AN ASSESSMENT OF THE CONTRIBUTIONS OF AFRIKANER, HEREFORD AND SIMMENTALER IN COMPOSITE BREED DEVELOPMENT IN BEEF CATTLE

by

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I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or part submitted it at any university for a degree.

ABSTRACT

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The objective of this study was to obtain more information regarding the characterisation of Afrikaner (A), Hereford (H) and Simmentaler (S) breeds in an initial crossbreeding programme and subsequent composite development. This involves the estimation of breed additive effects, breed maternal, individual heterotic effects and maternal heterotic effects in the initial crossbreeding phase and the estimation of genetic parameters and prediction of breeding values in later generations for birth weight (BW), weaning weight (WW) and cow efficiency (CE; WW/dam weight$^{0.75}$ x 100) in an intensive environment under high stocking rates.

In the analysis of the initial crossbreeding phase, the S breed direct effects, expressed as deviation from the general mean, were positive (P $\leq$ 0.01) for both BW and WW. Hereford and A breed direct effects were negative (P $\leq$ 0.01) for both BW and WW. Afrikaner direct maternal effects were positive (P $\leq$ 0.01) for both BW and WW. The H direct maternal effect was negative (P $\leq$ 0.05) (-2.8%) for WW. Simmentaler maternal effect was negative (P $\leq$ 0.01) for BW but non-significant (P $\geq$ 0.05) for WW. Individual heterotic effects for BW were significant (P $\leq$ 0.01) in H x S (3.5%) and S x A (11.0%) only. Individual heterotic effects were positive (P $\leq$ 0.01) for WW, with that of the H x A (9.8%) and S x A (6.7%) crosses exceeding the H x S (3.1%) cross. Maternal heterotic effects were non-significant (P $\geq$ 0.05) for both BW and WW.

Investigations of the contributions of the A, H and S during composite development in later generations, respectively, were made to estimate direct heritabilities (h^2_a) and maternal heritabilities (h^2_m) for BW and WW of the calf and CE of the dam. Calves were born between 1968 and 1993 (n = 52628). Calves of this composite population had varying levels of A, H and S genes ranging from 0 to 75%, 0 to 100% and 0 to 96.9%, with an average of 4.3, 19.3 and 33.4%, respectively.

For the A, direct heritabilities fitting unitrait models were 0.67, 0.53 and 0.19 for BW, WW and CE, respectively, with corresponding estimates of h^2_m being 0.22, 0.36 and 0.58. Genetic correlations between direct and maternal effects (r_{am}) were negative for all three traits, varying from -0.32 to -0.62. Direct breeding values for BW increased and reached a maximum value at 0.11 proportion of A. The maternal breeding values for BW decreased linearly between 1.6 to 37.5% A proportion and increased linearly between 37.5 to 75% A proportion. For WW, the direct breeding values decreased linearly with increasing A proportion, while the maternal breeding values were not affected by proportion of A. Cow efficiency was unaffected by an increase in proportion of A.

For the H, direct heritabilities fitting unitrait models were 0.67, 0.52 and 0.21 for BW, WW and CE, respectively, with corresponding estimates of h^2_m being 0.22, 0.36 and 0.60. Genetic correlations between direct and maternal effects (r_{am}) were negative for all three traits, varying from -0.32 to -0.64. Direct breeding values and maternal breeding values for BW and WW decreased with increasing proportion of H. Direct breeding value for CE increased, while the maternal breeding value for CE reached minimum value at 0.62 proportion of H.

For the S, 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 S. Cow efficiency was unaffected by an increase in proportion of S.

The study suggests that in the initial crossbreeding phase, purebred S breeding seems to be the best breeding practice for this environment and that during composite development, high A and H contributions could lead to low BW and WW (except the maternal contribution of the A for BW and WW). The advantage of the S lies more in the maternal contribution than in the direct contribution suggesting that the S is a large-framed maternal line rather than a terminal sire line.

OPSOMMING

'N WAARDEBEPALING VAN DIE BYDRAE VAN DIE AFRIKANER, SIMMENTALER EN HEREFORD TYDENS KOMPOSIETE RAS-ONTWIKKELING BY VLEISBEESTE

deur

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Die doel van die studie was om inligting aangaande die karakterisering van die Afrikaner (A), Hereford (H) en Simmentaler (S) rasse tydens die oorspronklike aanvangsfase van kruisteling en daaropvolgende komposiet ontwikkeling te verkry. Dit het die beraming van direkte additiewe, individuele heterose, direkte materne en materne heterotiese effekte tydens die aanvangsfase van die kruisteeltprogram, die beraming van genetiese parameters en die voorspelling van die teeltwaardes in latere generasies behels. Die eienskappe wat ingesluit is, is geboortegewig (BW), speengewig (WW) en koeidoeltreffendheid (CE; WW/koeigewig$^{0.75}$). Hierdie kudde is in 'n intensiewe maar onder 'n hoë weidingsdruk omgewing aangehou.

Tydens die ontleding van die eerste kruisteeltfase is die direkte additiewe effekte vir die S, uitgedruk as afwyking van die algemene gemiddelde, vir beide BW en WW positief ($P \leq 0.01$). Direkte additiewe effekte vir die H en A was vir beide BW en WW negatief ($P \leq 0.01$). Afrikaner materne effekte was vir beide BW en WW ($P \leq 0.01$) positief. Die H direkte materne effekte was negatief (-2.8%) ($P \leq 0.05$) vir WW. Simmentaler maternal effekte was ook vir BW negatief ($P \leq 0.01$), maar nie-betekenisvol ($P \geq 0.05$) vir WW. Individuele heterose was slegs betekenisvol ($P \leq 0.01$) vir kombinasies van H x S (3.5%) en S x H (11.0%) vir BW. Individuele heterose was positief ($P \leq 0.01$) vir WW waar H x A (9.8%) en S x A (6.7%) kruisings dié van die H x S (3.1%) kruising oortref het. Materne heterose was vir beide BW en WW nie-betekenisvol ($P \geq 0.05$).

Die relatiewe bydraes van die A, H en S is ook tydens komposiet-ontwikkeling bereken. Direkte additiewe oorerflikhede ($h^2{}_a$) en materne oorerflikhede ($h^2{}_m$) is vir BW en WW van die kalf en CE van die koei beraam. Kalwers in die komposiet kudde, gebore tussen 1968 en 1993 (n = 52628), het variërende vlakke van A, H en S gene. Die samestelling het gevarieer van 0 - 75%, 0 - 100% en 0 - 96.9%, met 'n gemiddeld van 4.3, 19.3 en 33.4%.

Vir die A was die direkte erfbaarhede (h^2_a), soos deur die passing van 'n enkeleienskapmodel beraam, 0.67, 0.53 en 0.19 vir onderskeidelik BW, WW en CE, met ooreenstemmende beramings van 0.22, 0.36 en 0.58 vir h^2_m. Genetiese korrelasies tussen direkte en materne effekte (r_{am}) was almal negatief en het tussen -0.32 en -0.62 gewissel. Direkte teelwaardes vir BW het met toenemende A-bydrae gestyg en het 'n maksimum waarde by 0.11 bereik. Die materne teelwaardes vir BW het lineêr gedaal tussen 1.6 en 37.5% A-bydrae en het weer lineêr tussen 37.5 en 75% A-bydrae gestyg. Vir WW het die direkte teelwaardes lineêr met toenemende A-bydrae gestyg, terwyl die materne teelwaardes nie deur A-bydrae beïnvloed was nie. Koeidoeltreffendheid was nie deur 'n toename in A-bydrae beïnvloed nie.

Vir die H was die direkte erfbaarhede (h^2_a), soos deur die passing van 'n enkeleienskapmodel beraam 0.67, 0.52 en 0.21 vir onderskeidelik BW, WW en CE, met ooreenstemmende beramings van 0.22, 0.36 en 0.60 vir h^2_m. Genetiese korrelasies tussen direkte en materne effekte (r_{am}) was almal negatief en het tussen -0.32 en -0.64 gewissel. Direkte teelwaardes en materne teelwaardes vir BW en WW het met toenemende H-bydrae gedaal. Direkte teelwaarde vir CE het ook met toenemende H-bydrae gedaal, terwyl die materne teelwaarde 'n minimum waarde by 0.62 H-bydrae bereik het.

Vir die S was die direkte erfbaarhede (h^2_a), soos deur die passing van 'n enkeleienskapmodel beraam 0.66, 0.53 en 0.21 vir onderskeidelik BW, WW en CE, met ooreenstemmende beramings van 0.22, 0.36 en 0.59 vir h^2_m. Genetiese korrelasies tussen direkte en materne effekte (r_{am}) was almal negatief en het tussen -0.32 en -0.63 gewissel. Direkte teelwaardes vir BW en WW het gedaal, terwyl die materne teelwaardes met toenemende S-bydrae gestyg het. Koeidoeltreffendheid was nie deur 'n toename in S-bydrae beïnvloed nie.

Die bevinding was dat tydens die ontleding van die eerste kruisteeltfase die teling van suiwer S aanbeveel word en dat tydens komposiete-ontwikkeling toenemende A- en H-bydraes neig om aanleiding te gee tot afnames in BW en WW (behalwe die materne bydrae van die A vir BW en WW). Die S-bydrae se voordeel is meer in die materne bydrae as in die direkte bydrae geleë en dui dus aan dat die S as 'n materne grootraam lyn i.p.v. as 'n terminale bul lyn gebruik moet word.

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CHAPTER 1
GENERAL INTRODUCTION

Crossbreeding in beef cattle is a widely accepted standard production practice in many countries of the world. Surveys showed that crossbreeding influenced about 80%, 90% and 65% of the cattle marketed in the USA, Canada and Australia, respectively. About 60% of the cattle sold to feedlots in South Africa are crossbred types (Schoeman, 1998). However, it was also proved in surveys by Sundstrom *et al.* (1994) that by far the minority of those crossbreeding operations were regarded as well planned and effective. They varied between only 15 and 45%. Although little information is available, it is suggested that almost the same situation prevails in South Africa.

According to Kinghorn & Simm (1999) the main reasons for crossbreeding are:

• Complementarity. This refers to the advantage of a crossbred over another crossbred or a purebred resulting from the manner in which two or more traits combine or complement each other, expressing the nett merit of the animal (Cartwright, 1970; Schoeman, 1999). In practice, complementarity is often used in combining growth potential of rapidly growing breeds with adaptive characteristics of another breed. The large number of composite breeds, *e.g.* Braford, Bonsmara, Santa Gertrudis, is the result of exploiting complementarity in practice. Complementarity gives rise to:

- The averaging of breed effects. For example, to get an animal of intermediate size to fit a particular pasture cycle or market demand. This may involve either regular systems of crossing (rotational, terminal or rotational-terminal crossing systems) or the creation of composite breeds (*e.g.* Cundiff *et al.*, 1986).

- Sire-dam complementation. Breed differences in direct and maternal effects may be turned into a complementary advantage using an appropriate cross. In optimising this advantage, breeds should be characterised as either sire or dam line. This indicates a need for the characterisation of additive and maternal effects for a variety of economically important traits. Breed characterisation is important to prevent inappropriate breed combinations during crossbreeding or composite breed creation which could lead to disastrous consequences, *e.g.* heavy birth weights are associated with dystocia, calf losses, cow losses, reduced calf performance and subsequent reduced cow fertility (Cundiff *et al.*, 1986). An appropriate crossbreeding system aims to use breeding cows that are of small or intermediate mature size (but not so small that dystocia is a problem) as well as fertile. When a large terminal-sire breed is used, the proportion of feed directed to growing animals is increased and the production system benefits

accordingly.

- Heterosis. Heterosis can be defined as the amount by which the F_1 population (crossbreds) mean exceeds the mean mid-parent value. The percentage increase in performance due to heterosis ranges form about 0 to 10% for growth traits and 5 to 25% for fertility traits. The effects of heterosis on the total production system can be even more than this, as effects accumulate over composite traits (*e.g.* Koger *et al.*, 1975; Gregory & Cundiff, 1980; Cundiff *et al.*, 1986). There are three types of heterosis (Schoeman, 1999), *viz.*:

  - Individual heterosis which is the improvement in performance in an individual animal relative to the mean mid-parent value that is not attributed to either maternal or paternal effects.

  - Maternal heterosis which refers to the heterosis attributable to the use of crossbred dams instead of purebred dams, or those effects in calf performance due to the influence of the crossbred dam; thus increased milk production, improved prenatal environment and fertility provided by the crossbred dam.

  - Paternal heterosis which refers to the improvement of performance in the progeny when a crossbred sire was used.

- A cheap source of breeding animals. This is evident in some crossbreeding systems- *e.g.* in the British and Irish beef industries, where many suckler cows have come form matings between beef bulls and dairy cows.

The wide variety of beef cattle types (approximately 30) in South Africa suggests the possibility of creating certain breed combinations that can increase production. Large differences among breed types also exist for a variety of traits, *e.g.* growth rate, size, fertility, maternal traits including milk production, carcass and meat traits (Gregory *et al.*, 1994; Schoeman, 1996). Cartwright (1970) reported that more rapid improvement could be achieved through selection between breeds and subsequent crossbreeding than by selection within breeds. It therefore suggests that breed characterisation is essential for effective selection among breeds for use either in programs for purebred breeding or crossbreeding (to use heterosis and complementarity) or composite breed development (to achieve and maintain the most optimum breed composition and to use heterosis) (Gregory *et al.*, 1985). There are basically two methods of characterisation of breeds. One is by directly comparing several breeds under the same but varying environmental conditions (Hetzel, 1988; Schoeman, 1989; 1996). However, this is not always possible and very costly. The second one is through crossbreeding and the estimation of crossbreeding parameters (breed additive effects, breed maternal, individual heterotic effects and maternal heterotic effects) under different environmental conditions (Alenda *et al.*, 1980; Dillard *et al.*, 1980; Robison *et al.*, 1981; Schoeman

et al., 1993; Arthur *et al.*, 1999). By doing this, breeds can also be characterised as sire or dam lines for specific environments. Consequently, accurate estimation of parameters influencing economically important traits in a variety of environmental conditions is needed to set up crossbreeding systems aimed at maximising weaner output since breed additive effects, breed maternal, individual heterotic effects and maternal heterotic effects vary with the environmental level (Barlow, 1981). A re-ranking of crossbred types was also obtained by Arthur *et al.* (1999) from one environment to another for several traits, indicating a significant crossbred group x heterosis interaction. Thus, an appropriate crossbreeding system with a particular combination of breeds in one environment may not be the appropriate system in another environment.

The objective of this study therefore was to obtain more information regarding the characterisation of Afrikaner, Hereford and Simmentaler breeds in an initial crossbreeding programme and subsequent composite development. This involves the estimation of breed additive effects, breed maternal, individual heterotic effects and maternal heterotic effects in the initial crossbreeding phase and the estimation of genetic parameters and prediction of breeding values in later generations for birth weight (BW), weaning weight (WW) and cow efficiency (CE; WW/dam weight$^{0.75}$ x 100) in an intensive environment under high stocking rates. The Simmentaler followed by the Hereford made the greatest contribution to the creation of this composite population. Afrikaner heifers are in great demand for crossbreeding purposes in South Africa. Indirectly, it also played an important role through its contribution as a foundation breed in the development of the Bonsmara, a composite beef breed.

CHAPTER 2

ESTIMATES OF CROSSBREEDING PARAMETERS

2.1 Introduction

Increasing efficiency of production in weaner production systems is of vital importance since the dam consumes approximately 94% of the total digestible nutrients of the dam/calf unit until weaning. Even if the calf is marketed after feedlot finishing, the dam still consumes up to 72% of the TDN of the dam/calf unit (Van der Westhuizen & Matjuda, 1999).

Crossbreeding can be used in cattle production to generate heterosis and to use differences among breeds to optimise average genetic merit of performance traits for adaptability to the various climatic and nutritive environments encountered in beef production (Gregory & Cundiff, 1980; Koch *et al.*, 1985). Since mating systems used in farm animals may change according to the importance of the kinds of gene action (additive or non-additive) affecting the economical traits, genetic manipulation would be more precise if the proportion of the genetic variance that is attributable to additive and non-additive gene action were known. In addition, knowledge of the maternal contribution to the performance of the offspring is also necessary in planning a sound crossbreeding programme (Dillard *et al.,* 1980). The cumulative advantage of employing these effects efficiently can be substantial when crossing genetically diverse breeds. Studies from Gregory & Cundiff (1980) showed that the cumulative effects of heterosis on traits that contribute to weight of calf weaned per cow exposed to breeding were 23.3% for crosses among breeds of *Bos taurus* cattle and 50% or more for crosses between *Bos taurus* and *Bos indicus* breeds of cattle. Results also showed that 60% or more of the observed cumulative heterosis was the result of heterosis effects on maternal characteristics.

Birth weight and weaning weight are two important traits especially in weaner production systems. Accurate estimation of parameters influencing these traits in a variety of environmental conditions is needed to set up crossbreeding systems aimed at maximising weaner output since breed additive effects, breed maternal effects, individual heterotic effects and maternal heterotic effects vary with the environmental level (Barlow, 1981), suggesting crossbreeding effect x environment interactions. Generally, the level of heterosis is higher under poor environmental conditions than under good environmental conditions, making crossbreeding the obvious breeding practice under unfavourable conditions. Consequently, the relative importance of these effects should be assessed

in a variety of environments. The objective of this study was to determine the contributions of breed additive effects, breed maternal effects, individual heterotic effects and maternal heterotic effects on birth weight (BW) and weaning weight (WW) of the Afrikaner, Hereford and Simmentaler breeds in an intensive environment under high stocking rates.

2.2 Material and Methods

2.2.1 Data

Data was derived from the farms of the Johannesburg Metropolitan Council which are situated in the Gauteng Province of South Africa. The Johannesburg Municipal beef cattle operation consists of two farms; namely the Northern Farm and the Olifantsvlei farm. These farms form part of the waste water management scheme of the Greater Johannesburg Metropolitan Council. The 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, mavovo (distillers grain) and silages (maize, sorghum and grass) when necessary. Management, replacement and selection procedures of the herd were described in more detail by Paterson (1978, 1981), Paterson *et al.* (1980) and MacGregor (1997).

After editing, the data consisted of 5923 BW and WW records collected from 1968 to 1982. The three breeds of cattle namely Afrikaner (A), Hereford (H) and Simmentaler (S) were mated to produce 25 different breed groups of calves - two purebred and 23 crossbred groups (Table 2.1). Hereford and Simmentaler sires were initially mated to Afrikaner dams, Simmentaler sires were mated to Hereford dams and Hereford sires were mated to Simmentaler dams to produce the F_1 calves. Calves of S x (1/8H 7/8S), S x (1/16A 1/16H 7/8S) and S x (1/8A 7/8S) crosses (*i.e.* 93% Simmentaler) were considered as purebred Simmentalers (S x S). Likewise, a few calves of H x (1/8A 7/8H), H x (1/16A 1/16S 7/8H) and H x (1/8S 7/8H) crosses (*i.e.* 93% Hereford) were considered as purebred Herefords (H x H) and were pooled with the purebred Herefords. Afrikaner purebred matings were not carried out and such data was therefore not available in this study.

Twenty nine Hereford sires were used with an average of 66 progeny per sire, that varied from two to 253. Eighteen Simmentaler sires were used with an average of 239 progeny per sire that varied from three to 620. The number of dams used was 2348 with an average of 6 calves per dam that varied from 1 to 11 calves. The number of calves born in each year for each breed group is presented in Table 2.1.

During editing, records of calves without birth dates or birth or weaning weights were omitted as well as those born "out of season" and with unidentified parents. Dam ages ranged from 2 to 16 years. Data from both farms was already pre-adjusted for dam age and weaning age of the calf. Therefore, dam age and weaning age of the calf were not included in both the initial and operational models. Fixed effects included in the models and means for BW and WW are presented in Table 2.2.

All matings were planned and artificial insemination (using the same sires across the two farms) was used throughout the cattle herd. Heifer calves 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 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.

2.2.2 Statistical analysis

The General Linear Models procedure (SAS, 1993) was used in an initial analysis of the data. All main effects and all possible first-order interactions were included in the initial models. These models were then fitted according to a step-down procedure in which main effects and first-order interactions not making a significant (P ≤ .05) contribution to the total variance were omitted in subsequent analyses. Farm and first-order interactions between year x farm and year x genotype were either non-significant or made a minor contribution to the total variance and were thus not included in the final model.

The final reduced model for estimating least-squares means (LS Means) with standard errors for BW and WW, respectively, was:

$$Y_{ijkl} = \mu + T_i + C_j + S_k + D_l + e_{ijkl}$$

where μ = least-squares means

T_i = the effect owing to year (15 levels)

C_j = effect owing to breed group (25 levels)

S_k = effect owing to the sex of the calf (2 levels)

D_l = effect of season of birth within year (2 levels)

e_{ijkl} = random error.

The LS Means and standard errors obtained from the SAS (1993) analysis were subsequently used to estimate the crossbreeding effects, using the CBE3 package of Wolf (1996) and fitting Kinghorn's Model 7 (Kinghorn, 1987; Wolf *et al.,* 1995), for BW and WW, respectively. This model provides a large variety of options to choose from in estimating crossbreeding effects. The following individual genetic crossbreeding effects were chosen: additive effects, dominance effects, additive maternal effects and maternal dominance effects. The model was:

$$G = m + \sum_i \alpha_i a_i + \sum_{i<j} \delta_{ij} d_{ij} + \left\{ \sum_i \delta_{ii} + \left(\sum_{j \neq i} \alpha_j\right) + \sum_{i<j} \delta_{ij} - 1/8 \left[\sum_{i<j} \delta^2_{ij} + \sum_{i<j<k} \left(\delta_{ij}\delta_{ik} + \delta_{ij}\delta_{jk} + \delta_{ik}\delta_{jk} \right) \right] \right\} e$$

G	=	predicted value of the genetic group G under consideration
m	=	general mean
α_i, α_j	=	proportion of genes from the ith and j^{th} source population in the given genetic group
a_i	=	additive effect of the ith source population
$\delta_{ij}, \delta_{ik}, \delta_{jk}$	=	probability that at a randomly chosen locus of a randomly chosen individual of the given genetic group, one allele is from the ith and the other allele from the jth source population, one allele is from the ith and the other allele from the kth source population, one allele is from the jth and the other allele from the kth source population
δ_{ii}	=	probability that at a randomly chosen locus of a randomly chosen individual of the given genetic group both alleles are from the same source population
d_{ij}	=	dominance effect of the combination of the ith and j^{th} source populations
e	=	epistatic effect (not estimated in this study).

Table 2.1. Number of calves born by year for each breed group

Breed group[1]	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Total
Pure breeds																
H x H	19	17	43	53	45	38	60	52	37	29	17	24	31	11	2	478
S x S								1	3	4	2	7	10	5		32
F₁																
S x A	86	60	44	34	31	32	13									300
S x H	125	119	72	50	40	38	2		1			3				450
H x A	22	1	15	11	3	8	3									63
H x S									2	2	2	3	14	1	9	33
Two-breed backcrosses																
H x (1/2A 1/2H)	186	21	23	16	10	16	14	8	3	3						300
H x (1/2H 1/2S)	1	2	9	12	17	22	12	14	14	12	8	7	6	5		141
S x (1/2A 1/2S)		1	15	33	15	19	24	14	11	7	7	3	1			150
S x (1/2H 1/2S)	1	3	14	46	24	42	29	22	18	10	5	3	3	1		221
H x (1/4A 3/4H)			1	3	1	3	10	9	11	5	4	5	3	1		56
H x (1/4S 3/4H)							2	4	5	4		5	5	1		26
S x (1/4A 3/4S)						2	2	4	4	6	3	3	5	2		31
S x (1/4H 3/4S)				2		5	3	6	9	15	12	11	8	4		75
H x (1/4H 3/4S)						5	6	11	8	6	4	4	5	3	1	53
Three-breed crosses																
H x (1/2A 1/2S)	4	6	23	12	14	20	4	5		3	1	3				95
S x (1/2A 1/2H)	311	297	308	223	203	156	91	52	30	16	12	2	1			1702
H x (1/4A 3/4S)						2	2	2	5	4	3	5	8		2	33
S x (1/4A 3/4H)			1	24	15	15	2	2	2	1	1		1			64
S x (1/4A 1/2H 1/4S)			4	2	4	2	3	2	1	1		2				21
S x (1/4A 1/4H 1/2S)			25	86	65	103	116	124	130	112	41	36	28	16		882
S x (1/8A 1/8H 3/4S)						3	7	10	23	31	21	24	14	11		144
H x (1/8A 5/8H 1/4S)				4	1		2	9	7	9	16	7	4	1		60
H x (1/8A 1/8H 3/4S)					1	15	8	20	21	24	21	38	47	15	11	221
H x (1/4A 1/4H 1/2S)			35	21	29	76	27	49	15	16	9	11	3	1		292
	755	527	628	628	521	625	439	414	363	318	183	215	200	81	26	5923

[1]Breed of sire is identified by first symbol in crosses.

2.3 Results and Discussion

2.3.1 Breed group differences

The analysis of variance for the two traits using the first model is presented in Table 2.2. All effects in the model were significant sources of variation. BW and WW were, respectively, 2.5 kg and 14.4 kg higher for bull calves than for heifer calves. Sex differences reported by Marlowe & Gaines (1958), Ellis *et al*. (1965), Cundiff *et al*. (1966), Brinks *et al*. (1972), Smith *et al*. (1976), Dillard *et al*. (1980) and Van Zyl *et al*. (1992) are in general agreement with these results. Breed group effects were also significant ($P \leq 0.001$) for both traits considered, accounting for 5.7 and 4.8% of the variation in BW and WW, respectively. Analysing data from a different crossbreeding project also involving Afrikaner, Simmentaler and Hereford breeds, Schoeman *et al*. (1993) found that breed group effects accounted for 17.3 and 39.9% of the variation in BW and WW which are considerably higher than in this study. This difference may be environmentally related.

Table 2.2. F values, error mean squares and test of significance of variances for BW and WW

Source	Traits (kg)	
	BW	WW
Years	33.3***	53.0***
Breed group	17.9***	17.2***
Sex	384.5***	353.8***
Season of birth	14.9***	89.9***
Error mean square	23.7	864.1
Mean ±SD	34.7 ± 4.86	191.6 ± 29.39
R ² model (%)	21.9	31.4

***$P \leq 0.001$

The R^2 (coefficient of determination) accounted by the model for BW and WW were 21.9 and 31.4%, respectively. In another study Schoeman *et al*. (1993) reported R^2 values of 32.5 and 64.1% for BW and WW, respectively, for the models fitted by these authors. This indicates that a large amount of variation was not accounted for in the models fitted in the present study. This may be due to unidentified sources of variation resulting from management practices and between-year consistency in feed availability owing to the irrigated pastures.

LS Means for the breed and crossbred groups are presented in Table 2.3. It should be noted that "dummy LS Means" were allocated to two breed groups. Without these "dummy LS Means" some crossbreeding effects could not have been estimated. These LS Means for BW and WW were calculated as follows: The purebred breed group of Afrikaner was adjusted proportionally from the Hereford and Simmentaler LS Means with values which were obtained from the National Beef Cattle Performance and Progeny Testing Scheme (Schoeman, 1996) since there was no information on Afrikaner x Afrikaner matings available. No data on matings between Afrikaner sires and other types of crosses were available either, therefore, the LS Means of A x (1/2H 1/2A) for BW and WW were calculated from the mid-parent value adding 8% (assumed) heterosis (Long, 1980).

BW was heavier in the F_1 (34.4 kg) than in the other mating types. Likewise, BW of the F_1 was heavier in the Mara crossbreeding project (Schoeman *et al.*, 1993) than the other mating types. The three-breed cross (186.6 kg) performed the best of all mating types and exceeded the purebred means (177 kg) by 5.4% for WW, except the purebred Simmentaler which had the highest WW (205.4 kg) and exceeded the three-breed cross mean by 10.1% for WW. The means of F_1 and two-breed backcrosses for WW were 185.9 and 185.7, respectively.

Differences in breed additive, maternal additive, individual heterotic and maternal heterotic effects are the most important reasons for differences in performances among breed groups (Dillard *et al.*, 1980). The crossbreeding components, obtained from the second model, are presented in Table 2.4.

2.3.2 Breed direct effects

2.3.2.1 Birth weight

The direct additive contributions for BW were positive for Simmentaler (10.9%) and negative for both the Hereford (2.9%) and the Afrikaner (8.0%). These values were all significant ($P \leq 0.01$) and the Hereford direct additive effects exceeded those of the Afrikaner. Chapters 3, 4 and 5 illustrated that the direct breeding values for BW declined with an increase in Afrikaner, Hereford and Simmentaler proportion, respectively. Investigations of Cunningham & Magee (1988) showed that the direct additive effect for BW was negative (-0.04 kg) for the Simmentaler, compared to the Hereford breed. Schoeman *et al.* (1993) also obtained a positive direct additive effect (0.74 kg) for the Hereford, compared to the Afrikaner breed.

Simmentalers produced heavier calves than Herefords and Herefords produced heavier calves than Afrikaners. These results are in accordance with those of Burns *et al.* (1988), Schoeman *et al.*

Table 2.3. Observed LS Means (± SE) and predicted LS Means of BW and WW for breed groups

Breed group[1]	Observed Traits (kg)		Predicted Traits (kg)	
	BW	WW	BW	WW
Pure breeds	31.6*	177.0*	32.0*	174.9*
H x H	31.9 ± 0.51	170.3 ± 3.06	31.8	169.1
A x A[2]	29.3 ± 0.75	155.2 ± 4.51	29.3	155.2
S x S	33.7 ± 0.99	205.4 ± 5.96	34.5	200.3
F_1	34.4*	185.9*	34.2*	188.1*
S x A	35.7 ± 0.54	192.2 ± 3.28	35.6	191.1
S x H	35.8 ± 0.51	191.7 ± 3.09	35.2	188.6
H x A	32.4 ± 0.71	178.3 ± 4.66	32.6	180.4
H x S	33.7 ± 1.00	181.4 ± 6.04	33.4	192.2
Two-breed backcrosses	30.6*	185.7*	33.4*	185.0*
H x (1/2A 1/2H)	32.8 ± 0.55	180.2 ± 3.35	32.2	175.8
H x (1/2H 1/2S)	33.6 ± 0.61	185.8 ± 3.70	33.3	182.2
S x (1/2A 1/2S)	35.2 ± 0.61	194.3 ± 3.67	34.8	193.4
S x (1/2H 1/2S)	35.7 ± 0.56	195.5 ± 3.41	35.6	196.0
A x (1/2H 1/2A)[2]	29.9 ± 0.60	171.6 ± 3.53	29.9	171.6
H x (1/4A 3/4H)	31.6 ± 0.80	166.3 ± 4.81	32.0	172.5
H x (1/4S 3/4H)	32.6 ± 1.07	173.1 ± 6.44	32.6	175.7
S x (1/4A 3/4S)	34.2 ± 0.99	194.3 ± 5.97	34.7	196.9
S x (1/4H 3/4S)	35.8 ± 0.73	199.9 ± 4.41	35.1	198.1
H x (1/4H 3/4S)	33.7 ± 0.97	196.1 ± 4.89	33.4	187.2
Three-breed crosses	34.0*	186.6*	34.1*	188.7*
H x (1/2A 1/2S)	32.8 ± 0.55	185.9 ± 4.10	32.8	184.1
S x (1/2A 1/2H)	35.5 ± 0.48	191.6 ± 2.88	35.3	190.9
H x (1/4A 3/4S)	33.1 ± 0.81	191.2 ± 5.83	33.1	188.1
S x (1/4A 3/4H)	33.1 ± 0.77	181.3 ± 4.63	35.3	189.7
S x (1/4A 1/2H 1/4S)	34.9 ± 1.16	189.2 ± 7.00	35.5	193.4
S x (1/4A 1/4H 1/2S)	35.1 ± 0.49	194.2 ± 2.94	35.2	194.7
S x (1/8A 1/8H 3/4S)	34.6 ± 0.62	195.4 ± 3.74	34.9	197.5
H x (1/8A 5/8H 1/4S)	31.8 ± 0.78	168.7 ± 4.74	32.7	177.3
H x (1/8A 1/8H 3/4S)	33.3 ± 0.57	187.4 ± 3.42	33.2	187.8
H x (1/4A 1/4H 1/2S)	32.6 ± 0.54	181.0 ± 3.26	33.0	183.1

[1]Breed of sire is identified by first symbol in crosses.   *Mean values

[2]"Dummy" breed groups.

(1993) and Schoeman (1996).

2.3.2.2 Weaning weight

The direct additive contributions for WW were positive for Simmentaler (12.2%) and negative for both the Hereford (3.9%) and the Afrikaner (8.3%). These values were all significant (P ≤ 0.01) and the Hereford direct additive effects exceeded those of the Afrikaner. The high direct additive effects of the Simmentaler indicate that using this breed as one parent in a crossbreeding system involving Hereford and Afrikaner will increase both BW and WW.

In the investigation carried out by Schoeman *et al.* (1993) at the Mara Research Station, the Hereford's additive contribution was small positive (4.1%) and that of the Simmentaler large positive (21.9%) when compared to the Afrikaner. MacNeil *et al.* (1982) obtained negative estimates of direct breed effects for Hereford (-19.0 kg) and Angus (-12.2 kg), but positive estimates for Charolais (12.4 kg) and Simmentaler (14.6 kg). Calves of Simmentalers were heavier at weaning than calves of Herefords while Herefords produced heavier calves than Afrikaners in this study. These results are in accordance with those of Cunningham & Magee (1988), Schoeman (1989, 1996) and Schoeman *et al.* (1993). The direct breeding values for WW in Chapters 3, 4 and 5 showed a linear decline with an increase in Afrikaner, Hereford and Simmentaler proportion, respectively. Average weaning weights of Hereford and Simmentaler cattle taking part in the National Beef Cattle Performance Testing Scheme (Schoeman, 1996) were 24.7 kg (or 14.5%) and 30.6 kg (or 14.9%) heavier, respectively, than the observed LS Means of the purebred Hereford and Simmentaler in this herd, possibly indicating a relative unfavourable environment in which the herd is managed. In the Vaalhartz crossbreeding project (Els, 1988) it was also shown that the average WW of Simmentaler and Hereford were 15 kg (or 7.3%) and 30 kg (or 17.6%) heavier, respectively, than in this herd. Likewise, mean WW of both Simmentaler and Hereford were on average 36.5 kg (or 17.8%) and 34.6 kg (or 20.3%) heavier, respectively, in the Mara crossbreeding project (Schoeman *et al.*, 1993), also supporting this conclusion. The relatively intensive unfavourable environment may be due to high stocking rates in the herd, thus leading to overgrazing and limited feed availability.

2.3.3 Breed maternal effects

The breed maternal effects are the environmental influences the dam has on her offspring's performance, but it depends on the genotype of the dam and its associated environmental effects (Koch, 1972; Baker, 1980; Schoeman *et al.*, 1993). It therefore quantifies the maternal ability of the

dam, which is for WW, mostly a reflection of the dam's milk production. Direct maternal effects were significant in 4 of the 6 estimates obtained (Table 2.4).

2.3.3.1 Birth weight

For BW, the breed maternal effect was positive (8.3%) and significant ($P \leq 0.01$) for the Afrikaner, but negative (7.2%) and significant ($P \leq 0.01$) for the Simmentaler. Calving difficulties when crossbreeding with Simmentaler is therefore most likely the result of the positive direct effect on BW.

The high positive Afrikaner maternal direct effect contradicts reports that seem to indicate that Sanga and Zebu type dams restrict the BW of their calves (Roberson *et al.*, 1986; Comerford *et al.*, 1987; Tawonezvi *et al.*, 1988; Scholtz *et al.*, 1990; Van Zyl *et al.*, 1992; Franke, 1994), even when mated to late maturing *Bos taurus* sires with a positive additive effect on BW (Alenda *et al.*, 1980) by way of a large negative maternal effect (Roberson *et al.*, 1986).

The direct maternal effect for the Hereford was positive in some investigations (Alenda *et al.*, 1980; Dillard *et al.*, 1980; Cunningham & Magee, 1988; Schoeman *et al.*, 1993; Arthur *et al.*, 1994; Franke, 1994), while it was negative in others (Gregory *et al.*, 1978), depending on the breeds it was compared to. The maternal breeding values for BW declined linearly with an increase in Hereford proportion (Chapter 4) and increased linearly with an increase in Simmentaler proportion (Chapter 5) in later generations of the same population. Schoeman *et al.* (1993) also obtained a negative direct maternal effect for the Simmentaler while Cunningham & Magee (1988) obtained positive direct maternal effects for the Simmentaler.

2.3.3.2 Weaning weight

For WW, the direct maternal effect was negative (2.8%) and significant ($P \leq 0.05$) for the Hereford, and positive (4.7%) and significant ($P \leq 0.01$) for the Afrikaner. The direct maternal effect for the Simmentaler was non-significant ($P \geq 0.05$).

The direct maternal effect for the Hereford was positive in some investigations (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), depending on the breeds it was compared with. In Chapter 4 the maternal breeding value decreased linearly with an increase in proportion of Hereford. It is also known that the Hereford is a low milk

producing breed (Jenkins & Ferrell, 1992). Meyer (1992a) and Schoeman *et al.* (1993) associated the low WW in Hereford dams to the low milk production of the Hereford dam. Other investigations (Van Zyl, 1990; Schoeman *et al.*, 1993) also suggested that Afrikaner dams were superior in terms of milk production to Hereford dams. The maternal breeding value for the Afrikaner on WW in Chapter 3, on a subset of the same dataset, was not influenced by proportion of Afrikaner. Bonsma (1949) reported that where climatic conditions have a restrictive effect upon milk production, the Afrikaner produces more milk than *Bos taurus* breeds.

Contrary to the results obtained in this study, both Cunningham & Magee (1988) and Schoeman *et al.* (1993) obtained high positive direct maternal effects for the Simmentaler. Being a dual-purpose breed it is known that Simmentaler dams are superior in milk production compared to Hereford dams (Cunningham & Magee, 1988; Jenkins & Ferrell, 1992; Schoeman *et al.*, 1993). In analysing part of the same dataset, Chapter 5 illustrated that the maternal breeding values for WW increased linearly with an increase in Simmentaler proportion in later generations.

Arthur *et al.* (1994) evaluated Brahman and Hereford cattle and their crosses on high, medium and low quality pastures and found that the Brahman maternal additive effect, compared to the Hereford, was negative on the high and medium quality pastures, and highly positive and significant in the low quality pastures. This clearly illustrated the re-ranking of breeds for crossbreeding parameters in differing environments. Likewise, the positive maternal additive effect of Afrikaner and the non-significant effect of Simmentaler on WW of calves in this study may be an indication of a relatively unfavourable nutritional environment in this herd. High stocking rates with high nutritional requirements of the Simmentaler may partly explain the reason for the high positive maternal effects of the Afrikaner *versus* the non-significant direct maternal effect of the Simmentaler and the contradiction with other studies (Schoeman *et al.*, 1993). The Afrikaner should therefore be considered as an appropriate dam line for this specific environment in crossbreeding.

2.3.4 Individual heterotic effects

2.3.4.1 Birth weight

Individual heterotic effects for BW were significant ($P \leq 0.01$) in H x S and S x A only (Table 2.4). The individual heterosis contributions for H x S and S x A were 3.5 and 11.0%, respectively. Schoeman *et al.* (1993) obtained a larger and significant heterosis component for the H x A (5.3%) cross, while in the H x S (1.6%) and S x A (0.05%) crosses it was non-significant. In beef cattle

direct heterosis effects generally range from 1 to 11% for BW, with values for *Bos indicus* x *Bos taurus* at the upper end of the scale (Long, 1980; Cundiff *et al.*, 1986; Arthur *et al.*, 1999). The percentage heterosis obtained in this study is thus within the range of reported literature values. Franke (1994) reported in a study from crosses among Angus, Brahman, Charolais and Hereford breeds that the direct heterotic effect from Brahman combinations for BW increased over other breed combinations.

2.3.4.2 Weaning weight

Individual heterotic effects for WW were all significant ($P \leq 0.05; P \leq 0.01$) (Table 2.4). The heterosis contributions for H x A, H x S and S x A were 9.8, 3.1 and 6.7%, respectively. The heterotic effects obtained by Schoeman *et al.* (1993) were also significant ($P \leq 0.01$) for all three breed combinations and were 11.0% for H x S, 10.1% for H x A, and only 3.1% for S x A. In beef cattle, direct heterosis effects generally range from 3 to 16% for WW, with values for *Bos indicus* x *Bos taurus* at the upper end of the scale (Long, 1980; Cundiff *et al.*, 1986; Arthur *et al.*, 1999). The percentage heterosis obtained in this study is thus within the range of reported literature values. Large heterotic effects are thought to be due to the extreme diversity in the development of *Bos indicus* and *Bos taurus* breeds (Roberson *et al.*, 1986). Franke (1994) reported, from crosses made between Angus, Brahman, Charolais and Hereford breeds, that the direct heterotic effect from Brahman combinations for WW increased over other breed combinations. A comparative study by Hetzel (1988) reported that crosses between indigenous breeds and exotic *Bos taurus* or Brahman did not improve maternal performance above the most productive indigenous breeds. However, the growth rate of progeny was increased. Thus, crossbreeding programmes using the superior indigenous breeds as dams and exotic *Bos taurus* as terminal sire breeds are recommended where controlled mating is feasible. In this study, the H x A and S x A combinations seem to be more favourable than the H x S combination, supporting previous evidence that more heterosis is generated when crossing large exotic sires to indigenous dams.

2.3.5 Maternal heterotic effects

Maternal heterotic effects refer to the heterosis in a population attributable to using crossbred dams instead of purebred dams (increased milk production, improved prenatal environment and fertility). This effect is probably the result of increased environmental advantage of the progeny from crossbred dams because of the increased milk production and prenatal environment provided by the crossbred cow (McDonald & Turner, 1972; Sheridan, 1981; Schoeman *et al.*, 1993). In most studies these estimates are positive which indicates that calves of crossbred dams have a better

maternal environment to express their growth potential (Arthur *et al.*, 1999).

2.3.5.1 Birth weight

Maternal heterotic effects for BW were non-significant (P ≥ 0.05) for all of the 3 estimates (Table 2.4). McDonald & Turner (1972) reported that non-significant or negative maternal heterosis for BW reflects an advantage of the crossbred dam, especially when mated to sires known to produce large calves at birth. Therefore, crossbred cows in this study did not provide a stronger *in utero* environment effect to increase the probability of dystocia as it is affected by calf birth weight. Studies of McDonald & Turner (1972), Dillard *et al.* (1980), Sacco *et al.* (1989), Van Zyl (1990) and Arthur *et al.* (1994, 1999) are in general agreement with the existence of non-significant maternal heterotic effects for BW. In most investigations (Cundiff *et al.*, 1974; Roberson *et al.*, 1986; Dearborn *et al.*, 1987; Elzo *et al.*, 1990; Schoeman *et al.*, 1993) significant maternal heterotic effects for BW have been reported.

2.3.5.2 Weaning weight

Maternal heterotic effects for WW were non-significant (P ≥ 0.05) for all of the 3 estimates (Table 2.4). These results are in contrast with estimates obtained by Dillard *et al.* (1980), Peacock *et al.* (1981), Roberson *et al.* (1986), Dearborn *et al.* (1987), Schoeman *et al.* (1993) and Arthur *et al.* (1994) who all reported significant maternal heterosis effects for WW. However, non-significant maternal heterosis effects for WW involving crosses between Hereford and Brahman were also reported by Arthur *et al.* (1999) in a temperate environment. The non-significant values of WW may be also explained by a possible unfavourable environment where the performance of the crossbred dam could not be expressed to its full potential. Lamb *et al.* (1992) reported that purebred dams require less energy than crossbred cows and thus a reduction in performance (milk production) may be expected when energy availability is limited. According to Schoeman (1999) a high level of nutrition and management is sometimes needed before the higher potential in crossbred cows can be fully utilised.

Investigations of Peacock *et al.* (1981) showed (although the values obtained were much higher and significant) that the maternal heterotic effect was the largest for Angus-Brahman, intermediate for the Charolais-Brahman and lowest for the Angus-Charolais crosses. It confirms the theoretical expectation of greater heterosis in more genetic diverse breed types (especially for *Bos taurus* x *Bos indicus*) (Cundiff *et al.*, 1974; Koger *et al.*, 1975; Moyo *et al.*, 1996). Although not significant, this tendency was also present in this study.

Table 2.4. Crossbreeding component estimates (± SD) for BW and WW

	Traits (kg)	
Component	BW	WW
General mean	33.20 ± 0.24**	181.08 ± 0.08**
Additive genetic		
Hereford (H)	-0.96 ± 0.29**	-7.05 ± 1.77**
Afrikaner (A)	-2.65 ± 0.41**	-15.04 ± 2.46**
Simmentaler (S)	3.61 ± 0.32**	22.09 ± 1.99**
Individual heterosis		
H x A	1.35 ± 0.72	17.82 ± 4.48**
H x S	1.16 ± 0.45**	5.65 ± 2.71*
S x A	3.62 ± 0.62**	12.07 ± 3.75**
Maternal additive		
Hereford	-0.35 ± 0.35	-5.16 ± 2.17*
Afrikaner	2.75 ± 0.53**	8.44 ± 3.20**
Simmentaler	-2.40 ± 0.38**	-3.28 ± 2.31
Maternal heterosis		
H x A	0.40 ± 0.39	3.75 ± 2.37
H x S	-0.30 ± 0.45	0.31 ± 2.74
S x A	-0.51 ± 0.43	2.06 ± 2.80

* $P \leq 0.05$, **$P \leq 0.01$

2.4 Conclusions

The means of all crossbred types exceeded those of the purebred means, except the purebred Simmentalers which had the highest WW and thus were the highest weaner producers. Within the crossbred groups, those having high Simmentaler proportions, were also the highest producers. Due to the high positive breed additive contributions for WW of Simmentaler (12.2%) and the high LS Means for WW of 205.4 kg, purebred Simmentaler breeding seems to be the best breeding practice for this environment. The breed maternal effects of the Afrikaner was in this study superior to the exotic *Bos taurus* breeds within this specific environment, suggesting a possible genotype x environmental interaction when compared to other environments. In this study the H x A and S x A combinations seem to be more favourable than the H x S combination, supporting previous evidence that more heterosis is generated when crossing large exotic sires to indigenous dams. It

might furthermore be suggested that crossbred dams did not provide the expected maternal superiority and thus a higher nutritional level and improved management is possibly needed in this herd to utilise the higher potential of crossbred dams and to utilise crossbreeding to its full potential. The re-ranking of crossbred mating types and genotypes *versus* purebreds might occur if other traits *e.g.* fertility, cow efficiency, total weaning weight of calves weaned etc., thus composite traits, were included in this investigation.

CHAPTER 3
THE AFRIKANER

3.1 Introduction

The Afrikaner is a native beef breed of the Republic of South Africa that has been developed over many years. This breed originated from cattle owned by the Hottentots and was initially developed as draft animals by the Dutch settlers but were subsequently developed as a beef breed which is used in either straight or crossbreeding (Payne, 1973). In 1998 the Afrikaner Breed Society membership was 114 with 10518 registered females (Hofmeyer, 1999).

According to the literature, *Bos taurus* cattle have a submetacentric Y chromosome and *Bos indicus* has an acrocentric Y chromosome. The Afrikaner was initially classified as *Bos indicus* because of its morphological characteristics, but the presence of a submetacentric Y chromosome was confirmed in the Afrikaner, Drakensberger, Bonsmara and Nguni, and suggested a more accurately classification as *Bos taurus africanus* (Meyer, 1984; Stranzinger *et al.*, 1987). The Afrikaner was used to develop the Bonsmara ($^5/_8$ Afrikaner, $^3/_{16}$ Shorthorn, $^3/_{16}$ Hereford), Sanganer (½ Afrikaner x ½ Nguni), Huguenot (Afrikaner x Charolais) and Afrigus (Afrikaner x Angus) and contributed to the development of the Drakensberger in South Africa (Payne, 1973; Payne & Hodges, 1997; Anon, 1999). The Belmont Red (½ Afrikaner, $^1/_4$ Hereford, $^1/_4$ Shorthorn) was developed in Australia (Seifert & Rudder, 1984; Payne & Hodges, 1997).

Animals which are adapted to subtropical climatic conditions are endowed with resistance against intense radiation, high temperatures, parasites, they can make the most efficient use of the variable feed conditions typical of the semi-arid tropics and can be economically productive under these conditions (Bonsma, 1949). Bonsma (1944) demonstrated that Afrikaner cattle and Afrikaner x exotic breed crosses were more resistant to *Amblyomma hebraeum* and heartwater than imported exotic breeds. In a mixed population of Afrikaner, Afrikaner x exotic breed and exotic breeds, 21.8% of the total number of ticks counted through naturally infestation, were found on the purebred Afrikaner, while 27.5% of the total number of ticks counted were found on the Afrikaner x exotic breed crosses and 50.7% of the total number of ticks counted were found on the exotic breeds. The smooth coat and skin thickness apparently play an important role in the tick-repellent capacity of the Afrikaner. Afrikaner cattle have a yellow or red coat with a dark hide which is an

ideal combination to render an animal resistance to the temperature and intense radiation of the heat and short-wave rays. Other characteristics of the Afrikaner are that they are well adapted to extensive conditions. They have low maintenance requirements owing to their smaller size – 100 Afrikaner cows with calves can thrive on the same pasture area as 80 large framed cows with calves. They have a quiet temperament with good meat quality traits and can be early marketed off the veld and in feedlots (Studbook, anonymous).

Over many years the Afrikaner has become popular in crossbreeding systems and composite breed development. Despite this, there is still a lack of scientific evidence of the role of the Afrikaner in various production environments. The objective of this study was to determine the effect of different levels of Afrikaner breeding in a multibreed beef cattle herd in a relatively intensive but high stocking rate environment and to obtain the desired proportion of Afrikaner for preweaning traits therein. Data form this herd is also compared to crossbreeding results of the Mara crossbreeding project, Vaalhartz project and Neudamm project.

3.2 Material and Methods

3.2.1 Data

Data was obtained from a large (approximately 2500-3000 breeding females) multibreed composite beef cattle herd of the Johannesburg Metropolitan Council and consisted of 52628 calf birth and weaning weight records collected from 1968 to 1993. The herd is kept on two different farms on an intensive management system (Paterson, 1978, 1981; Paterson *et al.*, 1980; MacGregor, 1997). Females were all artificially inseminated using the same sires across the farms.

Breed development started in 1962 with the first initial crosses and was terminated in 1981. Other breeds were also included in 1982 to a small degree. Schoeman & Jordaan (1998) in an earlier paper as well as Chapter 5 described the breeds used in this crossbreeding project. The number of sires used was 362 with an average of 199 calves per sire which varied from 1 to 1612 per sire. The number of dam weight records was 6239 and was only recorded since 1989. The number of dams with calf weaning weights recorded was 15539, with an average of 3.4 calves per dam that varied from 1 to 14 calves. Afrikaner sire contribution and Afrikaner dam contribution (excluding all zero Afrikaner proportions) are presented in Table 3.1 and Table 3.2, respectively. Purebred Afrikaner sires were only used in 1969, 1972, 1973 and 1976. It should be noted from Table 3.2 that no

Table 3.1 The number of sires with Afrikaner contribution (pure and crossbred) used per year per varying level of Afrikaner proportion

Proportion of Afrikaner in Sires

																		Year									
	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	Total
0.008																				1				1			2
0.016																				1	1		2	3	1		8
0.031													1	1	2	1	1	3	2	4	4	4	3	5	6	2	39
0.047																	1				2	1		3			7
0.063										2	2	2	4	1	5	2	5	6	5	2	3	6	4	4	4	2	59
0.070																					1		1	2			4
0.078																	1				2	1		1	2		7
0.086																							1			1	2
0.094																1		1			1	1	1	1	2	2	10
0.125							2	2	2	2	6	4	5	2	1	3	5	3	6	1	1	4			3	2	54
0.141																	1			1							2
0.156															1			1		1							3
0.188												1					2				2			1			6
0.250					1	2	4	6	2	7	5	2		1	3	2											35
0.313									1																		1
0.375																1											1
0.500							1	1	2				1														5
1.000		2			2	1			2																		7
		2			3	3	7	9	9	11	13	9	11	6	11	10	15	15	13	14	14	17	13	20	18	9	252

Table 3.2. The number of dams calved, with Afrikaner contribution per varying level of Afrikaner proportion per year

Proportion of Afrikaner in Dam

	Year																										Total
	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	
0.008																				2	1	2	5		5	8	23
0.023																			1	1		1	5	1	2	1	12
0.039																			4	10	2	2	3	1	1	1	24
0.055																			1		3	2	2	2	1	2	13
0.063							2	4	40	61	90	130	161	153	331	352	271	273	292	327	232	192	139	102	94	54	3300
0.070																			7	8	1	7	2	10	5	11	51
0.078															1	12	10	20	23	47	40	29	26	24	23	18	273
0.086																					1			1			2
0.094													7	6	43	44	32	43	82	95	56	56	43	27	22	13	569
0.102																		1	8	9	3	5	2	2	1	2	33
0.109																		1	9	10	8	12	9	8	10	5	72
0.125					33	59	136	184	274	337	325	425	436	405	409	375	282	230	238	211	158	119	97	78	25	19	4855
0.133																			2	1		3	1	1		1	9
0.141										1					1	3	4	7	9	11	4	7	4	5	5	4	65
0.156												1	8	8	17	19	11	14	27	33	9	11	7	6	7	1	179
0.164																										1	1
0.188									2	6	8	22	33	24	39	38	28	31	28	27	16	14	7	4	5	1	333
0.203																		1	2	2		2	1			1	9
0.250		10	212	343	447	581	555	541	512	472	393	380	315	273	158	160	118	77	65	52	46	67	37	55	14	1	5884
0.281													2	1	5	4	4	4	3								23
0.297																		1									1
0.313									6	6	2	3	6	5	11	10	6	7	6	5		1	1	1	1	1	78
0.328															1				1	1	1				1		5
0.344															1				1								2
0.375						1	2	2	3	11	16	14	8	6	5	4	3	2	3	2		1	1	1	1	1	87
0.406															2	1	1		1	1	1	1					8
0.500	874	942	742	558	557	482	360	255	161	110	91	66	36	29	18	8	4	2	1			4	4	5	3		5312
0.531											1	1	1	1	1	1	1		1								8
0.563											2	1															3
0.625							1	5	4	3	2	3	1	1	1												21
0.750					1			1	1																		3
	874	952	954	901	1038	1123	1056	992	1003	1006	930	1047	1014	912	1044	1031	776	715	814	855	585	538	397	332	223	146	21258

purebred Afrikaner dams were used. Maximum Afrikaner proportion in the dams was only 75% ($^3/_4$ Afrikaner) of which only three were available. Dam ages ranged from 2 to 16 years. Due to the small number of cows older than 10 years, they were pooled with the 10-year-old group. The number of animals in the pedigree file was 57078.

Birth weight (BW) and weaning weight (WW) of the calf and dam weight at the time of weaning of her calf (DW) were recorded. From WW and DW cow efficiency indices (CE) (WW/CW$^{0.75}$ x 100) were calculated.

Heifer calves were inseminated to calve for the first time at approximately two years of age. The majority of calves were born during June to September (winter), while the rest were born during December through March (summer). Season of birth was thus recorded as summer or winter born. Calves were weighted after birth and at weaning at approximately 210 days of age.

The proportion of Afrikaner, with the individual contribution of other breeds ignored, was fitted to the models. Due to the small number of observations in some groups, certain groups were pooled together (e.g. $^7/_{16}$ to $^9/_{16}$ were pooled with ½ Afrikaner). There were 15 genetic groups with varying proportion of Afrikaner. The total number of calves recorded per proportion of Afrikaner is presented in Table 3.3 for BW and WW and in Table 3.4 for CE. The majority of calves for BW and WW therefore were either $^1/_4$, $^1/_8$, $^1/_{16}$,$^1/_{32}$,$^3/_{32}$ or $^1/_{64}$ of Afrikaner contribution. Large numbers of records for CE were available for $^1/_{64}$, $^3/_{32}$ or $^1/_{32}$ of Afrikaner contribution while the rest had only a few records.

Table 3.3. The total number of calves (n) recorded per level of Afrikaner proportion (%) for BW and WW

	Proportion of Afrikaner (%)														
	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
n	2289	4954	6493	1707	6347	530	565	95	5533	163	159	718	13	36	12

Table 3.4. The total number of calves (n) recorded per level of Afrikaner proportion (%) for CE

	Proportion of Afrikaner (%)									
	1.6	3.1	6.3	9.4	12.5	15.6	18.8	21.9	25	31.3
n	1258	1706	1282	409	224	79	13	1	15	3

3.2.2 Statistical Analysis

Data was 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
$\mathbf{b}$	=	a vector of fixed effects
X	=	a known incidence matrix relating observations to the fixed effects
Z_1 and 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 unitrait models were fitted to the data. These models accounted for direct 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 model fitted to each trait and trait means are presented in Table 3.5.

Table 3.5. Statistical models for unitrait analyses of birth weight (BW) and weaning weight (WW) of the calf and cow efficiency (CE) calculated as WW/cow weight$^{0.75}$ at calf weaning x 100

Effects	Type	Number of levels	Traits BW	Traits WW	Traits CE
Year	Fixed	26(6)	X	X	X
Farm	Fixed	2(2)	X	X	X
Afrikaner proportion	Fixed	16(11)	X	X	X
Sex of calf	Fixed	3(3)	X	X	X
Season of birth	Fixed	2(2)	X	X	X
Dam age	Covariate	1(1)	X	X	X
Weaning age of calf	Covariate	1(1)		X	X
Maternal	Animal	57078(57078)	X	X	X
Animal	Animal	57078(57078)	X	X	X
Means ± SD			35.5 ± 5.2	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 Afrikaner breeding. Similarly, Best Linear Unbiased Estimates (BLUE) for each trait was also estimated and regressed on proportion of Afrikaner breeding. Linear regressions were fitted, excluding those animals with no Afrikaner contribution.

3.3 Results and Discussion

3.3.1 Variation in breed composition of the herd

The Afrikaner contribution to the calves born between 1989 and 1993 was only 4.3%. Individual contributions of the other breeds were reported in Chapter 5. The composition of individual calves born varied from 0 to 75% Afrikaner. The proportion of Afrikaner contribution per year of calves born and Afrikaner proportion variance are presented in Figure 3.1. The contribution of Afrikaner decreased from 1968 to 1993. Of the calves born in 1969, 1972 and 1974 the contribution of Afrikaner showed increases due to the use of sires with high Afrikaner composition of 37.5, 50 and 100%. The breed proportion variance declined from 1968 to 1988 and was stable and low between 1988 to 1993. Equilibrium is not reached at this point in time since both parents and calf did not have the same proportion of Afrikaner genes yet.
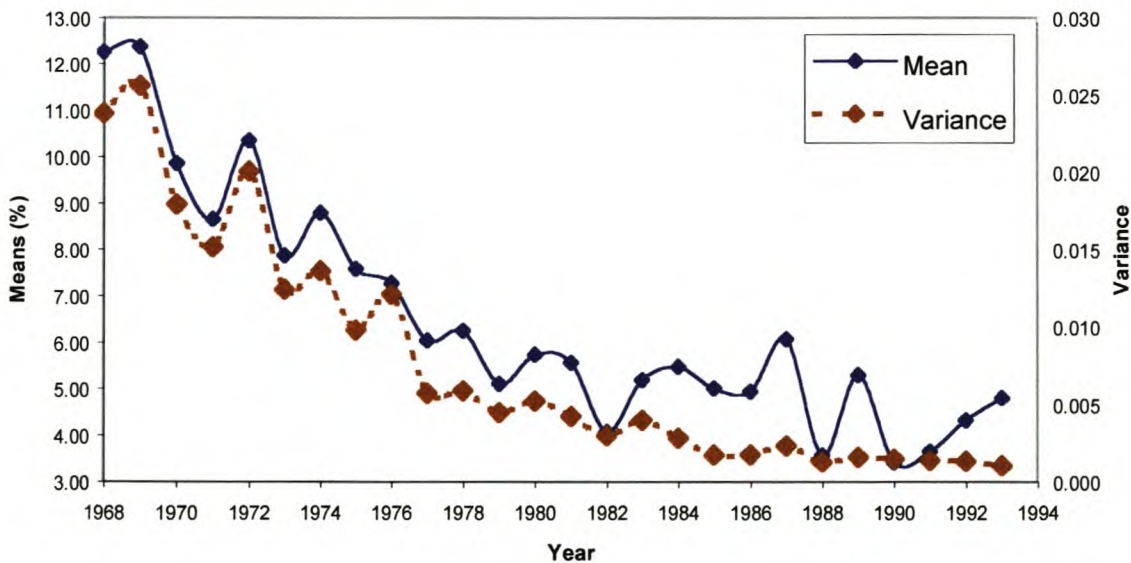
Figure 3.1 Changes in mean Afrikaner contribution (%) and variance in proportion of Afrikaner per year.

3.3.2 Birth weight

Direct heritability for BW ($h^2_a = 0.67$) as is presented in Table 3.6 is considerably higher than those reported by Mohiuddin (1993), Koots *et al.* (1994a) and Mostert *et al.* (1998). Both Mackinnon *et al.* (1991) and Tawah *et al.* (1993) reported (Table 3.6) direct heritabilities for BW which correspond closely to those obtained in this study. The direct heritability for BW was larger than the maternal heritability. This trend is common in beef cattle and is verified in Table 3.6. The negative correlation ($r_{am} = -0.35$) is in agreement with the mean values in the reviews of Mohiuddin (1993) and Koots *et al.* (1994b). Reasons for the fairly high heritability and the high negative genetic correlation between maternal and direct effects will be discussed in more detail in Chapter 4.

Table 3.6. Published estimates of heritabilities and correlations for beef cattle

BW			WW			Breeds	References
h^2_a	h^2_m	r_{am}	h^2_a	h^2_m	r_{am}		
0.61	0.11	0.01	0.20	0.32	0.00	AX, AXBX	Mackinnon *et al.* (1991)
0.30	0.10	-0.35	0.22	0.13	-0.15	various	Mohiuddin (1993)*
0.65	0.22	-0.93	0.29	0.27	-0.39	composite	Tawah *et al.* (1993)
0.31	0.14	-0.35	0.24	0.13	-0.16	various	Koots *et al.* (1994a; 1994b)*
0.55	0.08	0.14	0.37	0.06	0.13	composite	Bennett & Gregory (1996)
0.52	0.07	-0.57	0.23	0.13	-0.26	Afrikaner	Groeneveld *et al.* (1998)
0.39	0.11	-0.51	0.24	0.13	-0.63	various	Mostert *et al.* (1998)*
0.51	0.09	0.17	0.33	0.13	-0.11	composite	Tosh *et al.* (1999)
0.67	0.22	-0.32	0.53	0.36	-0.52	composite	This study

* mean estimates
AX = 50% Afrikaner, 25% Hereford, 25% Shorthorn
AXBX =25% Brahman, 25% Afrikaner, 25% Hereford, 25% Shorthorn

Regressions of BLUE's and direct and maternal breeding values on proportion of Afrikaner for BW are presented in Figures 3.2 (a to c), respectively. BW was influenced by proportion of Afrikaner (Fig. 3.2a). Both the mean BLUE's (Fig. 3.2a) and the mean maternal breeding values (Fig. 3.2c) decreased linearly between 1.6 to 37.5% Afrikaner proportion and increased linearly between 37.5 to 75% Afrikaner proportion. The mean high BLUE values and mean maternal breeding values between 37.5 to 75% Afrikaner proportion were unexpected. However, in total only 718 (or 2.4%), 13 and 36 of the calves born were 50, 56.3 and 62.5% Afrikaner, respectively. Of those 72% (or 518), 100% (or 13) and 77.8% (or 28) were 50, 56.3 and 62.5% Afrikaner, respectively, combined with differing contributions of Charolais, Brown Swiss and Simmentaler. Thus, the high BLUE's and maternal breeding values between 37.5 to 75% Afrikaner proportion may partly be explained by the high contribution of differing proportions of Charolais, Brown Swiss and Simmentaler all of which are relative large breeds compared to the Afrikaner.

Mean direct breeding values (Fig. 3.2b) increased and reached a maximum value at 0.11 proportion of Afrikaner, after which it declined again. The direct breeding value of Afrikaner on BW is important because it can have a mayor influence on calving ease, indicating that less calving difficulties would be expected with an increase in the proportion of Afrikaner. In Chapter 2, when dealing with another subset of the same data, a negative ($P \leq 0.01$) direct additive effect was obtained for the Afrikaner of 8.0% of the mean. Van Zyl (1990) also illustrated the influence of percentage Afrikaner breeding in the calf on BW, where 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 Mara crossbreeding project, Schoeman *et al.* (1993) indicated that the use of the large-framed European Simmentaler as one parent in a crossbreeding system with Afrikaner or Hereford would increase birth weight.

A negative maternal breeding value for BW reflects the potential of the dam or the bull's female progeny to limit the growth of the fetus within her uterus. In analysing part of the same dataset (Chapter 2) when comparing Simmentaler, Hereford and Afrikaner cattle, a significant ($P \leq 0.01$) positive direct maternal effect of 8.3% of the mean was observed for the Afrikaner. Both Mentz (1977) and Els (1988) concluded that the use of Charolais sires on Afrikaner dams lead to extremely high BW and dystocia problems. Due to the increased BW and associated increase in the frequency of dystocia with high proportions of Charolais, Simmentaler and Brown Swiss it is apparent that the choice of a breed for the production of Afrikaner crossbred calves is of utmost importance. Higher levels of Afrikaner in crossbreeding or composite populations are thus recommended in preventing increased calving difficulties.

Various crossbreeding investigations (Mentz, 1977; Els, 1988; Schoeman *et al.*, 1993 and others) were carried out with the Afrikaner as dam combined with different breeds of sires. Mentz (1977) concluded that the sire effect had a large influence on BW. In his study Simmentaler and Hereford sires produced F_1-calves (Table 3.7) which were significant heavier by 10.7% and 6.4%, respectively, than purebred Afrikaners. Hereford x Afrikaner (7.7%) and Simmentaler x Afrikaner (6.9%) calves showed a higher frequency for dystocia than the purebred Afrikaner calves (3.0%). The weighted mean BW of Afrikaner calves in the first three studies carried out by of Mentz (1977), Els (1988) and Schoeman *et al.* (1993) (Tabel 3.7) was 33.2 kg, with those of Hereford x Afrikaner and Simmentaler x Afrikaner calves were on average 5.2% and 9.8%, respectively heavier than Afrikaner calves. Els (1988) compared BW between Bonsmara and Afrikaner dams which were mated to Brahman, Charolais, Hereford and Simmentaler sires and found that the sire effect had a

bigger influence on Afrikaner dams than on Bonsmara dams. Mentz (1977) obtained between Afrikaner dams large variation in calving difficulties of which as high as 19% of first-calving heifers experienced calving difficulties. Els (1988) obtained similar results for first-calving heifers, but only 2.1% of the older Afrikaner cows experienced calving difficulties and concluded that the Afrikaner is a late maturing beef breed. Both Mentz (1977) and Els (1988) found that the calf/dam weight ratio had a large influence on dystocia and that Afrikaner cows that experienced calving difficulties had above average calf/cow weight ratios at birth.
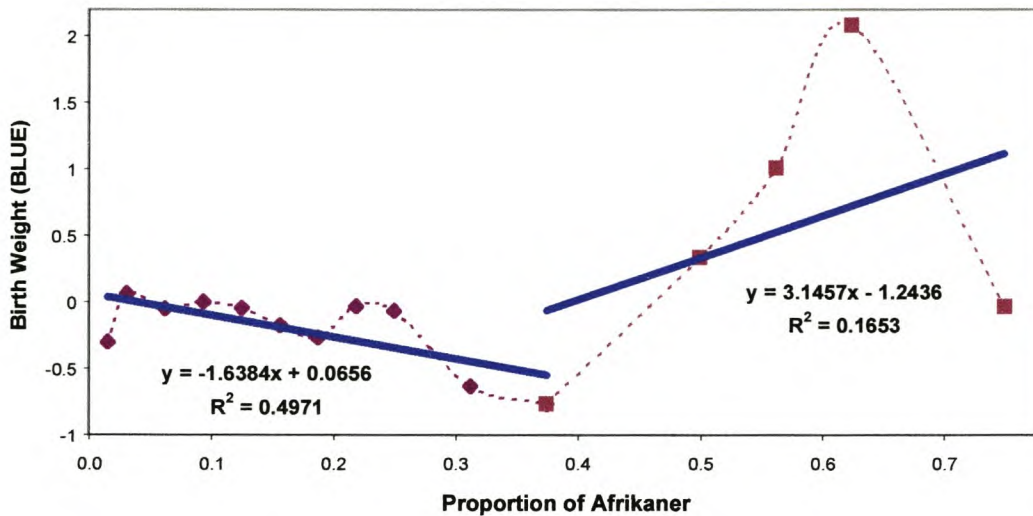
Figure 3.2(a) Regression of BLUE for birth weight on proportion of Afrikaner breeding.
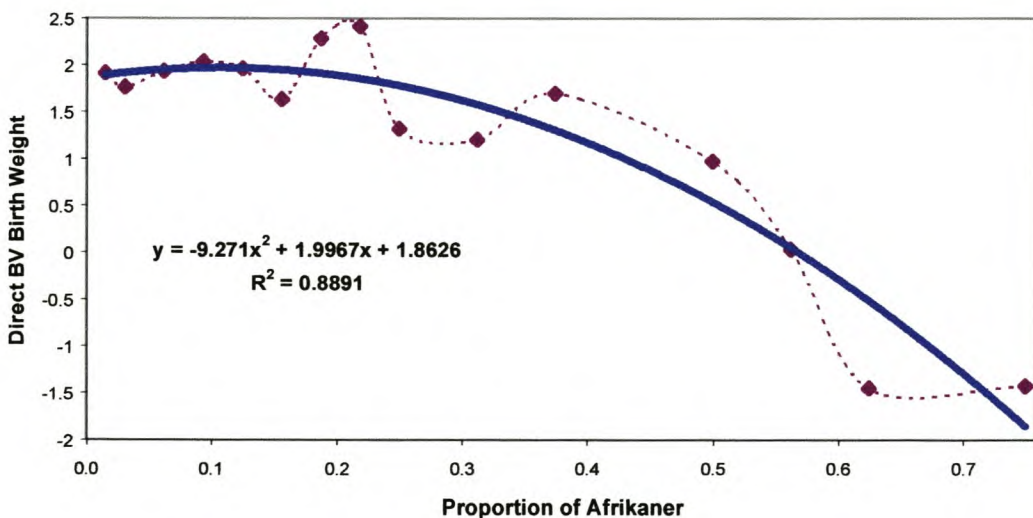
Figure 3.2(b) Regression of direct breeding value for birth weight on proportion of Afrikaner breeding.
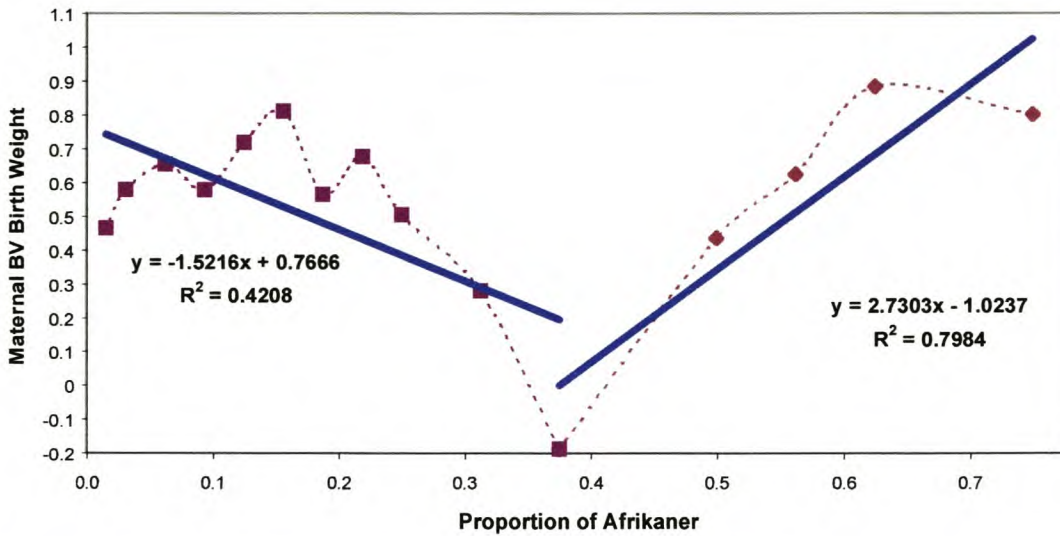
Figure 3.2(c) Regression of maternal breeding value for birth weight on proportion of Afrikaner breeding.

Table 3.7. Published LS-Means of birth weight (BW) in Afrikaner, Afrikaner x Hereford and Afrikaner x Simmentaler crossbred groups

Breed[1]	n	BW	Year	References
A x A	227	32.8	1967-1971	Vaalhartz crossbreeding project
H x A	117	34.9		(Mentz, 1977)
S x A	170	36.3		
A x A	41	34.5	1976-1980	Vaalhartz crossbreeding project
H x A	31	36.7		(Els, 1988)
S x A	32	39.6		
A x A	504	33.3	1972-1984	Mara crossbreeding project
H x A	43	37.5		(Schoeman *et al.*, 1993)
S x A	90	38.2		
S x A	300	35.7	1968-1982	Johannesburg Metropolitan Council
S x H	450	35.8		This study
H x A	63	32.4		
H x S	33	33.7		

A= Afrikaner, H= Hereford, S=Simmentaler

[1] Breed of sire is identified by first symbol in crosses

3.3.3 Weaning weight

The direct heritability for WW (h^2_a = 0.53) was considerably higher than the corresponding estimates reported in Table 3.6. The direct heritability for WW was larger than the maternal heritability (h^2_a = 0.36). This is common in beef cattle for WW. The negative correlation between direct and maternal heritabilities (r_{am} = -0.52) tends to be higher than those reported in Tabel 3.6, except for the mean r_{am} estimate of -0.63 obtained by Mostert *et al.* (1998) for five beef cattle breeds

in South Africa. Reasons for the fairly high heritability and the high negative genetic correlation between maternal and direct effects will be discussed in more detail in Chapter 4.

Regressions of BLUE's and direct and maternal breeding values on proportion of Afrikaner for WW are presented in Figures 3.3 (a to c), respectively. WW was negatively influenced by proportion of Afrikaner (Fig. 3.3a). Both the mean BLUE's (Fig. 3.3a) and mean direct breeding values (Fig. 3.4b) decreased linearly with increasing Afrikaner proportion, while maternal breeding values for WW were not affected by proportion of Afrikaner (Fig. 3.3c).

In Chapter 2 the direct additive effect for WW was also found negative ($P \leq 0.01$) for the Afrikaner and deviate by 8.3% from the mean while the direct maternal effect was significant ($P \leq 0.01$) and positive (4.7%).

Various crossbreeding investigations (Sievers, 1965; Mentz, 1977; Els, 1988; Schoeman *et al.*, 1993 and others) with Simmentaler and Hereford sires mated to Afrikaner dams were carried out in the past. In the investigation carried out by Schoeman *et al.* (1993) at the Mara Research Station, the Simmentaler maternal ability tends to exceed that of both Afrikaner and Hereford, while Afrikaner maternal ability was superior to that of the Hereford for WW. The use of Afrikaner sires depressed WW whereas Simmentaler sires had a pronounced improving effect thereon (Schoeman *et al.* 1993). The study of Sievers (1965) (Tabel 3.8) showed that Hereford crosses were significantly heavier than purebred Afrikaner (11.6%) and Simmentaler crosses (8.1%), respectively. The difference between purebred Afrikaner and Simmentaler crosses was only 5.9 kg and non-significant. It should, however, be noted that in the Neudamm project only one Hereford sire, one Simmentaler sire and four Afrikaner sires were used. The LS Means of WW for S x A and H x A were virtually identical (Tabel 3.8) in the study of Schoeman *et al.* (1993) and also in this study. The weighted mean WW of Afrikaner calves from the first four studies was 186 kg, with those of Hereford x Afrikaner and Simmentaler x Afrikaner calves being 3.3% and 5.6% heavier, respectively. Els (1988) compared WW between Bonsmara and Afrikaner dams which were crossbred to Brahman, Charolais, Hereford and Simmentaler sires, and found that the crossbred calves from Afrikaner dams do not differ much, possibly due to a restricting effect of the Afrikaner as dam breed. Van Zyl *et al.* (1992) illustrated that the optimum percentage of Afrikaner breeding in the crossbred dam which was mated to either Simmentaler or Hereford sires was 37.8% or 50%, respectively. WW increased from purebred Hereford or Simmentaler sires with increasing Afrikaner proportion to 37.5% with the Simmentaler or to 50% with the Hereford, but declined at higher proportions of

Afrikaner breeding suggesting that 37.5 to 50% proportion of Afrikaner in the dams are superior to other contributions.
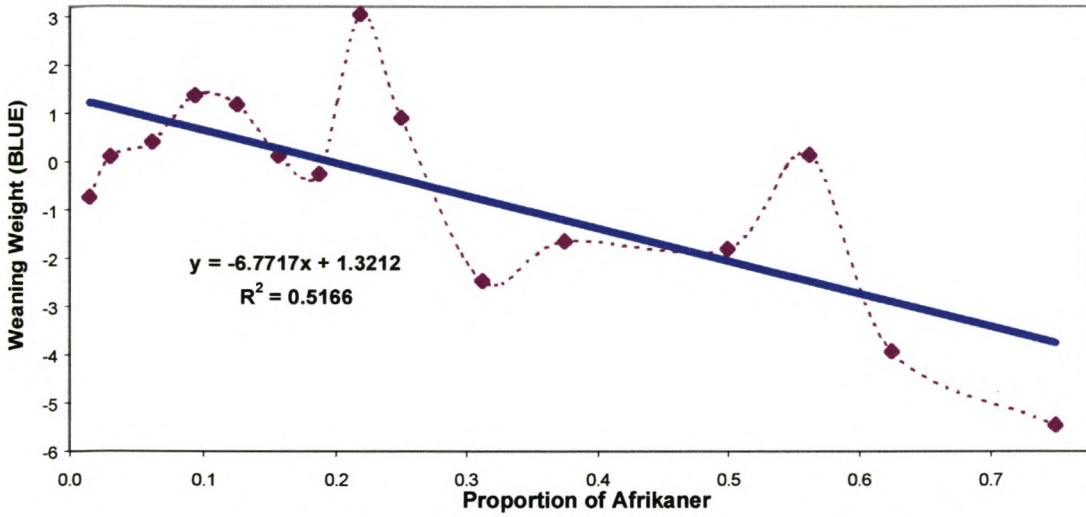

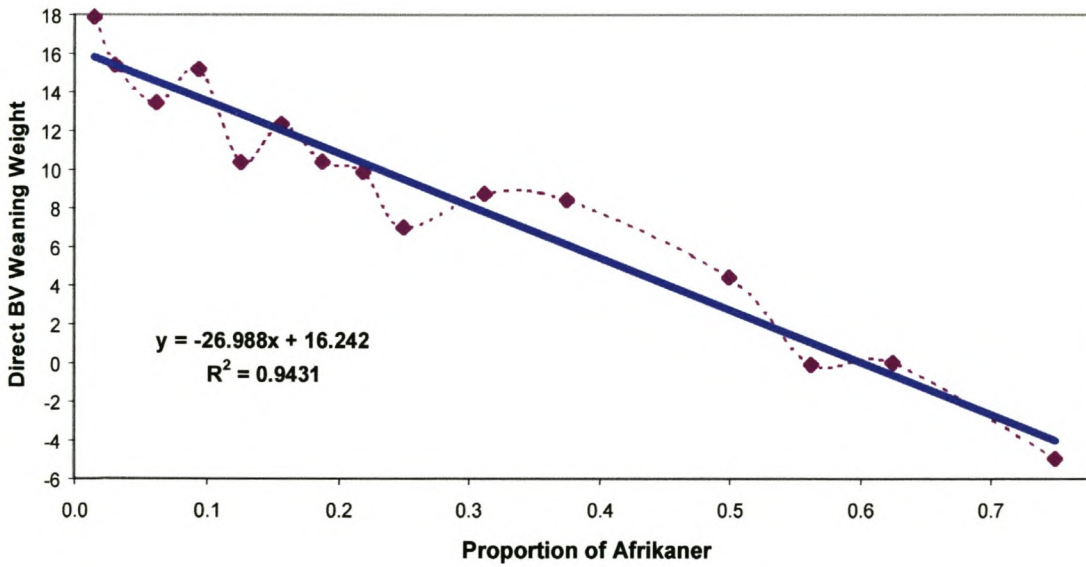**Figure 3.3(a)** Regression of BLUE for weaning weight on proportion of Afrikaner breeding.

Figure 3.3(b) Regression of direct breeding value for weaning weight on proportion of Afrikaner breeding.
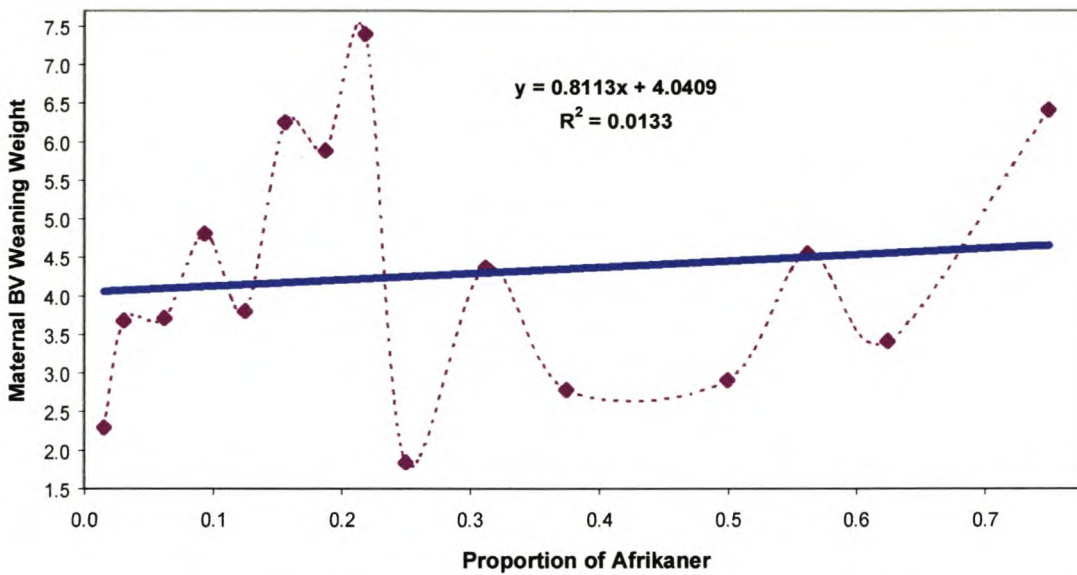
Figure 3.3(c) Regression of maternal breeding value for weaning weight on proportion of Afrikaner breeding.

Table 3.8. Published LS-Means of weaning weight (WW) in Afrikaner, Afrikaner x Hereford and Afrikaner x Simmentaler crossbred groups

Breed[1]	n	WW	Year	References
A x A	58	168.2	1956-1958	Neudamm crossbreeding project*
H x A	71	187.7		(Sievers, 1965)
S x A	60	173.6		
A x A	227	175.5	1967-1971	Vaalhartz crossbreeding project
H x A	117	193.0		(Mentz, 1977)
S x A	170	199.0		
A x A	41	184.0	1976-1980	Vaalhartz crossbreeding project
H x A	31	195.0		(Els, 1988)
S x A	32	209.8		
A x A	504	193.9	1972-1984	Mara crossbreeding project
H x A	43	220.7		(Schoeman *et al.*, 1993)
S x A	90	220.4		
S x A	300	192.2	1968-1982	Johannesburg Metropolitan Council
S x H	450	191.7		This study
H x A	63	178.3		
H x S	33	181.4		

A= Afrikaner, H= Hereford, S=Simmentaler

* WW at 8 months of age

[1] Breed of sire is identified by first symbol in crosses

3.3.4 Cow efficiency

The direct heritability for CE (Tabel 3.9) was considerably lower (h^2_a = 0.19) than the maternal heritability (h^2_m = 0.58). Schoeman & Jordaan (1999) obtained direct heritabilities for CE which

varied from 0.32 to 0.54 on a subset of the same data when analysing the (co)variance components for growth and efficiency traits. The high r_{am} for CE (r_{am} = -0.62) resulted in a low total heritability (h^2_T = 0.12) for CE. No other comparable estimates were found in the literature for this trait.

Table 3.9. Direct additive (h^2_a) and maternal heritability (h^2_m) and genetic correlations between direct and maternal effects (r_{am}) for cow efficiency (CE) of the dam

Trait	Estimates		
	h^2_a	h^2_m	r_{am}
CE	0.19	0.579	-0.619

Regressions of BLUE's and direct and maternal breeding values on proportion of Afrikaner for CE are presented in Figures 3.4 (a to c). Direct breeding values for CE (Fig. 3.4b) increased and reached a maximum value at 0.39 proportion of Afrikaner, after which it declined again. Maternal breeding values for CE (Fig. 3.4c) decreased and reached a minimum value at 0.40 proportion of Afrikaner, after which it increased again. The regression of maternal breeding value on proportion of Afrikaner breeding is almost the reverse of the regression of direct breeding values on proportion of Afrikaner contribution. This phenomenon does most likely not express a true antagonism between direct and maternal breedig values with increasing proportions of Afrikaner, but may be a reflection of the high negative correlation (r_{am} = -0.62) obtained between direct and maternal effects, most likely caused by environmentally induced negative covariances as was suggested by Meyer (1992b). BLUE's for CE between 1.6% and 31.3% Afrikaner proportion were not affected by proportion of Afrikaner (Fig. 3.4a). This may be owing to the positive direct and negative maternal breeding values which cancels each other. The low values at 0.22 and high value at 0.25 proportion of Afrikaner were most likely the result of a small number of observations in these two categories (1 and 15, respectively). The increase in direct breeding values for CE up to 0.39 proportion of Afrikaner, 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 also be noted that the number of observations for CE was much less than for WW (Tables 3.3 and 3.4).

Both Mentz (1977) and Els (1988) investigated differences in WW ratio (calf WW/cow weight after calving) as a measure of efficiency. Mentz (1977) showed that purebred Afrikaners and Hereford crossbred cows were the least efficient, while Els (1988) found them to be superior. The poorer performances reported by Mentz (1977) may be due to the inclusion of first-calving heifers. Cows

with 50% or more Simmentaler breeding (Mentz, 1977; Els, 1988) and cows with 50% or more Afrikaner breeding (Els, 1988) had the highest WW ratios.
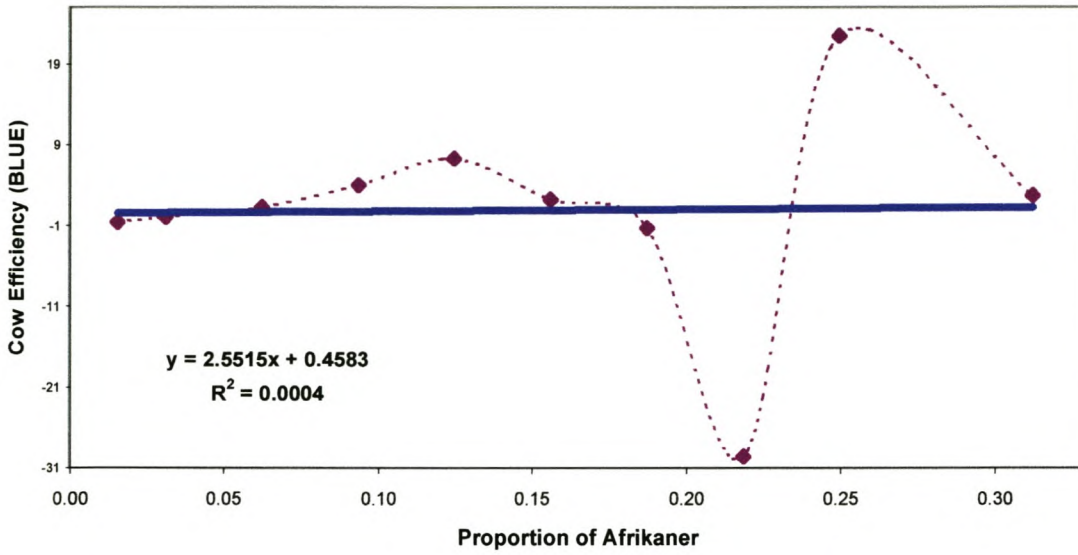

Figure 3.4(a) Regression of BLUE for cow efficiency on proportion of Afrikaner breeding.
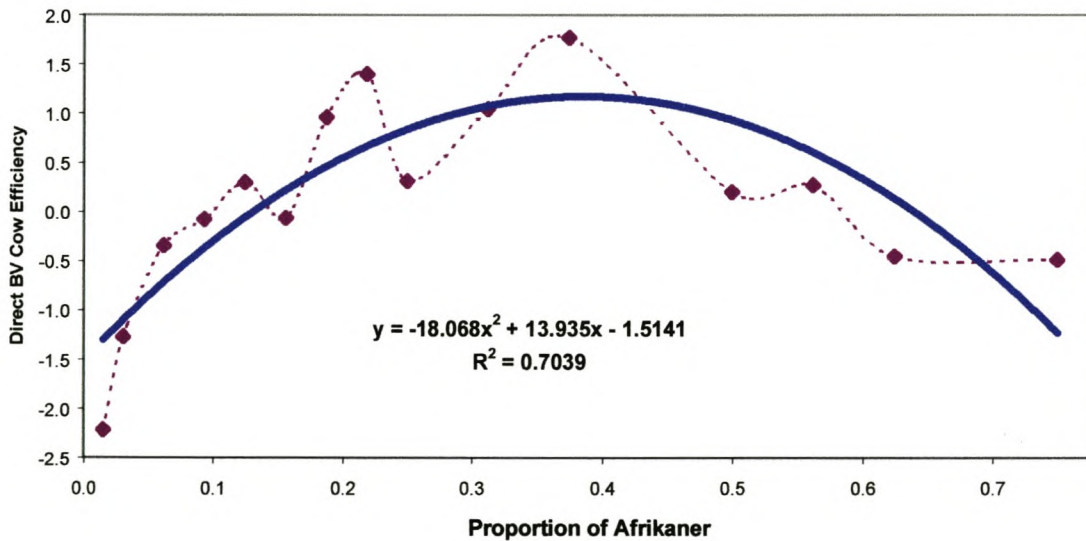

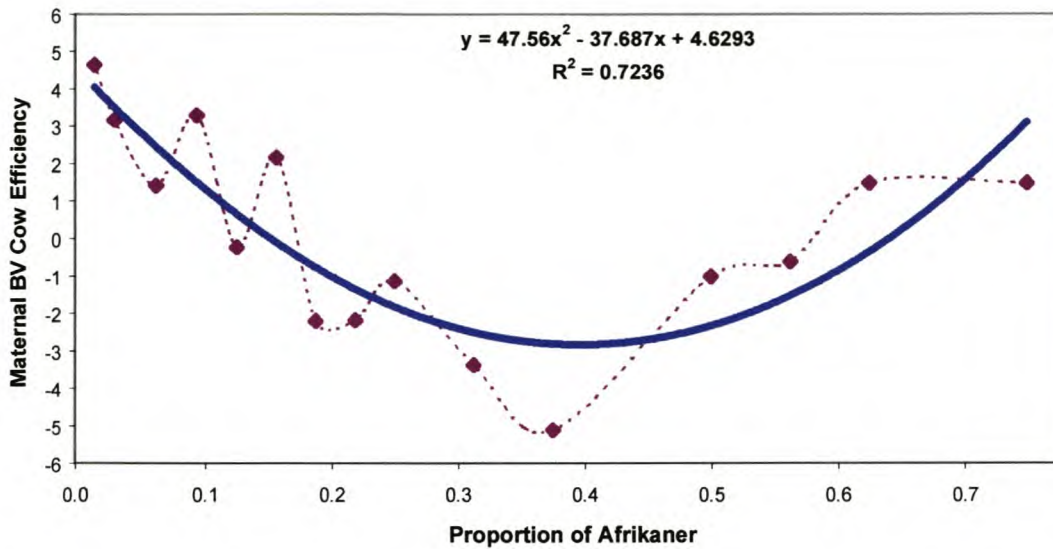**Figure 3.4(b)** Regression of direct breeding value for cow efficiency on proportion of Afrikaner breeding.

Figure 3.4(c) Regression of maternal breeding value for cow efficiency on proportion of Afrikaner breeding.

3.4 Conclusions

Over many years Afrikaner cattle played an important role in crossbreeding in South Africa and was evaluated in a number of crossbreeding projects. Most of the results obtained from this study supported evidence from previous investigations. In general, a decrease in direct breeding values for both BW and WW were obtained with increased proportions of Afrikaner when crossbred to Hereford and Simmentaler. Relative to the Afrikaner, direct effects of large framed beef breeds have positive effects on BW. The use of such breeds as sires should be considered with caution, since the use of such sires on Afrikaner dams could lead to high BW and dystocia problems. Weaning weight decreased with increasing proportions of Afrikaner, while the maternal effect on WW was either negligible or slightly positive. The direct opposite trends between the direct breeding value and maternal breeding value for CE may be the direct result of the extremely high negative correlation between the direct and maternal effects, which could be environmentally induced and biased. The direct breeding values for CE increased and reached a maximum value at 0.39 proportion of Afrikaner. The maternal breeding values for BW decreased linearly between 1.6 to 37.5% Afrikaner proportion and increased linearly between 37.5 to 75% Afrikaner proportion. The maternal breeding values for CE decreased and reached a minimum value at 0.40 proportion of Afrikaner. It should be noted that there were only a few records for certain groups of Afrikaner proportions, especially for CE and due to the imbalanced nature of breed combinations the results may be biased.

CHAPTER 4

THE HEREFORD

4.1 Introduction

The wide variety of cattle types in the world suggests the possibility of creating certain breed combinations, *e.g.* in the development of composite breeds, to increase and improve the production in commercial beef cattle.

Combining different breeds in order to create a "new breed" provides an excellent opportunity to exploit breed complementarity (breed additive differences) and heterosis for a variety of traits. It also provides, through judicious selection of breeds the 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 combing 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: consistency of performance, produce their own replacements and are easy to manage 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 but high stocking rate environment and to obtain the desired proportion of Hereford breeding for individual pre-weaning growth related traits therein. The Simmentaler made the greatest contribution followed by the Hereford which made the second greatest contribution to the creation of this composite population.

4.2 Materials and Methods

4.2.1 Data

Management, replacement and selection procedures of the herd were described in more detail by Paterson (1978, 1981), Paterson *et al.* (1980) and MacGregor (1997). Breed development started in 1962 with the first initial crosses and was terminated in 1981. Other breeds were also included in 1982 to a small degree. Schoeman & Jordaan (1998) in an earlier paper as well as Chapter 5 described the breeds used in this crossbreeding project.

The data from both the Northern Farm and the Olifantsvlei farm consisted of 52628 calf birth and weaning weight records collected from 1968 to 1993. The number of dam weight records was 6239 and was only recorded since 1989. The number of sires used was 362 with an average of 199 calves per sire which varied from 1 to 1612 per sire. Hereford contribution in both sires and dams varied from 7.8 to 100%. Purebred Hereford sires were only used from 1968 to 1981. The number of dams with calf weaning weights recorded was 15539, with an average of 3.4 calves per dam that varied from 1 to 14 calves. The number of animals in the pedigree file was 57078.

Birth weight (BW) and weaning weight (WW) of the calf and dam weight at the time of weaning of her calf (DW) were recorded. From WW and DW cow efficiency indices (CE) (WW/DW$^{0.75}$ x 100) were also calculated.

Dam ages ranged from 2 to 16 years. The small number of cows older than 10 years, they were pooled with the 10-year-old group. Average age of cows before pooling was 5.37 years and after pooling it was 5.23 years.

All matings were planned and therefore artificial insemination (using the same sires across the two farms) was used throughout the cattle herd. Heifer calves were first inseminated to calve 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 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.

Breed composition, or proportion of different breeds in each animal was calculated from the original

pedigrees. Females were identified as "Remainder" where the breed was unknown or the breeds were introduced at a later stage. A total number of 5741 genetic groups were identified 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. Due to the small number of observations in some groups, groups 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 recorded per proportion of Hereford is presented in Table 4.1.

Table 4.1. The total number of calves (n) recorded per level of Afrikaner proportion (%)

	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
n	349	1493	3660	1842	7210	1914	2027	1223	8605	3038	1943	3638	1107	1266	1233	458	459

4.2.2 Statistical Analysis

Data was 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

$\mathbf{b}$ = a vector of fixed effects

X = a known incidence matrix relating observations to the fixed effects

Z_1 and 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 unitrait models were fitted to the data. These models accounted for direct 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 model fitted to each trait and trait means are presented in Table 4.2.

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 was also estimated and regressed on proportion of Hereford breeding. Linear regressions were fitted, excluding those animals with no Hereford contribution.

Table 4.2. Statistical models for unitrait analyses of birth weight (BW) and weaning weight (WW) of the 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(2)	X	X	X
Hereford proportion	Fixed	18(16)	X	X	X
Sex of calf	Fixed	3(3)	X	X	X
Season of birth	Fixed	2(2)	X	X	X
Dam age	Covariate	1(1)	X	X	X
Weaning age of calf	Covariate	1(1)		X	X
Maternal	Animal	57078(57078)	X	X	X
Animal	Animal	57078(57078)	X	X	X
Means ± SD			35.5 ± 6.0	207.3 ± 38.5	212.0 ± 32.5

( ) number of levels for CE

4.3 Results and Discussion

4.3.1 Heritabilities and genetic correlations

Heritability estimates and the correlations between direct and maternal genetic effects for BW, WW and CE are presented in Table 4.3. In general, direct heritabilities tend to be higher than those reported in other studies. However, all estimates correspond very closely to those obtained in Chapters 3 and 5, on the same datasets, when analysing the influence of Afrikaner and Simmentaler contribution, respectively. The direct heritability for BW ($h^2_a = 0.67$) 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 by Mohiuddin (1993) and Koots *et al.* (1994a) (0.30 and 0.31) in their respective reviews. The same, although to a smaller degree applied to WW, where the direct heritability was 0.52. 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 ($h^2_a = 0.21$). No comparable estimates were found in the literature for this trait.

Table 4.3. Direct (h^2_a) and maternal heritability (h^2_m) 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	0.665	0.219	-0.322
WW	0.522	0.361	-0.535
CE	0.213	0.601	-0.641

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 several breeds (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 to the inclusion of non-additive genetic variances. Similarly, a dominance effect was not fitted in the model, and 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 for composite populations heritability estimates for early growth traits 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.* (2000) 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 was the lowest for BW ($r_{am} = -0.32$) and the highest for CE ($r_{am} = -0.64$). This resulted in

a low total heritability (h^2_T = 0.12). These negative estimates are common in beef cattle 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, as were 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.

4.3.2 Variation in breed composition of the herd

The breeds making the largest contribution to the population were the Angus, Bonsmara, Charolais, Hereford and Simmentaler. Individual contributions were reported in Chapter 5. The Hereford made the second largest contribution (19.3%) to the calves born between 1989 and 1993.
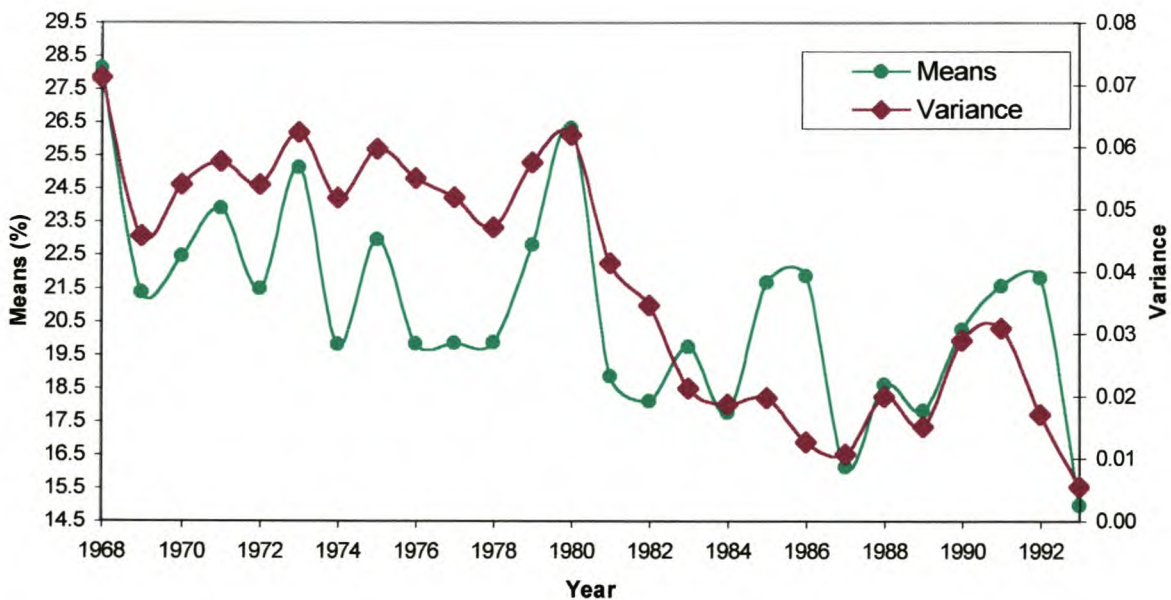
Figure 4.1 Changes in mean Hereford contribution (%) and variance in proportion of Hereford per year.

The composition of individual calves born varied from 0 to 100% Hereford. The proportion of

Hereford contribution per year of calves born and Hereford proportion variance are presented in Figure 4.1. The contribution of Hereford decreased from 1968 to 1993. In 1980, 1985, 1986, 1991 and 1992 there were increases in the contribution of the Hereford. This was due to the use of some of the older sires with relatively high Hereford composition. The Hereford composition of the sires used in those years was 50, 53.2, 56.3, 62.5 and 100%. 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, as a result of the introduction of other breeds. Equilibrium is not reached at this point of time since equilibrium could only be attained when both parents and calf have the same proportion of Hereford genes. However, in 1993 the variance as far as Hereford contribution is concerned, was low.

4.3.3 Effect of Hereford contribution

4.3.3.1 Birth weight

Regressions of BLUE's and direct and maternal breeding values on proportion of Hereford for BW are presented in Figures 4.2 (a to c), respectively. BW was influenced by proportion of Hereford (Fig. 4.2a). It increased and reached a maximum value at 0.47 proportion of Hereford, after which it declines again. The maximum phenotypic value at an intermediate level of proportion of Hereford is surprising and not obvious. It may partly be 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. Relative high contributions of Afrikaner, Angus and Bonsmara at low Hereford proportion could also be a reason for the lower birth weights at low Hereford proportion. Mean direct breeding values (Fig. 4.2b) and maternal breeding values (Fig. 4.2c) decreased linearly with increasing Hereford proportion. The low average breeding values at 75% Hereford *versus* the high average breeding values at 87.5% Hereford contribution is not obvious. A total of 3.0% (or 1233) calves consisted of 75% Hereford. Of those 525 (or 42.6%) were 75% Hereford combined with differing contributions of Brown Swiss, Charolais and Simmentaler. In total 1.1 percent (or 458) of calves born were 87.5% Hereford. Of those 250 (or 54.6%) were 87.5% Hereford combined with differing contributions of Brown Swiss, Charolais and Simmentaler, all of which are relatively large breeds compared to the Hereford. These large differences in breeding values could therefore not be explained by differences in Hereford x British *versus* Hereford x Continental breed contributions which one would have expected.

In other studies, the direct additive effect for the Hereford was positive in some investigations (Gregory *et al.*, 1978; Dillard *et al.*, 1980; Roberson *et al.*, 1986; Cunningham & Magee, 1988; Schoeman *et al.*, 1993), while it was negative in others (Alenda *et al.*, 1980; Franke, 1994), depending on the breeds it was compared with. In analysing part of the same dataset, in Chapter 2, when comparing Hereford, Simmentaler and Afrikaner cattle, a significant ($P \leq 0.01$) negative direct effect was obtained for the Hereford. The direct breeding value of Hereford on BW is important because it can have a major influence on calving ease, indicating that less 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 fetus 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; Chapter 2), depending on the breeds it was compared with. Higher levels of Hereford in crossbreeding or composite populations are recommended in preventing increased calving difficulties if it is a problem.
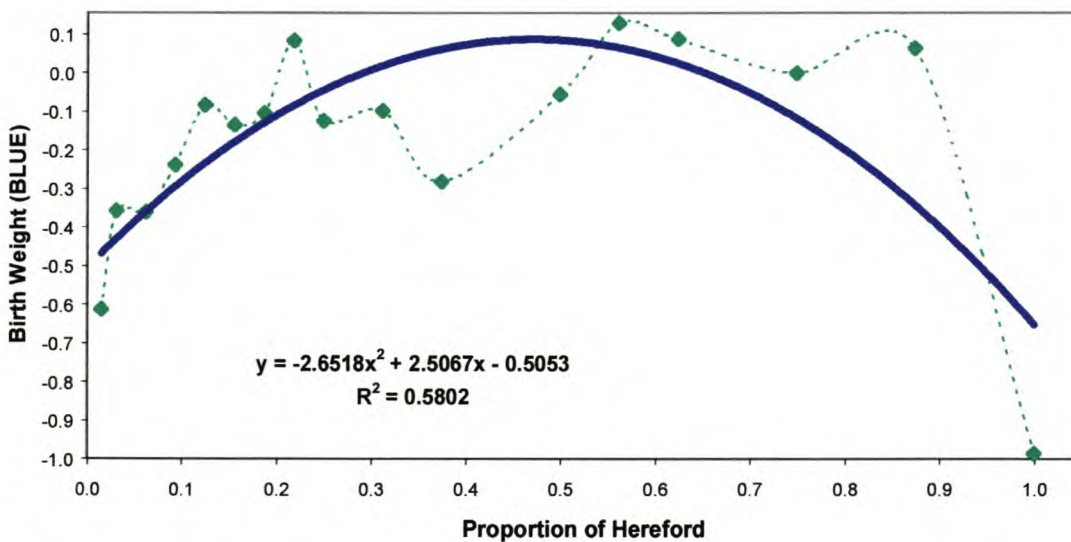
Figure 4.2(a) Regression of BLUE for birth weight on proportion of Hereford breeding.
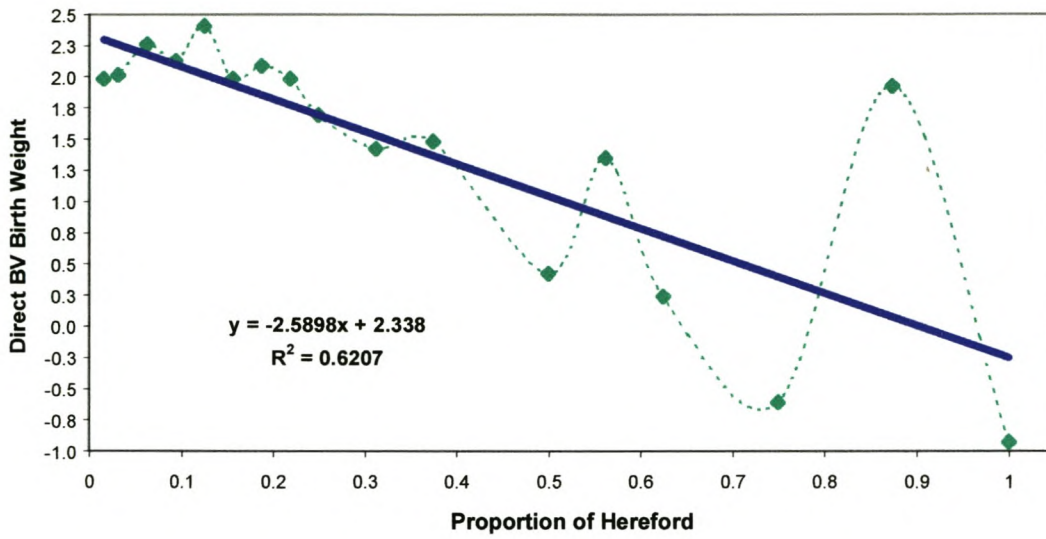
Figure 4.2(b) Regression of direct breeding value for birth weight on proportion of Hereford breeding.
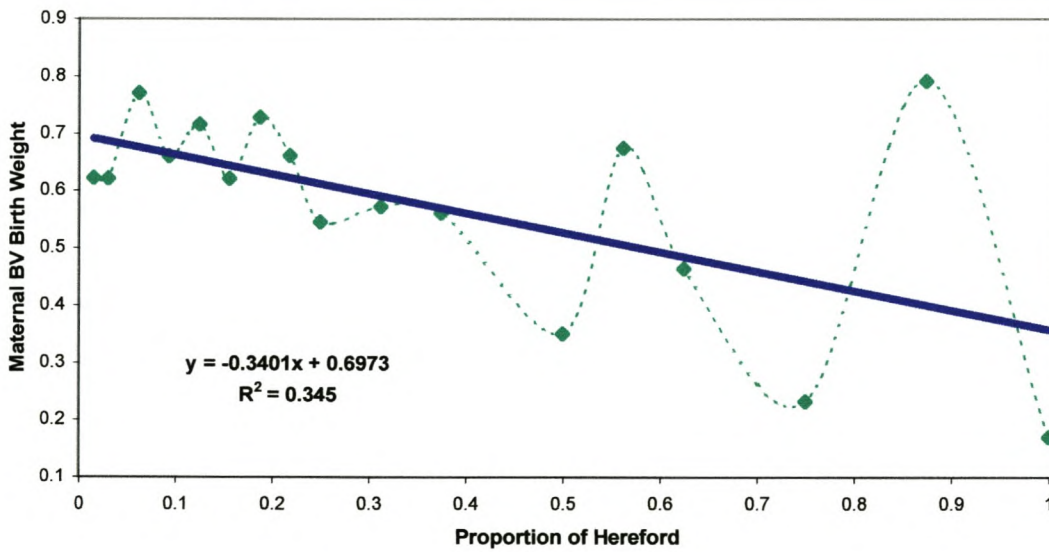
Figure 4.2(c) Regression of maternal breeding value for birth weight on proportion of Hereford breeding.

4.3.3.2 Weaning weight

Regressions of BLUE's and direct and maternal breeding values on proportion of Hereford for WW are presented in Figures 4.3 (a to c), respectively. WW was influenced by proportion of Hereford (Fig. 4.3a). It increased and reached a maximum value at 0.13 proportion of Hereford, after which it declines again. Both mean direct breeding values (Fig. 4.3b) and maternal breeding values (Fig. 4.3c) decreased linearly with increasing Hereford proportion. As for BW, the mean maternal breeding value 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.

In other studies, the direct additive effect was positive in some investigations (Dillard *et al.*, 1980; Cunningham & Magee, 1988; Franke, 1994), while it was negative in others (Gregory *et al.*, 1978; Alenda *et al.*, 1980; MacNeil *et al.*, 1982; Franke, 1994; Chapter 2). In this study, the direct breeding value for WW are 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 (Chapter 5). 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. Both chapters 2 and 5, analysing parts of the same dataset, indicated a relative 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, which predicts the milk production of an animal and also reflects the milking ability of the animal's daughters (Bradfield & Erasmus, 1999), showing in Fig. 4.3(c) a decrease in WW breeding values with an increase in Hereford contribution. It is also suggested that the Hereford is a low milk producing breed (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; Chapter 2). Both Meyer (1992a) and Schoeman *et al.* (1993) associated the low WW in Hereford calves to the low milk production of the Hereford dam. The results in this study clearly illustrated a decrease in performance levels and breeding values with increasing Hereford contribution. It indicated that no desired optimal Hereford proportion was evident in this multibreed beef cattle herd within this specific environment.
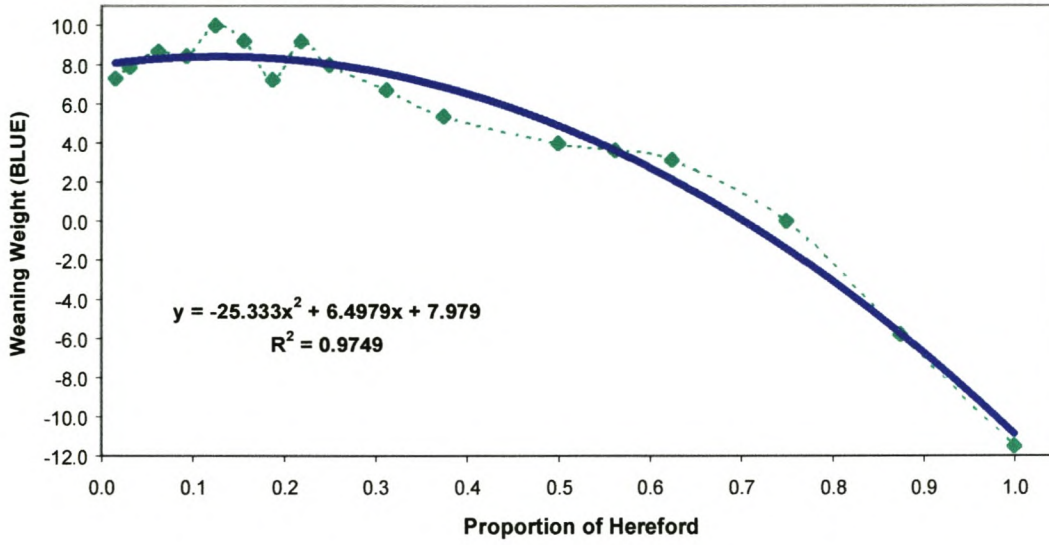
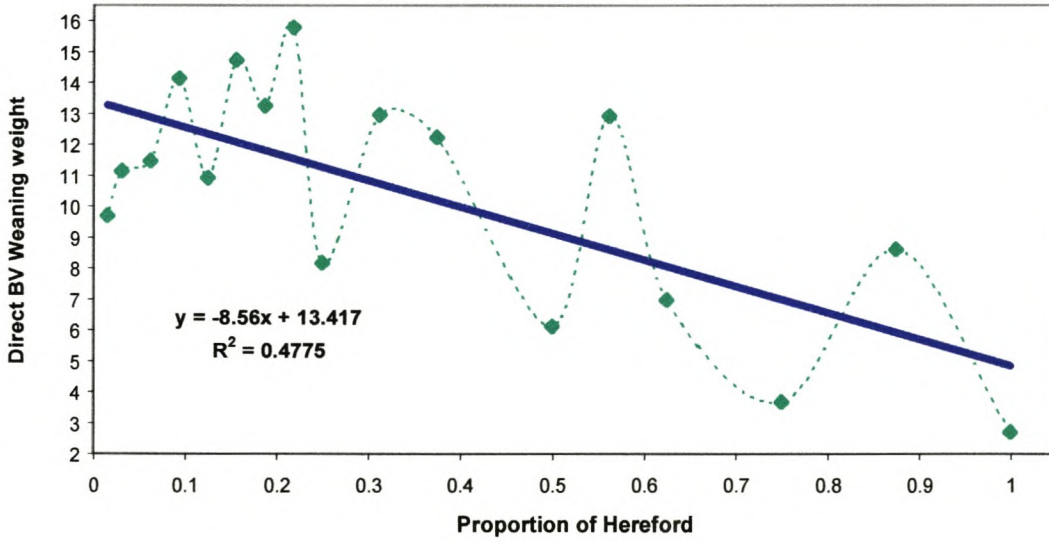**Figure 4.3(a)** Regression of BLUE for weaning weight on proportion of Hereford breeding.

Figure 4.3(b) Regression of direct breeding value for weaning weight on proportion of Hereford breeding.
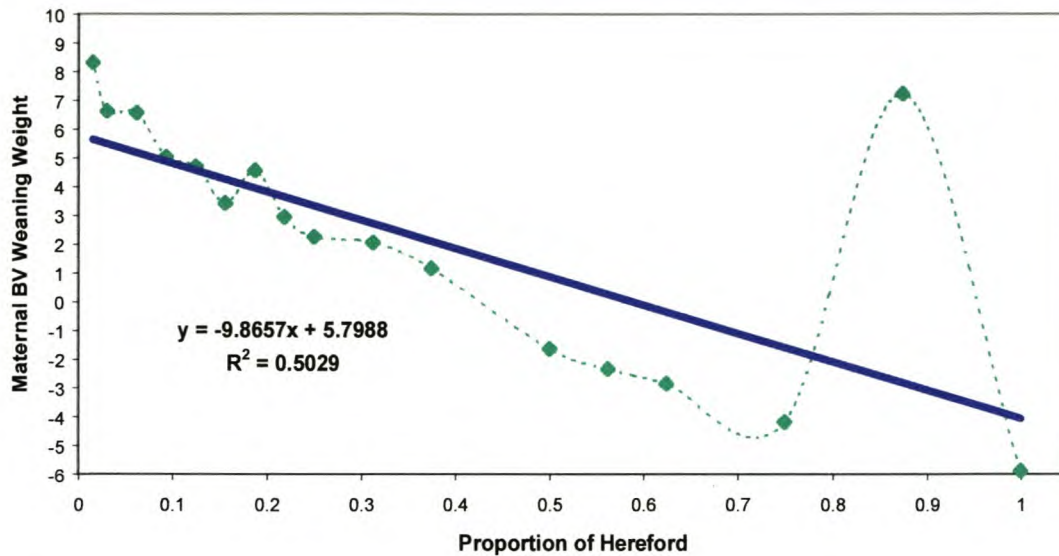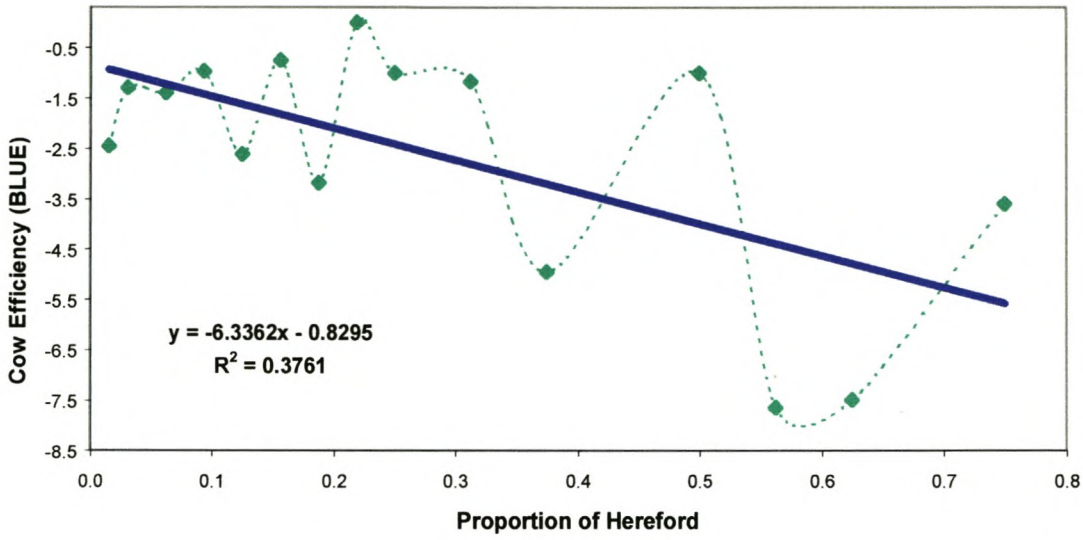
Figure 4.2(c) Regression of maternal breeding value for weaning weight on proportion of Hereford breeding.

4.3.3.3 Cow efficiency

Regressions of BLUE's and direct and maternal breeding values on proportion of Hereford for CE are presented in Figures 4.4 (a to c), respectively. BLUE's for CE was influenced by proportion of Hereford (Fig. 4.4a) which decreased linearly with increasing Hereford proportion. Contrary to that, mean direct breeding values (Fig. 4.4b) 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 (Fig. 4.4c) decreased and reached minimum value at 0.62 proportion of Hereford, after which it increased again. As for BW and WW, the mean maternal direct breeding value 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 like Bonsmara, Angus, Afrikaner and South Devon.

Figure 4.4(a) Regression of BLUE for cow efficiency on proportion of Hereford breeding.
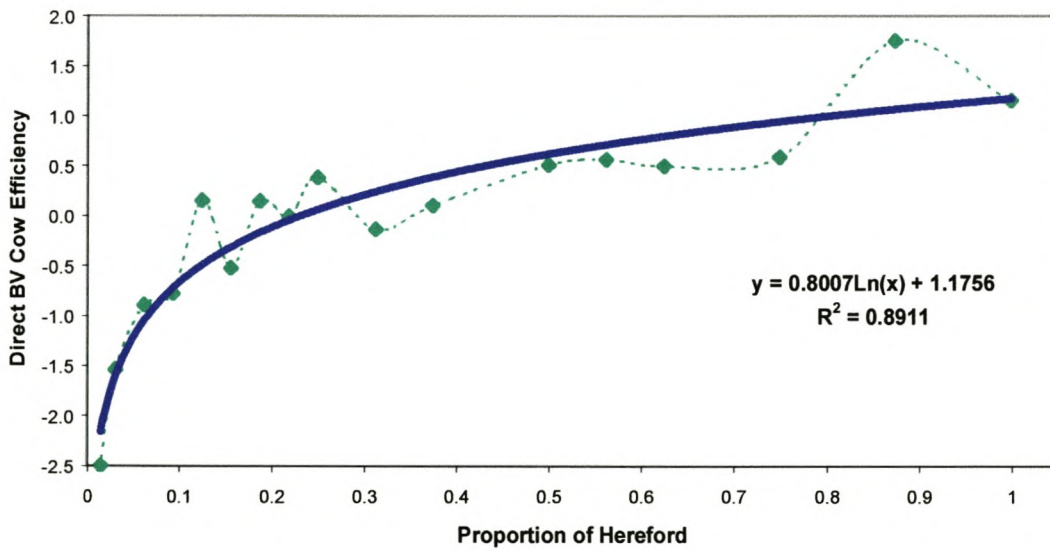

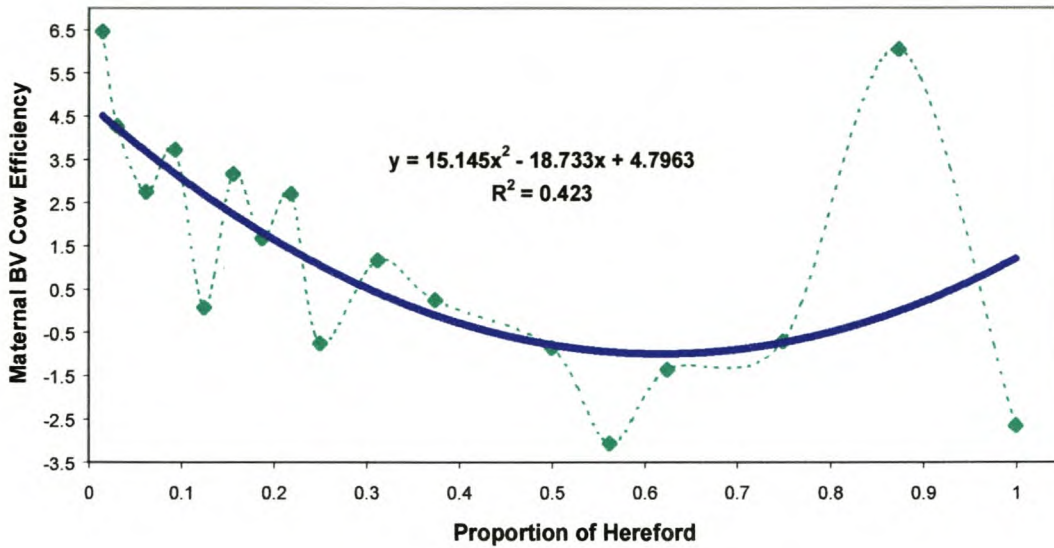**Figure 4.3(b)** Regression of direct breeding value for cow efficiency on proportion of Hereford breeding.

Figure 4.2(c) Regression of maternal breeding value for cow efficiency on proportion of Hereford breeding.

3.4 Conclusions

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 may be environmentally induced. These results clearly illustrated 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.

CHAPTER 5
THE SIMMENTALER

5.1 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 by 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 but high stocking rate environment 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.

5.2 Material and Methods

5.2.1 Animals

Data was obtained from the multibreed synthetic beef cattle population of the Johannesburg Metropolitan Council. The large herd, comprising of approximately 2500 breeding females was kept on two different farms on an intensive management system (Paterson *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, postweaning gain and breeding soundness, without taking breed composition into account. The objective was to eventually reach optimal or desired 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. 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 by using a relationship matrix that includes all sires and 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 almost throughout the year, the majority of calves were born in winter (June to September), while the rest were born during December through 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 1989.

5.2.2 Data description

The data consisted of 52628 calf birth and weaning weight records collected from 1968 to 1993.

The number of dam weight records was 6239. The number of sires used was 362 with an average of 199 calves per sire which varied from 1 to 1612 per sire. The number of dams with calf weaning weights recorded was 15539, 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 57078.

Birth weight (BW) and weaning weight (WW) of the calf and dam weight at the time of weaning of her calf (DW) were recorded. From WW and DW cow efficiency indices (CE) (WW/DW$^{0.75}$ x 100) were also calculated.

Dam ages ranged from 2 to 16 years. The small number of cows older than 10 years, were pooled with the 10-year-old group. Average age of cows before pooling was 5.37 years and after pooling 5.23 years.

Breed composition, or proportion of different breeds in each animal was calculated from the original pedigrees. In the case of females where breed was unknown, and breeds introduced at a later stage, they were identified as "Remainder". The total number of genetic groups, taking all breeds and breed combinations into account was 5741. 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 ½ Simmentaler. There were 16 genetic groups with varying proportions of Simmentaler.

5.2.3 Statistical analysis

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

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_1a} + \mathbf{Z_2m} + \mathbf{e}$$

where

y	=	a vector of observations
b	=	a vector of fixed effects
X	=	a known incidence matrix relating observations to the fixed effects

Z_1 and Z_2 = known incidence matrices relating elements of **a** and **m** to **y**

a = a random vector of direct additive genetic effects

m = a random vector of maternal additive genetic effects

e = a random vector of residual errors.

Only unitrait models were fitted to the data. These models accounted for direct 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 model fitted to each trait and trait means are presented in Table 5.1.

Table 5.1. Statistical models for unitrait analyses of birth weight (BW) and weaning weight (WW) of the 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	25	X	X	X
Farm	Fixed	2	X	X	X
Simmentaler proportion	Fixed	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	Animal	57078	X	X	X
Animal	Animal	57078	X	X	X
Means ± SD			34.5 ± 5.92	207.3 ± 38.5	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 was also estimated and regressed on proportion of Simmentaler breeding. Linear regressions were fitted, excluding those animals with no Simmentaler contribution.

5.3 Results and Discussion

5.3.1 Heritabilities and genetic correlations

Heritability estimates and the correlations between direct and maternal genetic effects for BW, WW and CE are presented in Table 5.2. In general, direct heritabilities tend to be higher than those reported in other studies. However, all estimates correspond very closely to those obtained in Chapters 3 and 4, on the same datasets, when analysing the influence of Afrikaner and Hereford contribution, respectively. The direct hertability 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. The same, although to a smaller degree applied to WW, where 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. 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. Correlations between direct and maternal genetic effects were negative for all three traits. As is 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 ($h^2_T = 0.14$). Reasons for the fairly high heritability and the high negative correlation between maternal and direct effects have already been discussed in more detail in Chapter 4.

Table 5.2. Direct (h^2_a) and maternal heritability (h^2_m) 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

5.3.2 Variation in breed composition of the herd

In total 15 breeds contributed to the composition of the herd. For all calves born between 1989 and 1993, the contributions of individual breeds are presented in Table 5.3. 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 5.3. 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 (x 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 are presented in Figure 5.1. The contribution of Simmentaler increased from 1968 to 1980, but was more or less 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 to 1971) maximum percentage of Simmentaler was 75%, which resulted from backcrossing Simmentaler with ½ 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. 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 owing to the introduction of other breeds. However, it should be noted that equilibrium could only be attained when both parents and calf have the same proportion of Simmentaler genes. This is not reached at this point of time.
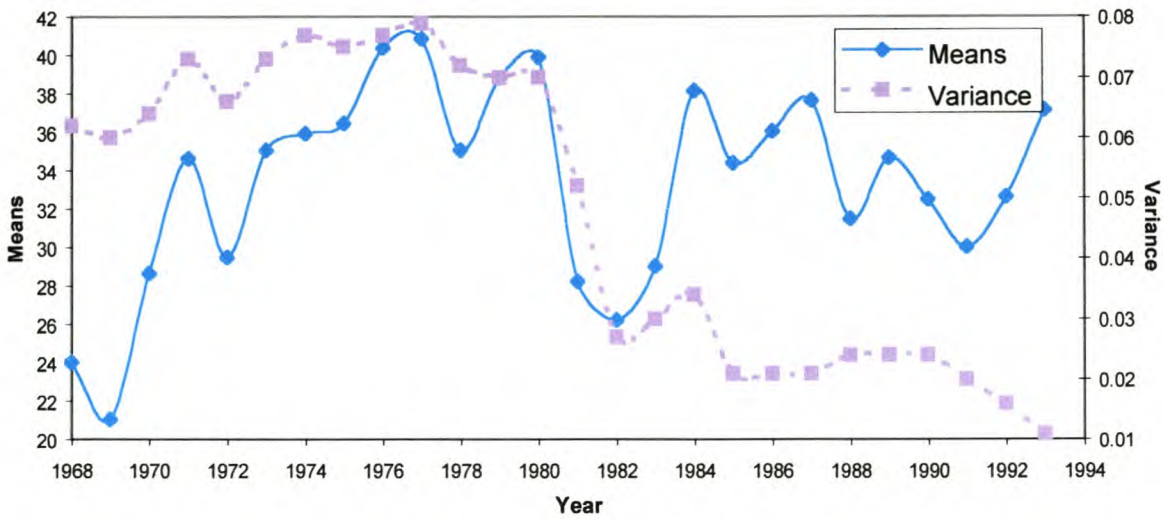
Figure 5.1 Changes in mean Simmentaler contribution (%) and variance in proportion Simmentaler per year.

5.3.3 Effect of Simmentaler contribution

5.3.3.1 Birth weight

Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for BW are presented in Figures 5.2 (a to c). BW was influenced by proportion of Simmentaler and increased with increasing Simmentaler contribution (Fig. 5.2a). Likewise, maternal breeding values increased almost linearly with increasing Simmentaler proportions (Fig. 5.2c), while mean direct breeding values decreased with increasing Simmentaler proportion (Fig. 5.2b). Although 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 percent (or 10851) of calves born were ½ Simmentaler. Of those 7286 (or 67.2%) were ½ Simmentaler combined with differing contributions of Afrikaner, Angus, Bonsmara, Hereford and South 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.

In several crossbreeding studies positive direct effects were reported for Simmentaler (Cunningham & Magee, 1988; Schoeman *et al.*, 1993). In Chapter 2, analysing part of the same dataset when comparing Simmentaler, Hereford and Afrikaner cattle, a positive direct effect and a negative

maternal effect both significant ($P \leq 0.01$) for BW of 10.9 and 7.2%, respectively, of the mean were 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.
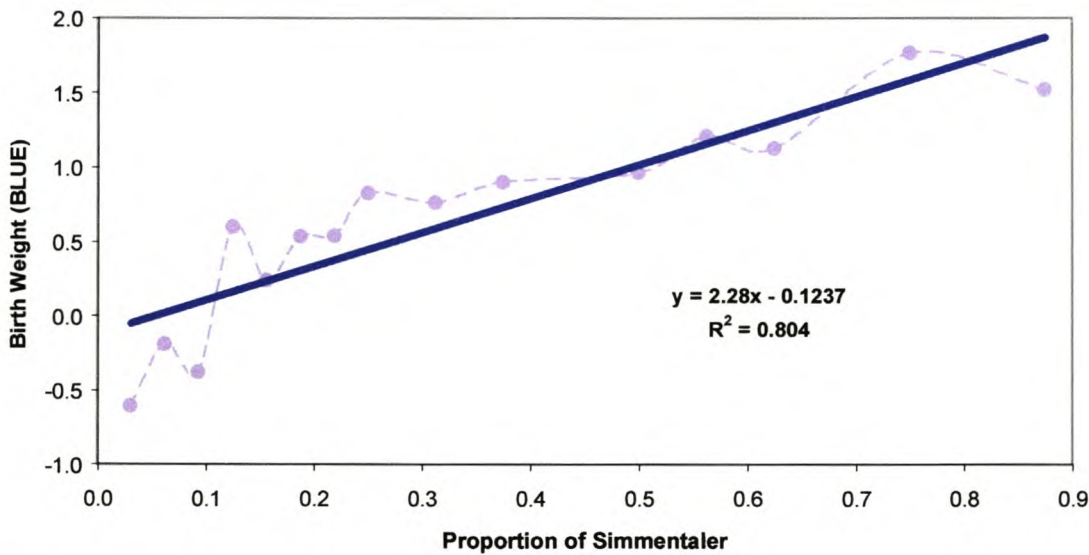
Figure 5.2(a) Regression of BLUE for birth weight on proportion of Simmentaler breeding.

$$y = -0.4337x + 2.301$$
$$R^2 = 0.0932$$
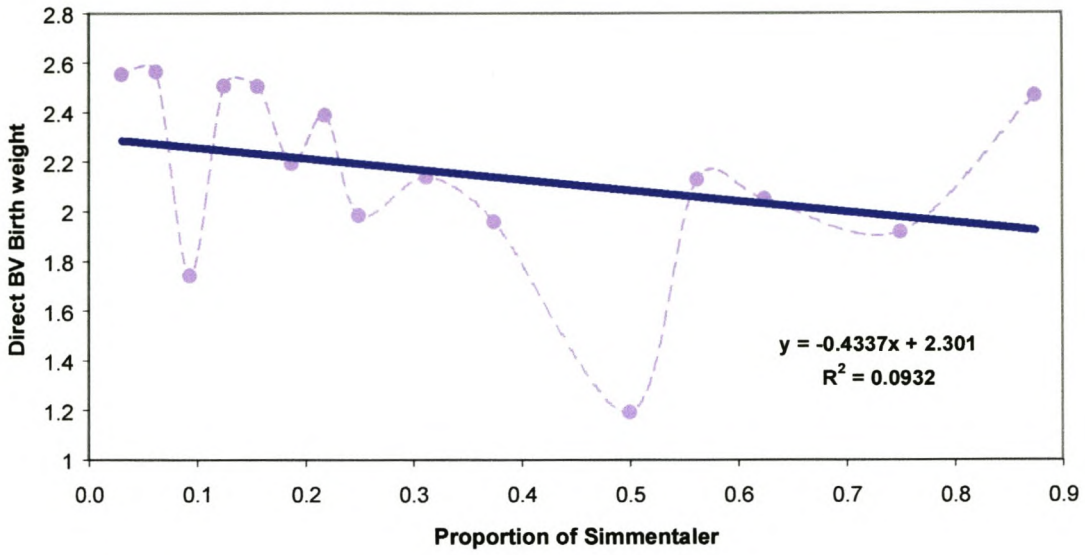
Figure 5.2(b) Regression of direct breeding value for birth weight on proportion of Simmentaler breeding.
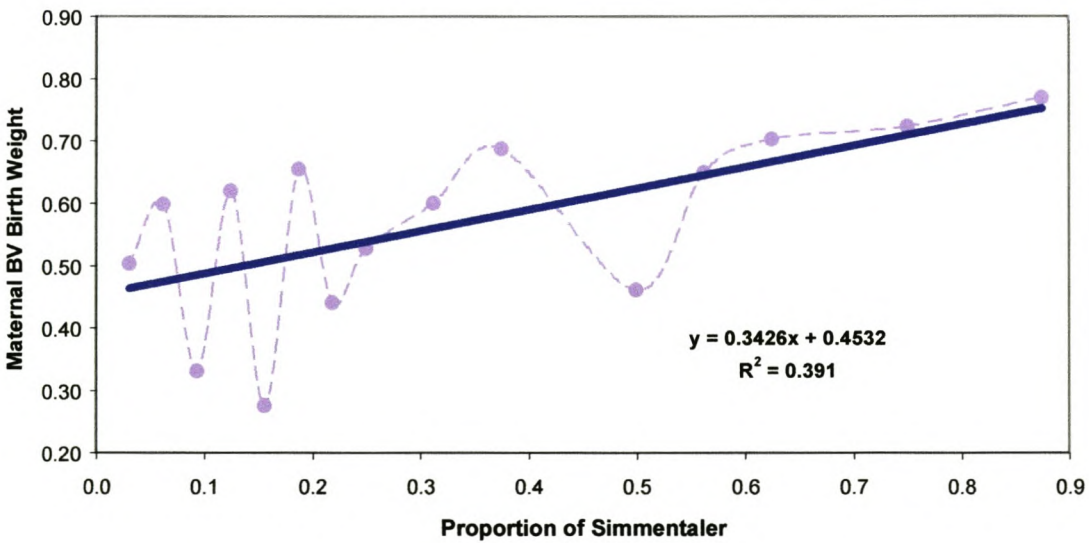

$$y = 0.3426x + 0.4532$$
$$R^2 = 0.391$$

Figure 5.2(c) Regression of maternal breeding value ffor birth weight on proportion of Simmentaler breeding.

5.3.3.2 Weaning weight

Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for WW are presented in Figures 5.3 (a to c), respectively. WW increased linearly with an increase in Simmentaler proportion (Fig. 5.3a). This is in contrast with the general decrease in direct breeding values (Fig. 5.3b) but in accordance with the increase in maternal (Fig. 5.3c) breeding values, respectively. This contradiction may also be the result of the fairly high, possibly environmentally induced, negative correlation between direct and maternal effects (Table 5.2) so that maternal breeding values increased where direct breeding values decreased or *vise versa*. As for BW, mean direct breeding values of ½ Simmentaler was unexpectedly low. Although reasons for this are not obvious, it may also be related to the unbalanced nature of breed combinations in the dataset and especially due to the contribution of late maturing large frame-sized breeds such as the Charolais, as was discussed earlier. In most other crossbreeding studies (Cunningham & Magee, 1988; Schoeman *et al.*, 1993), high positive maternal effects of Simmentaler were obtained. 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. In Chapter 2 the direct effect for WW in a probably less favourable environment was 12.2% and significant ($P \leq 0.01$). Average WW of Simmentaler cattle taking part in the National Beef Cattle Performance Testing Scheme is approximately 35 kg (or 17.4%) higher 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).
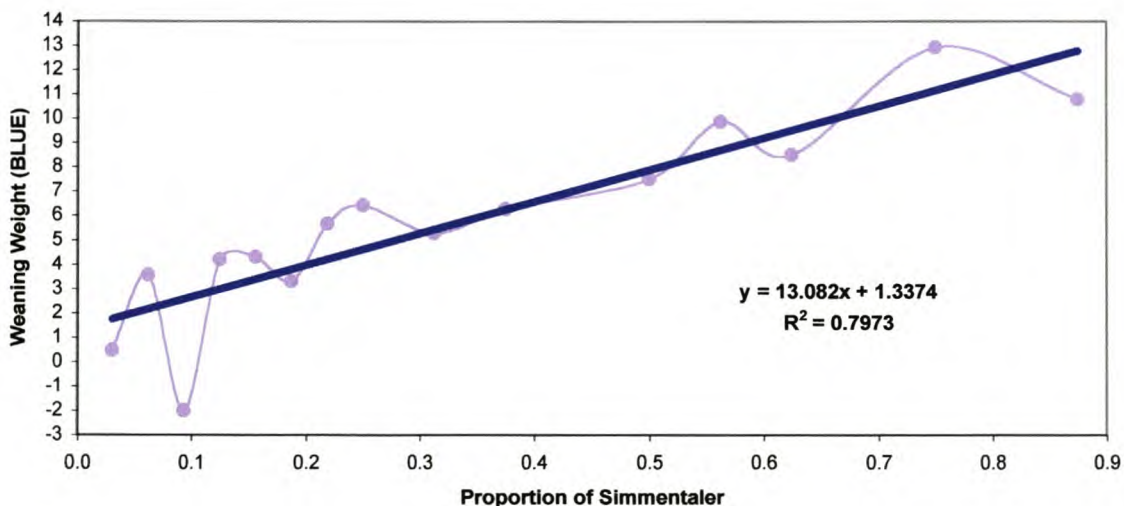

Figure 5.3(a) Regression of BLUE for weaning weight on proportion of Simmentaler breeding.
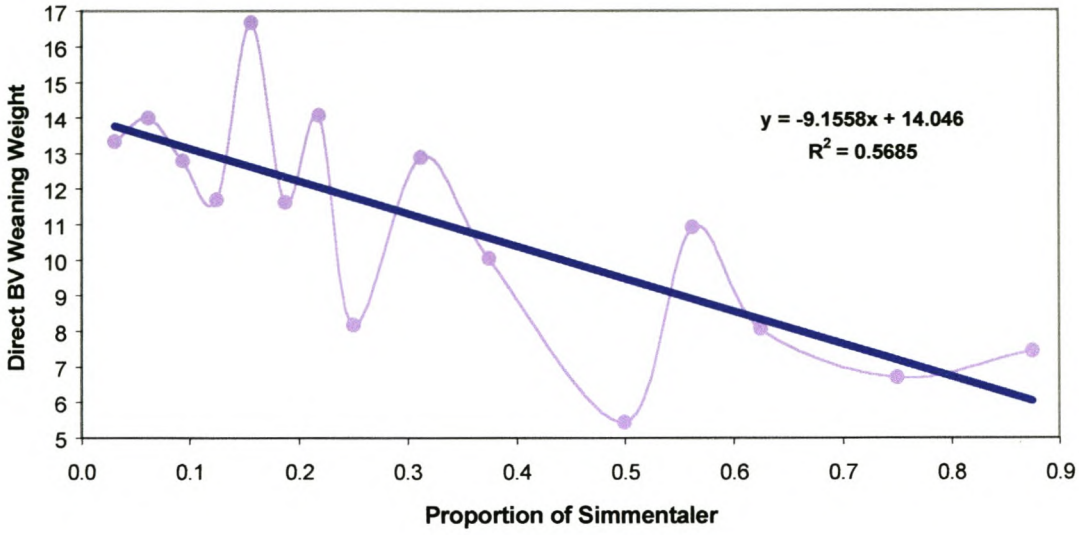
Figure 5.3(b) Regression of direct breeding value for weaning weight on proportion of Simmentaler breeding.
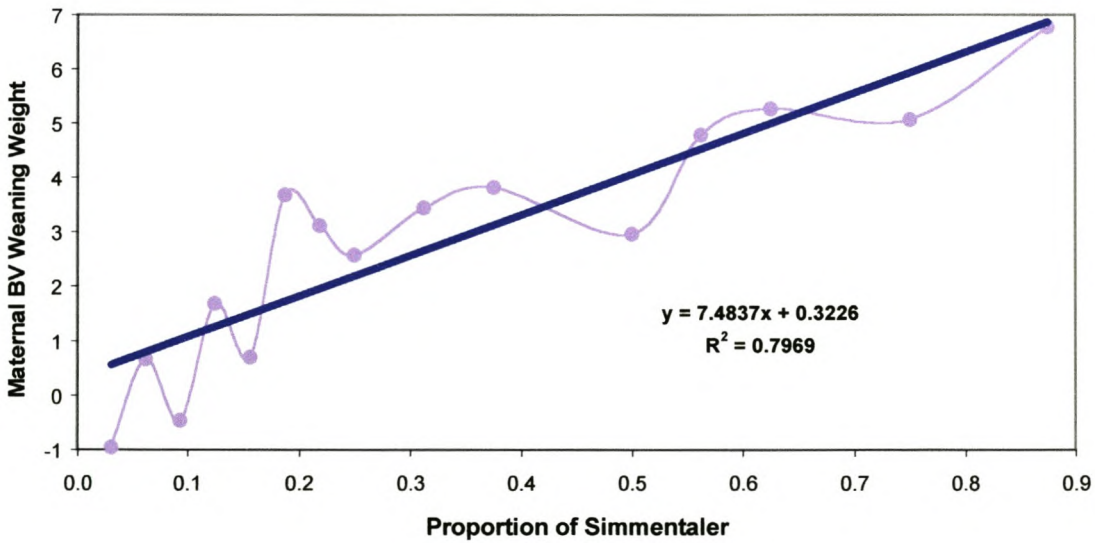

Figure 5.3(c) Regression of maternal breeding value for weaning weight on proportion of Simmentaler breeding.

5.3.3.3 Cow efficiency

Regressions of BLUE's and direct and maternal breeding values on proportion of Simmentaler for CE are presented in Figures 5.4 (a to c), respectively. Direct breeding values (Fig. 5.4b) and maternal breeding values (Fig. 5.4c) 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 (Fig. 5.4a). 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 for WW.
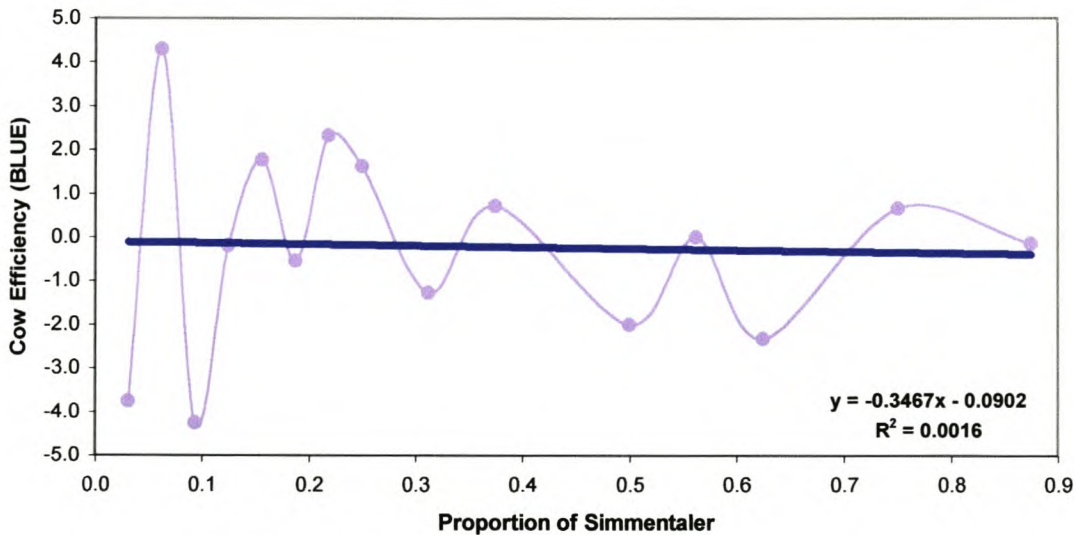

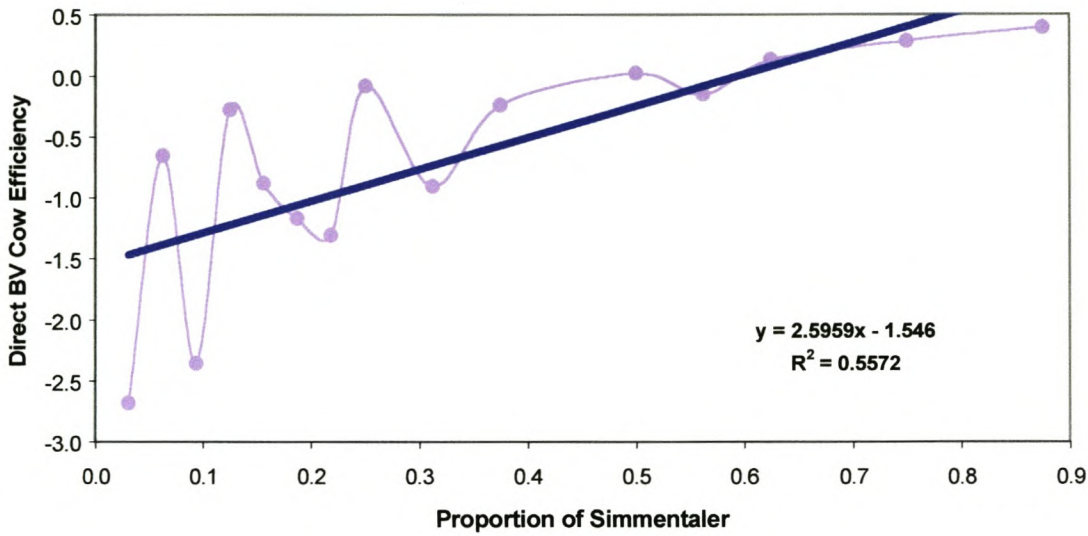**Figure 5.4(a)** Regression of BLUE for cow efficiency on proportion of Simmentaler breeding.

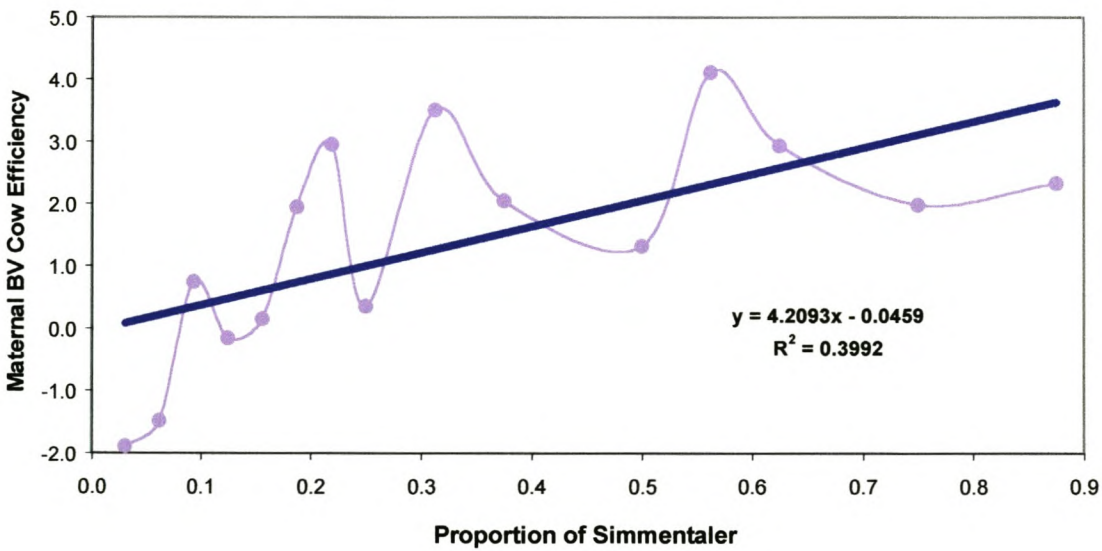**Figure 5.4(b)** Regression of direct breeding value for cow efficiency on proportion of Simmentaler breeding.

Figure 5.4(c) Regression of maternal breeding value for cow efficiency on proportion of Simmentaler breeding.

5.4 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.

CHAPTER 6
GENERAL CONCLUSIONS

An assessment of was made the contributions of the Afrikaner, Hereford and Simmentaler in composite breed development in beef cattle for birth weight (BW), weaning weight (WW) and cow efficiency (CE), managed in a relatively intensive but high stocking rate environment.

In the initial crossbreeding phase genetic and crossbreeding parameters for the Afrikaner, Hereford and Simmentaler were estimated. From this study it was clear that purebred Simmentaler breeding appears to be the best breeding practice for this environment, due to the high positive breed additive contributions for WW of Simmentaler (12.2%) and the high LS Means for WW of 205.4 kg. The high breed direct effect of the Simmentaler also indicates that using this breed as one parent in a crossbreeding system involving Hereford and Afrikaner will increase both BW and WW. The Afrikaner's direct maternal effect for BW was positive and higher than those of Hereford and Simmentaler, respectively, suggesting that Afrikaner dams do not restrict the BW of their calves as was suggested in previous investigations. The direct maternal effect of the Afrikaner (4.7%) for WW was in this study superior to the Hereford and Simmentaler dams within this specific environment, suggesting a possible genotype x environment interaction when compared to other environments. This study also supports previous evidence that more heterosis is generated when crossing large exotic sires to indigenous dams since both Hereford x Afrikaner (9.8%) and Simmentaler x Afrikaner (6.7%) crosses exceeded the Hereford x Simmentaler (3.1%) crosses. Estimates of maternal heterotic effects for WW were non-significant, suggesting that crossbred dams did not provide the expected maternal superiority and thus a higher nutritional level and improved management is possibly needed in this herd to utilise the higher potential of crossbred dams and to utilise crossbreeding to its full potential. Re-ranking of crossbred mating types and genotypes *versus* purebreds, when comparing the Afrikaner, Hereford and Simmentaler, might occur if other composite traits, *e.g.* cow efficiency, total weaning weight of calves weaned etc., were included in this investigation. Unfortunately, some of these were not recorded.

Investigations of the contributions of the Afrikaner, Hereford and Simmentaler during composite development in later generations, respectively, were made. From this investigations fairly high heritability and high negative correlations between maternal and direct effects were obtained. Reasons for the high heritability estimates were discussed. It may be biased and overestimated *inter*

alia 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. Likewise, the high negative correlations may be environmentally induced. The direct breeding values for BW declined with an increase in Afrikaner, Hereford and Simmentaler proportion, respectively. This may be caused by the contributions of large framed breeds such as the Charolais and Limousin. Relative to the Afrikaner, direct effects of large framed beef breeds have large positive effects on BW. The use of such breeds as sires should be considered with caution, since the use of such sires, especially on Afrikaner and Hereford dams could lead to high BW and dystocia problems. The maternal breeding values for BW declined linearly with an increase in Hereford proportion and increased linearly with an increase in Simmentaler proportion. This indicates that higher levels of Hereford in crossbreeding and composite development could be considered in preventing increased calving difficulties when it is a problem. However, the decline in the direct breeding value and the increase in the maternal breeding value for BW with an increase in Simmentaler proportion are unexpected because most literature studies obtained positive direct effects and negative maternal effects and therefore do not recommend high levels of Simmentaler breeding due to the high positive direct effect on BW, thus leading to high BW and dystocia problems. Although the actual reasons for this contradiction remains unclear, it may also be related to the contribution of other breeds such as Charolais and Limousin at low Simmentaler proportion levels.

The direct breeding values for WW, from the multibreed population, illustrated a linear decline with an increase in Afrikaner, Hereford and Simmentaler proportion, respectively. These results clearly illustrated that no desired optimal Hereford or Afrikaner proportions were evident in this multibreed beef cattle herd within this specific environment for WW. The decline in the direct breeding value with an increase in Simmentaler proportion is also unexpected, since various authors obtained high positive direct effects for the Simmentaler, which is a large framed-size beef breed. This might be the result of the fairly high, possibly environmentally induced, negative correlation between direct and maternal effects causing a reflection image as compared to the maternal breeding value. The maternal breeding values for WW decreased linearly with an increase in Hereford proportion and increased linearly with an increase in Simmentaler proportion. The maternal breeding value for the Afrikaner on WW was not influenced by proportion of Afrikaner. Relative to the other breeds in the composite, increasing Simmentaler contributions increased the milk production potential of the composite, while the Afrikaner is intermediate to the Simmentaler and Hereford. It therefore appears that the advantage of the Simmentaler lies more in the maternal contribution than in the

direct contribution in the development of this composite. These results therefore suggest that the Simmentaler is a large-framed maternal line rather than a terminal sire line.

For CE, the regressions of direct breeding values are almost the reverse of the regressions of maternal breeding values for both the Afrikaner and Hereford, respectively, most likely a reflection image. This trend may be due to the extremely high negative correlation between the direct and maternal effects, which could be environmentally induced and biased. Both direct breeding value and maternal breeding value increased with an increase in Simmentaler proportion. It should, however, be noted that there were only a few records for certain groups of breed proportions for CE, especially the Afrikaner, and due to the imbalanced nature of breed combinations the results may be biased.

In order to be able to obtain a more comprehensive picture of the relative contributions of the Afrikaner, Hereford and Simmentaler, they should be evaluated in context with the individual contributions of the other contributing breeds. Their respective roles should therefore also be investigated.

REFERENCES

AARON, D.K. & THRIFT, F.A., 1982. Influence of calf genetic type on preweaning traits under commercial beef cattle conditions. *Can. J. Anim. Sci.* 62, 287.

AHMAD, M. & VAN DER WERF, J.H.J., 1999. Additive and non-additive genetic effects in Friesian, Jersey and Sahiwal crosses in Pakistan. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 13, 243. (Mandurah, Western Australia)

ALENDA, R., MARTIN, M.R., LASLEY, J.F. & ELLERSIECK, M.R., 1980. Estimation of genetic and maternal effects in crossbred cattle of Angus, Charolais and Hereford parentage. I. Birth and weaning weights. *J. Anim. Sci.* 50, 226.

ALENDA, R. & MARTIN, T.G., 1981. Estimation of genetic and maternal effects in crossbred cattle of Angus, Charolais and Hereford parentage. III Optimal breed composition of crossbreds. *J. Anim. Sci.* 53, 347.

ANON, 1999. Afrikaner gebruik om die volgende rasse te teel. In: Afrikaner Journal (Afrikaner Breeders Association). Vol. 45, Dec. 1999, p. 124.

ARTHUR, P.F., HEARNSHAW, H., KOHUN, P.J. & BARLOW, R., 1994. Evaluation of *Bos indicus* and *Bos taurus* straightbreds and crosses. III Direct and maternal genetic effects on growth traits. *Aust. J. Agric. Res.* 45, 807.

ARTHUR, P.F., HEARNSHAW, H. & STEPHENSON, P.D., 1999. Direct and maternal additive and heterosis effects from crossing *Bos indicus* and *Bos taurus* cattle: cow and calf performance in two environments. *Livest. Prod. Sci.* 57, 231.

BAKER, R.L., 1980. The role of maternal effects in the efficiency of selection in beef cattle – a review. *Proc. N. Z. Soc. Anim. Prod.* 40, 285.

BARLOW, R., 1981. Experimental evidence for interaction between heterosis and environment in animals. *Anim. Breed. Abstr.* 49, 715.

BENNETT, G.L. & GREGORY, K.E., 1996. Genetic (co)variances among birth weight, 200-day weight and postweaning gain in composites and parental breeds of beef cattle. *J. Anim. Sci.* 74, 2598.

BONSMA, J.C., 1944. Hereditary heartwater-resistant characters in cattle. *Farming in South Africa* 19, 71.

BONSMA, J.C., 1949. Breeding cattle for increased adaptability to tropical and subtropical environments. *J. Anim. Sci.* 39, 205.

BRADFIELD, M.J. & ERASMUS, G.J., 1999. The use of EBVs in the South African beef industry. In: Beef Breeding in South Africa (Ch.4). Eds. Scholtz, M.M., Bergh, L. & Bosman, D.J. Agric. Res. Council (Anim. Improvement Institute), Irene, p. 37.

BRINKS, J.S., KNAPP, B.W., URICK, J.J. & PAHNISH, O.F., 1972. Heterosis in preweaning maternal traits among lines of Hereford cattle. *J. Anim. Sci.* 34, 14.

BURNS, B.M., VERCOE, J.E. & HOLMES, C.R., 1988. Productive and adaptive trait differences of Simmental, Hereford and Africander x Hereford cattle. *J. Agric. Sci., Camb.* 111, 475.

CANTET, R.J.C., KRESS, D.D., ANDERSON, D.C., DOORNBOS, D.E., BURFENING, P.J. & BLACKWELL, R.L., 1988. Direct and maternal variances and covariances and maternal phenotypic effects on preweaning growth of beef cattle. *J. Anim. Sci.* 66, 648.

CARTWRIGHT, T.C., 1970. Selection criteria for beef cattle for the future. *J. Anim. Sci.* 30, 706.

COMERFORD, J.W., BERTRAND, J.K., BENYSHEK, L.L. & JOHNSON, M.H., 1987. Reproductive rates, birth weight, calving ease and 24-h calf survival in a four-bred diallel among Simmental, Limousin, Polled Hereford and Brahman beef cattle. *J. Anim. Sci.* 64, 65.

CUNDIFF, L.V., WILLHAM, R.L. & PRATT, C.A., 1966. Effects of certain factors and their two-way interactions on weaning weight in beef cattle. *J. Anim. Sci.* 25, 972.

CUNDIFF, L.V., GREGORY, K.E., SCHWULST, F.J. & KOCH, R.M., 1974. Effects of heterosis on maternal performance and milk production in Hereford, Angus and Shorthorn cattle. *J. Anim. Sci.* 38, 728.

CUNDIFF, L.V., GREGORY, K.E., KOCH, R.M. & DICKERSON, G.E., 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. *Proc. 3rd World Cong. Genet. Appl. Livest. Prod.* IX, 271. (Nebraska, USA)

CUNNINGHAM, B.E. & MAGEE, W.T., 1988. Breed-direct, breed-maternal and non-additive genetic effects for preweaning traits in crossbred calves. *Can. J. Anim. Sci.* 68, 83.

DEARBORN, D.D., GREGORY, K.E., CUNDIFF, L.V. & KOCH, R.M., 1987. Maternal heterosis and grandmaternal effects in beef cattle: Preweaning traits. *J. Anim. Sci.* 65, 33.

DILLARD, E.U., RODRIQUEZ, O. & ROBISON, O.W., 1980. Estimation of additive and nonadditive direct and maternal genetic effects from crossbreeding beef cattle. *J. Anim. Sci.* 50, 653.

ELLIS, G.F., CARTWRIGHT, T.C. & KRUSE, W.E., 1965. Heterosis for birth weight in Brahman-Hereford crosses. *J. Anim. Sci.* 24, 93.

ELS, D.L., 1988. Kruisteling vir vleisproduksie. PhD Thesis. University of the Orange Free State, Bloemfontein, South Africa.

ELZO, M.A., OLSON, T.A., BUTTS, W.T., KOGER, M. & ADAMS, E.L., 1990. Direct and maternal genetic effects due to the introduction of *Bos taurus* alleles into Brahman cattle in Florida. II. Preweaning growth traits. *J. Anim. Sci.* 68, 324.

FRANKE, D.E., 1994. Genetic effects for beef cattle preweaning traits. *Proc. 5th World Cong. Genet. Appl. Livest. Prod.* 17, 296. (Guelph, Canada)

GREGORY, K.E., CUNDIFF, L.V., KOCH, R.M., LASTER, D.B., & SMITH, G.M., 1978. Heterosis and breed maternal and transmitted effects in beef cattle I. Preweaning traits. *J. Anim. Sci.* 47, 1031.

GREGORY, K.E. & CUNDIFF, L.V., 1980. Crossbreeding in beef cattle: Evaluation of systems. *J. Anim. Sci.* 51, 1224.

GREGORY, K.E., TRAIL, J.C.M., MARPLES, H.J.S. & KAKONGE, J., 1985. Characterization of breeds of *Bos indicus* and *Bos taurus* cattle for maternal and individual traits. *J. Anim. Sci.* 60, 1165.

GREGORY, K.E., CUNDIFF, L. V. & KOCH, R. M., 1994. Germplasm utilization in beef cattle. *Proc. 5th World Cong. Genet. Appl. Livest. Prod.* 17, 261. (Guelph, Canada)

GROENEVELD, E., 1994. VCE- a multivariate, multimodel REML covariance component estimation package. *Proc. 5th Wrld. Congr. Genet. Appl. Livest. Prod.* 22, 47. (Guelph, Canada)

GROENEVELD, E., 1997. VCE-4, User's guide and Reference manual. Institute of Animal Husbandry and Animal Behaviour, Mariensee, Germany.

GROENEVELD, E. & GARCIA-CORTÉS, A., 1998. VCE 4.0, a (co)variance component package for frequentists and Bayesians. *Proc. 6th Wrld. Congr. Genet. Appl. Livest. Prod.* 27, 455. (Armidale, Australia)

GROENEVELD, E., MOSTERT, B.E. & RUST, T., 1998. The covariance structure of growth traits in the Afrikaner beef population. *Livest. Prod. Sci.* 55, 99.

HAYES, B.J., NEWMAN, S. & SHEPERD, R.K., 1999. Developing composite cattle for beef production. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 13, 118. (Mandurah, Western Australia)

HETZEL, D.J.S., 1988. Comparative productivity of the Brahman and some indigenous Sanga and *Bos indicus* breeds of East and Southern Africa. *Anim. Breed. Abst.* 56, 243.

HOFMEYER, J., 1999. Afrikanerbees – Quo Vadis. In: Afrikaner Journal (Afrikaner Beef Cattle Breeders Association). Vol. 45, Dec. 1999, p. 76.

JENKINS, T.G. & FERRELL, C.L., 1992. Lactation characteristics of nine breeds of cattle fed various quantities of dietary energy. *J. Anim. Sci.* 70, 1652.

KINGHORN, B., 1980. A model for the optimisation of genetic improvement by the introduction of novel breeds into a native population. *Z. Tierzüchtg. Züchtgsbiol.* 97, 95.

KINGHORN, B., 1982. Genetic effects in crossbreeding. I. Models of merit. *Z. Tierzüchtg. Züchtgsbiol.* 99, 59.

KINGHORN, B.P., 1987. The Nature of 2-Locus epistatic interactions in animals: Evidence from Sewall Wright's guinea pig data. *Theor. Appl. Genet.* 73, 595.

KINGHORN, B.P. & SHEPHERD, R.K., 1999. Mate selection for the tactical implementation of breeding programmes. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 13, 130. (Mandurah, Western Australia)

KINGHORN, B.P. & SIMM, G., 1999. Genetic improvement of beef cattle. In: The genetics of cattle (Ch. 20). Eds. Fries, R. and Ruvinsky, A., CAB International 1999, Wallingford, UK, p. 577.

KOCH, R.M., 1972. The role of maternal effects in animal breeding: VI. Maternal effects in beef cattle. *J. Anim. Sci.* 35, 1316.

KOCH, R.M., DICKERSON, G.E., CUNDIFF, L.V. & GREGORY, K.E., 1985. Heterosis retained in advanced generations of crosses among Angus and Hereford cattle. *J. Anim. Sci.* 60, 1117.

KOGER, M., PEACOCK, F.M., KIRK, W.G. & CROCKETT, J.R., 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. *J. Anim. Sci.* 40, 826.

KOOTS, K.R., GIBSON, J.P., SMITH, C. & WILTON, J.W., 1994a. Analysis of published genetic parameter estimates for beef production traits. 1. Heritability. *Anim. Breed. Abstr.* 62, 309.

KOOTS, K.R., GIBSON, J.P. & WILTON, J.W., 1994b. Analysis of published genetic parameter estimates for beef production traits. 2. Phenotypic and genetic correlations. *Anim. Breed. Abstr.* 62, 825.

LAMB, M.A., TESS, M.W. & ROBISON, O.W., 1992. Evaluation of mating systems involving five breeds for integrated beef production systems: I. Cow-calf segment. *J. Anim. Sci.* 70, 689.

LAWLOR, T.J., KRESS, D.D., DOORNBOS, D.E. & ANDERSON, D.C., 1984. Performance of crosses among Hereford, Angus and Simmental cattle with different levels of Simmental breeding. I. Preweaning growth and survival. *J. Anim. Sci.* 58, 1321.

LIN, C.Y., 1996. Optimization of breed composition to maximize net merit of synthetic populations. *J. Anim. Sci.* 74, 1447.

LONG, C.R., 1980. Crossbreeding for Beef Production: Experimental Results. *J. Anim. Sci.* 51, 1197.

MacGREGOR, R.G., 1997. Evaluation of methods of measuring reproduction and production in beef cows. PhD Thesis. University of Pretoria, South Africa.

MacKINNON, M.J., MEYER, K. & HETZEL, D.J.S., 1991. Genetic variation and covariation for growth, parasite resistance and heat tolerance in tropical cattle. *Livest. Prod. Sci.* 72, 105.

MacNEIL, M.D., DINKEL, C.A. & VAN VLECK, 1982. Individual and maternal additive and heterotic effects on 205-day weight in beef cattle. *J. Anim. Sci.* 54, 951.

MALLINCKRODT, C.H., GOLDEN, B.L. & BOURDON, R.M., 1995. The effect of selective reporting on estimates of weaning weight parameters in beef cattle. *J. Anim. Sci.* 73, 1264.

MARLOWE, T.J. & GAINES, J.A., 1958. The influence of age, sex and season of birth of calf and age of dam on preweaning growth rate and type score of beef calves. *J. Anim. Sci.* 17, 706.

McDONALD, R.P. & TURNER, J.W., 1972. Estimation of maternal heterosis in preweaning traits of beef cattle. *J. Anim. Sci.* 35, 1146.

MENTZ, A.H., 1977. Produksiepotensiaal van verskillende eerstekruising Afrikanerbeeste. PhD Thesis. University of the Orange Free State, South Africa.

MEYER, E.H.H., 1984. Chromosomal and biochemical genetic markers of cattle breeds in Southern Africa. *Proc. 2nd World Cong. Sheep and Beef Cattle Breed.* 16-19 April, p. 328. (Pretoria, South Africa)

MEYER, K., 1992a. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. *Livest. Prod. Sci.* 31, 179.

MEYER, K., 1992b. Bias and sampling covariances of estimates of variance components due to maternal effects. *Genet. Sel. Evol.* 24, 487.

MOHIUDDIN, G., 1993. Estimates of genetic and phenotypic parameters of some performance traits in beef cattle. *Anim. Breed. Abstr.* 61, 495.

MOSTERT, B., GROENEVELD, E., RUST, T. & VAN DER WESTHUIZEN, J., 1998. Multitrait variance component estimation of South African beef breeds for growth traits. *Proc. 6th Wrld. Congr. Genet. Appl. Livest. Prod.* 23, 145. (Armidale, Australia)

MOYO, S., SWANEPOEL, F.J.C. & REGE, J.E.O., 1996. Evaluation of indigenous, exotic and crossbred cattle for beef production in a semi-arid environment: Reproduction performance and cow productivity. *Proc. Aust. Soc. Anim. Prod.* 21, 204. (Brisbane, Queensland)

NEWMAN, S., HAYES, B., KINGHORN, B., O'NEILL, C.J. & FRISCH, J.E., 1998. Prediction of optimal composites for growth from a tropical crossbreeding experiment. *Proc. 6th Wrld. Congr. Genet. Appl. Livest. Prod.* 23, 235. (Armidale, Australia)

NEWMAN, S. & COFFEY, S.G., 1999. Genetic aspects of cattle adaptation in the tropics. In: The genetics of cattle (Ch. 22). Eds. Fries, R. and Ruvinsky, A., CAB International 1999, Wallingford, UK, p. 637.

PATERSON, A.G., 1978. Statistical analyses of factors affecting preweaning growth of beef cattle under intensive pasture conditions. MSc (Agric.) Thesis. University of Pretoria, South Africa.

PATERSON, A.G., VENTER, H.A.W. & HARWIN, G.O., 1980. Pre-weaning growth of British, *Bos indicus*, Charolais and dual purpose type cattle under intensive pasture conditions. *S. Afr. J. Anim. Sci.* 10, 125.

PATERSON, A.G., 1981. Factors affecting post-weaning growth and reproduction of crossbred cattle under an intensive production system. DSc (Agric.) Thesis. University of Pretoria, South Africa.

PAYNE, W.J.A., 1973. African breeds. In: Cattle production in the tropics. Vol. 1: Breeds & Breeding (Ch. 4). Western Printing Services Ltd, Great Britain, p. 120.

PAYNE, W.J.A. & HODGES, J., 1997. Classification of Breeds. In: Tropical Cattle: Origins, Breeds and Breeding Policies (Part 2). Blackwell Science Ltd, Great Britain, p. 87.

PEACOCK, F.M., KOGER, M., OLSON, T.A. & CROCKETT, J.R., 1981. Additive genetic and heterosis effects in crosses among cattle breeds of British, European and Zebu origin. *J. Anim. Sci.* 52, 1007.

ROBERSON, R.L., SANDERS, J.O. & CARTWRIGHT, T.C., 1986. Direct and maternal genetic effects on preweaning characters of Brahman, Hereford and Brahman-Hereford crossbred cattle. *J. Anim. Sci.* 63, 438.

ROBINSON, D.L., 1996. Estimation and interpretation of direct and maternal genetic parameters for weights of Australian Angus cattle. *Livest. Prod. Sci.* 45, 1.

ROBISON, O.W., McDANIEL, B.T. & RINCON, E.J., 1981. Estimation of direct and maternal additive and heterotic effects from crossbreeding experiments in animals. *J. Anim. Sci.* 52, 44.

RODRIGUEZ-ALMEIDA, F.A., VAN VLECK, L.D., WILLHAM, R.L. & NORTHCUTT, S.L., 1995. Estimation of non-additive genetic variances in three synthetic lines of beef cattle using an animal model. *J. Anim. Sci.* 73, 1002.

SACCO, R.E., BAKER, J.F., CARTWRIGHT, T.C., LONG, C.R. & SANDERS, J.O., 1989. Production characters of straightbred, F1 and F2 cows: Birth and weaning characters of terminal-cross calves. *J. Anim. Sci.* 67, 1972.

SAS/STAT (Statistical Analysis System), 1993. SAS/STAT User's Guide (Version 6). SAS Institute, Inc., Cary, N.C.

SCHOEMAN, S.J., 1989. Recent research into the production potential of indigenous cattle with special reference to the Sanga. *S. Afr. J. Anim. Sci.* 19, 55.

SCHOEMAN, S.J., VAN ZYL, J.G.E. & DE WET, R., 1993. Direct and maternal additive and heterotic effects in crossbreeding Hereford, Simmentaler and Afrikaner cattle. *S. Afr. J. Anim. Sci.* 23, 61.

SCHOEMAN, S.J., 1996. Characterization of beef cattle breeds by virtue of their performances in the National Beef Cattle Performance and Progeny Testing Scheme. *S. Afr. J. Anim. Sci.* 26, 15.

SCHOEMAN, S.J., 1998. Perspektiewe op die gebruik van kruisrasbulle. In: Bonsmara Journal. Publication of the Bonsmara Cattle Breeders' Society of S.A. Vol. 6 no. 1, July 1998, p. 43.

SCHOEMAN, S.J. & JORDAAN, G.F., 1998. Animal x testing environment interaction on postweaning liveweight gains of young bulls. *Aust. J. Agric. Res.* 49, 607.

SCHOEMAN, S.J., 1999. Crossbreeding in beef cattle. In: Beef breeding in South Africa (Ch. 5). Eds. Scholtz, M.M., Bergh, L. and Bosman, D.J., Agric. Res. Council (Animal Improvement Institute), Irene, p. 43.

SCHOEMAN, S.J. & JORDAAN, G.F., 1999. Multitrait estimation of direct and maternal (co)variances for growth and efficiency traits in a multibreed beef cattle herd. *S. Afr. J. Anim. Sci.* 29, 124.

SCHOEMAN, S.J., JORDAAN, G.F. & ERASMUS, G.J., 2000. Heritabilities of pre-weaning traits in a multibreed beef cattle herd fitting models with or without a sire genotype x dam genotype interaction. *Proc. 38th SASAS Congr.*, 25-27 July 2000, p. 61. (Kwazulu-Natal, South Africa)

SCHOLTZ, M. M., ROUX, C.Z. & LOMBARD, P. E., 1990. Breeding strategies for beef cattle in the subtropics and tropics: Terminal crossbreeding. *Proc. 4th Wrld. Congr. Gen. Appl. Livest. Prod.* XV, 361. (Edinburg, Scotland)

SEIFERT, G.W. & RUDDER, T.H., 1984. Experience with Africander and Africander derived genotypes in Australian beef herds. *Proc. 2ⁿᵈ World Cong. Sheep and Beef Cattle Breed*. 16-19 April, p. 671. (Pretoria, South Africa)

SHERIDAN, A.K., 1981. Crossbreeding and heterosis. *Anim. Breed. Abst*. 49,131.

SIEVERS, C.F., 1965. Untersuchungen an Afrikanerrindern und deren Kreuzungen mit verschiedenen Fleischrinderrassen. Ein Beitrag zur Verbesserung der Rindfleischerzeugung in Südwestafrika. PhD (Agric.) Thesis. Georg-August-Universität, Göttingen.

SMITH, G.M., LASTER, D.B. & GREGORY, K.E., 1976. Characterization of biological types of cattle I. Dystocia and Preweaning growth. *J. Anim. Sci*. 43, 27.

STRANZINGER, G., ELMIGER, B. & HETZEL, D.T.S., 1987. Cytogenetic studies on different cattle breeds in Australia. *J. Anim. Breed. Genet*. 104, 231.

STUDBOOK, anonymous. The modern Afrikaner.
http://studbook.co.za/society/afrikaner/modern.htm

SUNDSTROM, B., BARLOW, R. & ARTHUR, P.F., 1994. Application of crossbreeding to beef production: opportunities, obstacles and challenges. *Proc. 5ᵗʰ World Cong. Genet. Appl. Livest. Prod*. 17, 280. (Guelph, Canada)

TAWAH, C.L., MBAH, D.A., REGE, J.E.O. & OUMATE, H., 1993. Genetic evaluation of birth and weaning weight of Gudali and two-breed synthetic Wakwa beef cattle populations under selection in Cameroon: genetic and phenotypic parameters. *Anim. Prod*. 57, 73.

TAWONEZVI, H.P.R., WARD, H.K., TRAIL, J.C.M. & LIGHT, D., 1988. Evaluation of beef breeds for rangeland weaner production in Zimbabwe. 2. Productivity of crossbred cows and heterosis estimates. *Anim. Prod*. 47, 361.

TOSH, J.J., KEMP, R.A. & WARD, D.R., 1999. Estimation of direct and maternal genetic parameters for weight traits and backfat thickness in a multibreed population of beef cattle. *Can. J. Anim. Sci*. 79, 433.

VAN DER MERWE, P.S. & SCHOEMAN, S.J., 1995. Effect of early calving of Simmentaler heifers under an extensive management system. *S. Afr. J. Anim. Sci.* 25, 36.

VAN DER WESTHUIZEN, J. & MATJUDA, L.E., 1999. Breeding objectives. In: Beef breeding in South Africa (Ch. 3). Eds. Scholtz, M.M., Bergh, L. and Bosman, D.J., Agric. Res. Council (Animal Improvement Institute), Irene, p. 27.

VAN ZYL, J.G.E., 1990. Studies on performance and efficiency of pure and crossbred cattle in an arid bushveld environment. PhD (Agric.) Thesis. University of Pretoria, South Africa.

VAN ZYL, J.G.E., SCHOEMAN, S.J. & COERTZE, R.J., 1992. Sire breed and breed genotype of dam effects in crossbreeding beef cattle in the subtropics. I. Birth and weaning mass of calves. *S. Afr. J. Anim. Sci.* 22, 161.

WOLF, J., DISTL, O., HYÁNEK, J., GROSSHANS, T. & SEELAND, G., 1995. Crossbreeding in farm animals. V. Analysis of crossbreeding plans with secondary crossbred generations. *J. Anim. Breed. Genet.* 112, 81.

WOLF, J., 1996. CBE, Version 4.0 (A universal program for estimating crossbreeding effects), User's Manuel for the Software Package. Research Institute of Animal Production, CZ 10400 Praha-Uhrineves, Czech Republic.