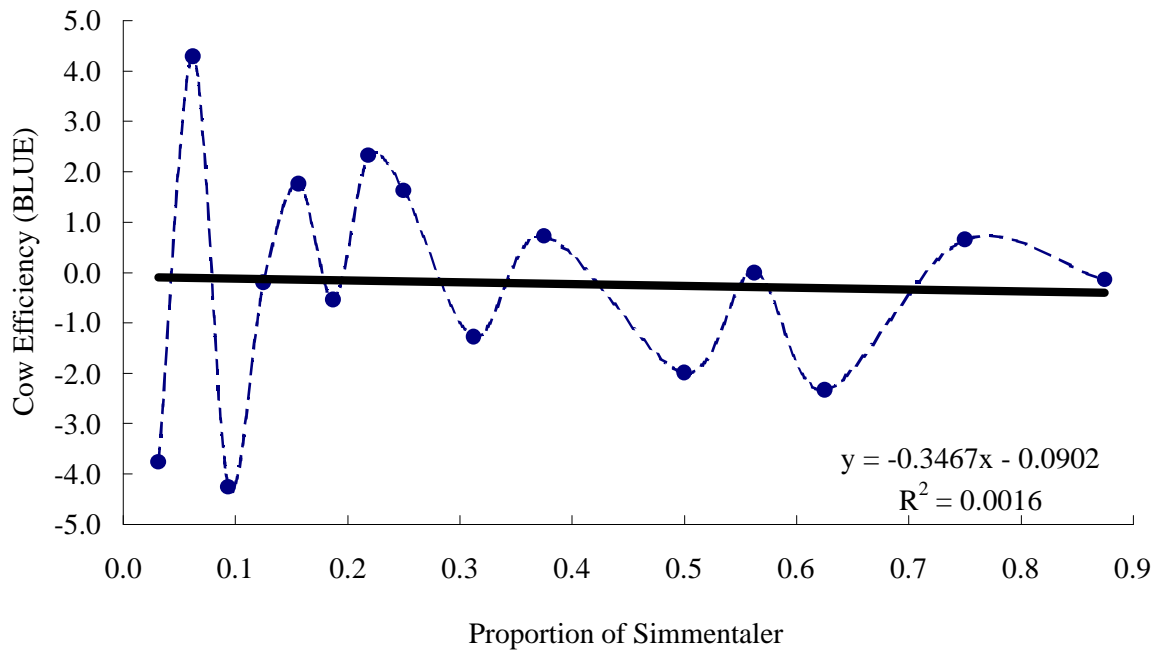


High positive maternal effects of Simmentaler were obtained in most other crossbreeding studies (Cunningham & Magee, 1988; Schoeman *et al.*, 1993). When comparing Simmentaler with Afrikaner and Hereford, Schoeman *et al.* (1993) obtained positive direct and maternal effects for Simmentaler of 20.8% and 3.0% of the mean respectively. The average WW of Simmentaler cattle taking part in the National Beef Cattle Performance Testing Scheme is approximately 35 kg higher (17.4%) than the predicted WW of purebred Simmentaler in this herd, suggesting that the environment in which the herd is managed is relatively unfavourable (Schoeman, 1996).

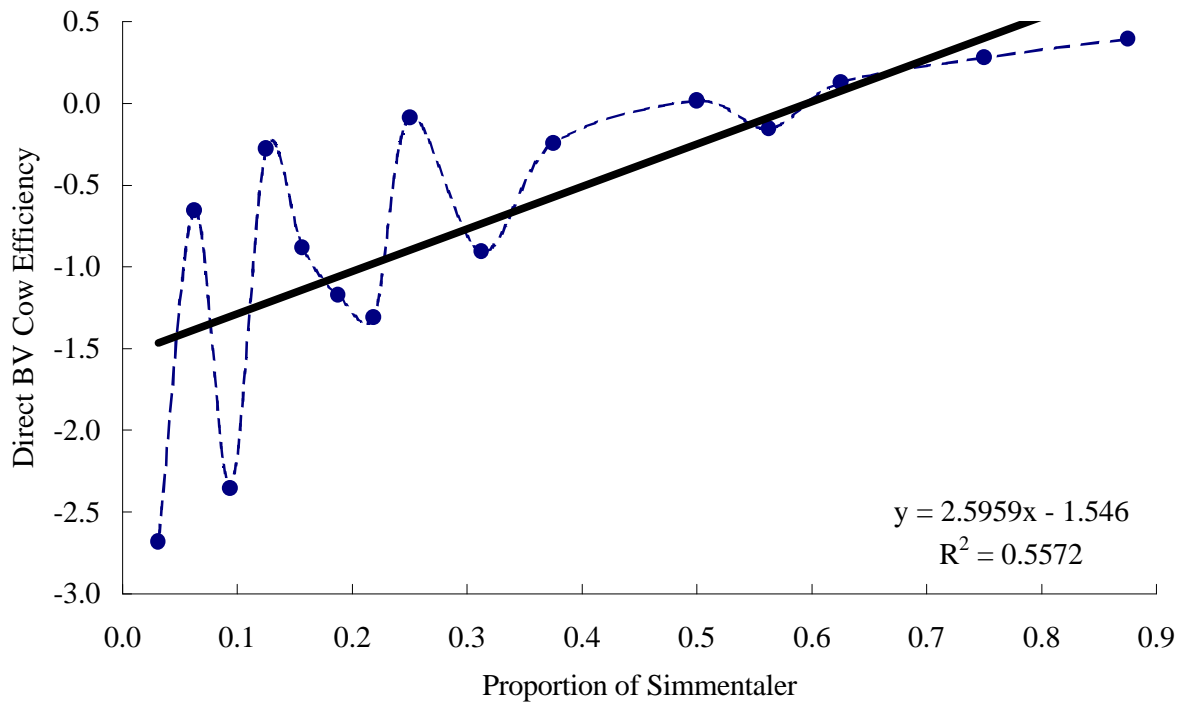
Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for CE are presented in Figures 4a-c. Direct breeding values (Figure 4b) and maternal breeding values (Figure 4c) both increased with an increase in proportion of Simmentaler. Despite these increased breeding values, BLUE's for CE were not affected by proportion of Simmentaler (Figure 4a). The metabolic size of the dam therefore increased at the same rate as WW with an increase in Simmentaler 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 that for WW.



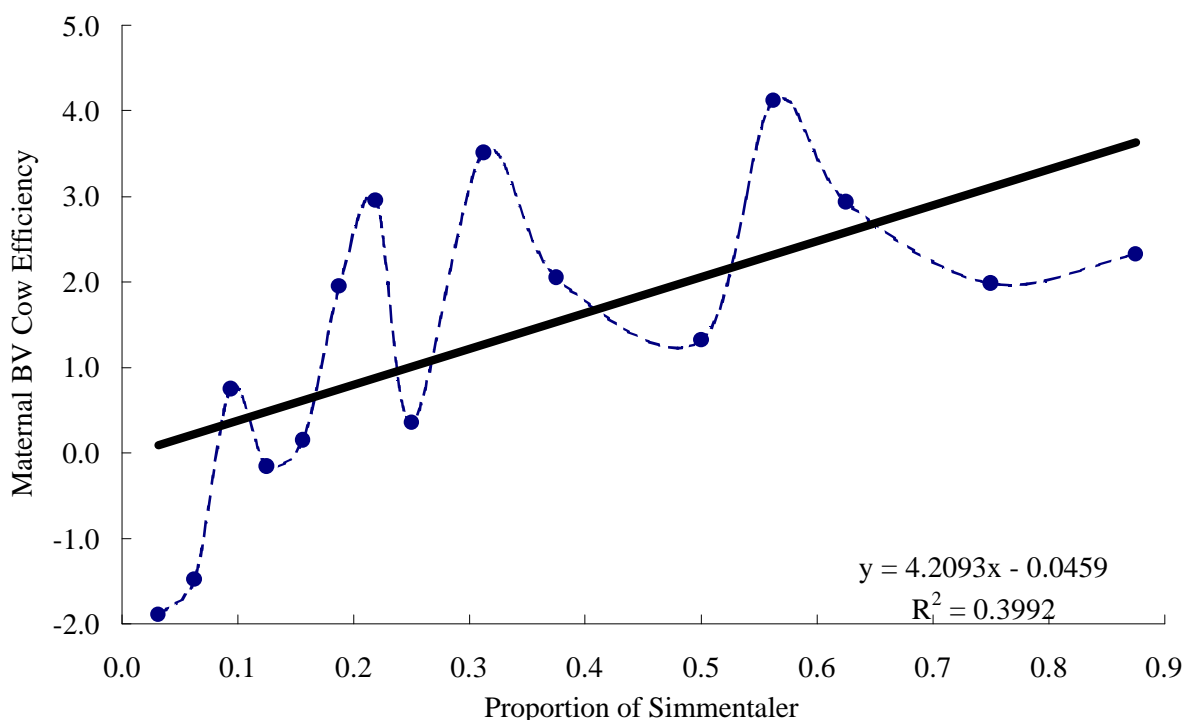
**Figure 4(a)** Regression of BLUE for cow efficiency on proportion of Simmentaler breeding.



**Figure 4(b)** Regression of direct breeding value for cow efficiency on proportion of Simmentaler breeding.



**Figure 4(c)** Regression of maternal breeding value for cow efficiency on proportion of Simmentaler breeding.



## Conclusions

Estimates of additive and maternal genetic variances may be biased due to the inclusion of selected base animals from different breeds. Genetic grouping may solve this problem. High negative genetic correlations between direct and maternal effects may be environmentally induced. These results show a decrease in direct breeding values for BW and WW but an increase for CE with increasing Simmentaler contribution. Maternal breeding values for BW, WW and CE increased with an increase in Simmentaler proportion. In order to be able to obtain a more comprehensive picture of the relative contribution of the Simmentaler, it should be evaluated in context with the individual contributions of the other contributing breeds. Their role should also be investigated. Reasons for the large negative correlations between the direct and maternal effects, together with the unexpected behaviour of direct and maternal breeding values for BW and WW with increased Simmentaler proportion need further investigation. Other traits of importance should also be investigated.

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